

Rolling Stock Manufacturers and New Rail Vehicles in Poland

Marek GRAFF¹

Summary

Ten rolling stock manufacturers were operating in Poland in 2020. These were both domestic enterprises (Pesa, Newag) as well as branches of foreign concerns (Siemens, Bombardier, Alstom, Stadler). A similar division can be deemed conventional since the aforementioned enterprises employ mostly Polish specialists or managers – and work with Polish subcontractors. On the other hand, Polish manufacturers use mainly imported components in the production process. The range of the currently manufactured rolling stock is quite wide – from multiple units to locomotives with electric and diesel drives, adapted to run on both standard and broad gauge tracks. Polish plants also manufacture underground train-sets, mostly for export. New rolling stock orders placed by operators are carried out with the support of EU funding programmes.

Keywords: rolling stock manufacturers, Poland, PKP

1. Introduction

After 1989, the overwhelming majority of the rolling stock in Poland was operated by virtually one operator – PKP. In most cases, it was manufactured fully or in part domestically or supplied by the CMEA countries². The majority of electric locomotives handling most of the transportation work were, however, manufactured in Poland (EU07, ET21, ET22 and ET41 series), only slightly supplemented by import (EP05, ET40 and ET42), while diesel locomotives that were primarily intended for freight traffic (ST43 and ST44 series) were imported. Passenger traffic vehicles (SP45, SU46), just like shunting vehicles (SM42, SM31), were mostly manufactured by domestic factories. No lightweight diesel vehicles (rail motored cars, *diesel MUs*) intended for local passenger services were in use after written off of the SN61 series (by Ganz-MÁVAG, Hungary).

The rolling stock assets of the time corresponded to the structure of Poland's economy, which relied on heavy industry mainly for political reasons. Therefore, the goods transported by rail included mainly coal, metal ores (especially iron), steel, as well as steel or timber products. Passenger transport, especially express routes with obligatory reservations, was neglected. Indeed, locomotives for high-speed passenger trains were not manufactured in Poland before the turn of the 1980s and 1990s (EP09 series). These

replaced the remaining EP05s built in the early 1960s and the slightly younger EP08s. Most locomotives owned by PKP were not modern, and first-world technology – such as pulsed start-up of traction motors – was at the stage of testing or prototyping (EM10 series). The electric multiple units operated by PKP were mainly the EN57 series, which had been manufactured for 30 years without significant changes. The import of modern technical solutions from western countries was hindered due to the lack of convertible currency and the reluctance of the authorities to take action. It should be added that, due to the poor development of individual motor transport and of the country's road network (especially motorways and expressways), railway was the primary means of transport, both for passenger and freight, until 1989.

The abandonment of the command-and-quota economic system in favour of the free market model in 1989 brought about the collapse of Poland's heavy industry and a decline in transport (especially on secondary routes). However, it also resulted in the opening of the Polish economy to the world. This created an opportunity to obtain new, previously unavailable technologies. Such a situation entailed a necessity to restructure PKP and expand (among others) the existing express routes (IC and EC trains) due to the growing demand resulting from the dynamic development of private business. The economic crisis of the

¹ PhD; Institute of Nuclear Chemistry and Technology, Warszawa; e-mail: marek.graff@infotransport.pl.

² Council for Mutual Economic Assistance – an economic organisation operating in the years 1949–1991 and associating the following countries: Albania, Bulgaria, Czechoslovakia, Cuba, Mongolia, Poland, Romania, Hungary, East Germany, Vietnam and the USSR.

1990s and the rather symbolic availability of EEC (EU predecessor) aid funds turned out, however, to be an obstacle to PKP's restructuring. The renovation and modernisation of the infrastructure as well as the purchase of new rolling stock were kept to a minimum, eventually becoming limited to the scrapping of unnecessary rolling stock (freight diesel locomotives primarily) and the decommissioning of side routes (transport financing from the state budget was minimal at the time).

Poland's accession to the EU in May 2004 and the funding received from aid programmes for infrastructure (e.g. OPI&E, CEF, etc.) made it possible to initiate the renovation and modernisation of the railway network [46] and to acquire up-to-date machinery, initially from domestic manufacturers (mainly PESA), and later also from western companies that had bought out failed state enterprises in Poland (e.g. Alstom – Konstal Chorzów; Adtranz/Bombardier – Pafawag Wrocław) or had built new factories from scratch (Stadler, Siedlce) [19, 20]. Poland's rolling stock manufacturers (Pesa and Newag) were transformed, and Rolling Stock Repair Plants (ZNTK) in Bydgoszcz and Nowy Sącz, respectively, were modernised. In addition to manufacturing tasks, the plants also deal with rolling stock overhauls and modernisation. However, some former manufacturers had to cease their activity (Fablok Chrzanów), while others failed to cope with the new, free-market reality (ZNTK Poznań, Kolzam Racibórz). In contrast, entirely new companies manufacturing trams as their core (Modertrans Poznań, Protram Wrocław) or additional products were also established (Solaris). It should be added that plants manufacturing rolling stock prior to 1989 (Pafawag Wrocław and H. Cegielski Poznań) lost their position as the main producers in Poland (primarily in the field of locomotives and EMU), and Pafawag's acquisition in 1997 by Adtranz/Bombardier resulted in changes in its production profile and a significant improvement in quality.

After restructuring, H. Cegielski Poznań limited its production to passenger carriages intended primarily for the domestic market. With time, the rolling stock manufactured by Newag has slowly become comparable to vehicles produced by the world-class manufacturers now present in Poland – Alstom, Bombardier, Siemens, and Stadler. The changes taking place in Poland's railroad activity are represented by the Pendolino units supplied by Alstom to PKP IC between 2014 and 2015, together with other vehicles intended for use in handling long-haul traffic – Flirt and Dart units manufactured by the consortium of Stadler and Newag, and Pesa, respectively. Western concerns offer not only a wide range of vehicles, but also railway instrumentation and control (I&C) equipment used in traffic safety systems (Bombardier, Siemens).

New trends among domestic manufacturers emerged after 1989 – vehicles are also exported (Germany, Italy, Czech Republic, Lithuania, and Ukraine, etc.), which was very rare previously (e.g. 201E locomotives for Moroccan Railways) [77], and vehicle import from the East virtually finished. Although Polish operators still use locomotives manufactured in the former USSR countries, these are modernised units (ST48, ST40s, and ST44-12xx series) or ones kept on in reserve (ET42 series). Furthermore, their numbers have dwindled (e.g. 1113 ST44 units plus 68 units for LHS were purchased; there are now fewer than 100 vehicles for 1435 track gauge use). The age of the aforementioned vehicles (30–40 years) is not without significance. Another new trend observed on Polish railways is the use of multi-voltage locomotives (virtually unused for passenger and freight trains prior to 1989) as a manifestation of the liberalisation of transportation between EU Member States.

The manufacturing of passenger and freight cars is an important issue. Whereas in the field of passenger carriage manufacturing after 1989, apart from the reduction of the number of units ordered by operators, the manufacturer has remained the same (a subsidiary of H. Cegielski Poznań) – Fabryka Pojazdów Szynowych (FPS-Railroad Vehicle Factory), the quality of the manufactured passenger carriages has improved. This greater focus on quality aims not only to meet new standards and regulations but also to satisfy the requirements of foreign railway operators from Germany, Czech Republic, Slovakia, Austria, and Hungary. Unfortunately, PKP IC, the operator managing long-distance routes, has concentrated rather on modernising the already existing rail car fleet instead of purchasing brand new rolling stock. Similar actions, caused by, among others, the lower costs of modernisation, will not be possible in the long term because the adoption of new technical requirements for passenger carriages will not always be feasible in the case of older rolling stock, manufactured e.g. 30 years ago. It should be added that nowadays it is standard to install A/C, closed-circuit monitoring, waste holding tanks, and electrical sockets by each passenger seat in the carriages. This all contributes to the fact that the travel standard has improved and the travel speed increased. The programmes of modernisation and purchase of new cars are being implemented with the use of EU funds. No cars for eastern passenger operators are currently manufactured, except for individual orders (e.g. prior to 1989, H. Cegielski produced many 1-WM gauge cars for SZD, based on provided documents).

Prior to 1989, freight cars were manufactured in Poland in large numbers, both for the domestic market and for export. The following plants were the leading manufacturers (in terms of volumes): Zastal

Zielona Góra, Pafawag Wrocław, the Wagon Factory in Świdnica, the Wagon Factory in Ostrów Wielkopolski, Marcel Nowotko Steelworks in Ostrowiec Świętokrzyski and more. Soviet Railways (SZD) as well as operators in Czechoslovakia, Hungary and Arab countries (Iraq, Syria and others) were the major purchasers [78]. In the post-1989 era, a significant decline in freight transport, resulting from the political transformation, as well as a slowdown in the export of freight cars to eastern operators led to the bankruptcy of several Polish manufacturers. Since freight transport is profitable, applying for EU aid funds is not necessary. At present, similar cars are manufactured by: Wagony Świdnica (owned by Greenbrier from the USA), Europejskie Konsorcjum Kolejowe WAGON in Ostrów Wielkopolski, and Tabor Dębica. Companies

operating in the field of manufacturing rail vehicles in Poland are listed in Table 1.

2. Characteristics of rolling stock manufacturers in Poland

This chapter provides background information on rolling stock orders for Polish operators and contracts implemented by rolling stock manufacturers in Poland (locomotives, multiple units, and underground, excluding trams) over the last few years. A detailed description of the rolling stock manufacturer situation in Poland after 1989 and orders received before 2015 are included in [21].

Table 1

Rolling stock manufacturers in Poland

Manufacturer	Origin	Manufacturing activity profile	New vehicles and equipment supplied to Polish operators after 1989.	Notes
Alstom Transport	France	locomotives, passenger cars, multiple units, underground, trams, high-speed trains, automatic train protection systems	high-speed trains underground, trams	global concern
Bombardier Transportation	Canada + Germany	locomotives, passenger cars, multiple units, underground, trams, high-speed trains, railway I&C equipment	locomotives, trams, passenger carriages, railway I&C equipment	global concern, acquired by Alstom in 2020
Europejskie Konsorcjum Kolejowe WAGON	Poland	freight wagons	freight wagons	transformed wagons Wielkopolski
Greenbrier	USA	freight wagons	freight wagons	global concern
H. Cegielski FPS	Poland	passenger cars	passenger carriages	transformed H. Cegielski Poznań
Newag	Poland	locomotives, multiple units, trams	locomotives, multiple units, trams	transformed ZNTK Nowy Sącz
Pesa	Poland	locomotives, multiple units, passenger cars, trams	locomotives, multiple units passenger carriages, trams	transformed ZNTK Bydgoszcz and ZNTK Mińsk Mazowiecki
Siemens Mobility	Germany	locomotives, passenger cars, multiple units, underground, trams, high-speed trains, railway I&C equipment	locomotives, underground, trams, railway I&C equipment	global concern
Škoda Transportation	Czech Republic	locomotives, multiple units, underground, trams	underground, trams	international concern
Stadler	Switzerland	locomotives, passenger cars, multiple units, underground, trams, high-speed trains	multiple units, trams	international concern
Tabor Dębica	Poland	freight wagons	freight wagons	some of the production output is exported

[Author's own study].

2.1. Alstom

Alstom is a global concern from France and manufactures rail vehicles of virtually every type (locomotives, trams, high-speed trains, underground, etc.) as well as railway I&C equipment. The Alstom Polish branch has, among others, a plant in Chorzów (formerly Konstal), which is a highly-specialised division of the concern, dealing with underground train engineering and construction. It has, however, recently been implementing a contract for the construction of multimodal multiple units for the main passenger carrier in the Netherlands – NS (Dutch *Nederlandse Spoorwegen*) (Fig. 1).



Fig. 1. ICNG EMU train set of the 3103 series (Alstom) operated by NS, Rotterdam Central Station [photo Mennov1996 / Wikimedia Commons]

Alstom has supplied, among others, the Metropolis trains for the Warsaw underground and EMU Pendolino for PKP IC, as well as Citadis trams for several Polish cities. The plant in Chorzów has manufactured underground rolling stock for export to underground rail systems in Amsterdam, Budapest, Riyadh, and Dubai. The Alstom plant in Chorzów was modernised and reorganised in the years 2016–2020, which cost EUR 100 m. and – according to [32] – made it possible to:

- increase the output from 1 to 2 million man-hours per year;
- enhance the production levels from 30 to 40 bodies per year;
- increase the production floor area from 65,000 sq. m to 90,000 sq. m;

and:

- construct on-site test tracks – 7 tangent tracks and 1 dynamic track (700 m long);
- establish a connection with the PLK network;
- obtain the certification of e.g. DIN 6701, which is required for approval to provide services to markets in Germany and the Netherlands;
- obtain the status of the largest centre of excellence for the construction of aluminium bodies, although steel bodies are also produced there;

- increase the share of aluminium bodies in the manufacturing volume from 2% to 23%;
- double the share of equipment assembly;
- erect a multi-axial welding robot station;
- create new manufacturing posts for semi-automatic welding, automatic machining, and confined paint shops.

The plant in Chorzów is Alstom's leading facility. It independently implements both vehicle project initiatives and manufacturing process innovations. It should be added that, apart from the Alstom plant, aluminium bodies are also manufactured in the Stadler plant in Siedlce, with other vehicle manufacturers in Poland producing only steel bodies for both multiple units and locomotives. Industrial robots are in common use at the Alstom plant in Chorzów (Fig. 2).



Fig. 2. Industrial robot at the Alstom Konstal plant in Chorzów [photo I. Burzyńska / Alstom]

2.2. Alstom contracts

In July 2013, Alstom was awarded a contract to construct a segment of the Riyadh underground system as a member of the FAST consortium, which was contracted to supply the rolling stock for lines 4, 5, and 6 – together with infrastructure equipment. A twelve-year contract with a preparatory period for the maintenance of lines 3, 4, 5 and 6 rolling stock was awarded to the FLOW consortium, with the participation of Ansaldo STS and Ferrovie Dello Stato Italiane (Italian Railways), among others. The contract was valued at EUR 2.5 bn, with the Alstom share at EUR 730 m., which also covered rolling stock maintenance. The Saudi party set a condition that the minimum Saudi participation share index must be at least 45% and 55% for the local contribution in the field of supplies and services associated with underground oper-

ation, including ground logistics support. The FLOW consortium committed itself to creating new jobs, for specialists, technicians, customer services personnel, security professionals, as well as administrative staff. The first Metropolis trains for Riyadh were manufactured in July 2016. Seats in three classes – first, family and single – separated with opaque glazing, were installed in the passenger section. In total, Alstom has supplied 69 two-carriage trains that will run on lines 4, 5, and 6. The first Alstom Metropolis train was shipped in March 2017. It was 36 m long, 2.71 m wide, and came with a capacity of 231 passengers. All of its axles are driven, which enables it to freely overcome slopes. Deliveries of Metropolis underground trains manufactured at the Alstom-Konstal plant in Chorzów were completed in mid-February 2019. The underground network was launched in November 2020, although the entire network was commissioned in 2021.

The first underground train manufactured by Alstom for the Dubai transport authority was delivered in mid-November 2018 [27]. It was the first of 50 Metropolis train sets intended to run on Dubai's Red and Green underground lines. The trains were transported by land, from Chorzów to the German port of Bremerhaven, and then by sea, to the recipient. At the turn of 2018 and 2019, Alstom conducted static and dynamic tests at the depot. In 2016, the ExpoLink consortium, headed by Alstom partnering with ACCIONA and Gulermak, concluded a contract with RTA (Dubai Road and Transport Authority) to design and execute the extension of the Dubai Underground Red Line and modernise the systems of the existing line. The entire contract, also known as Route 2020, was valued at EUR 2.6 bn, and the commercial operation was scheduled for 2020 (start of the World Expo).

Alstom's scope of responsibility covered supplying underground rolling stock, an automated control, communication, and security system, an automatic toll inspection system, conducting track work and constructing screen doors at platforms, together with a 3-year warranty for the entire system. In addition, Alstom will improve the existing underground line through modernising the power supply, control systems, and communication and traction equipment. Metropolis train sets for Dubai are 85.5 m long and consist of 5 carriages, with a maximum capacity of up to 700 passengers, in three separate classes: Silver, Family, and Golden.

In early October 2017, Alstom concluded a contract for the supply of EMU Coradia Stream trainsets for Italy's and the Netherlands' railway systems (FS and NS, respectively). These are units adapted to handling both regional traffic with a maximum speed of 160 km/h and long-distance traffic, with a speed of 200 km/h [7]. The manufacturer offered vehicles

composed of a maximum of 10 cars with aluminium bodies, adapted to run on lines supplied with: 1.5 kV DC, 3 kV DC, 15 kV 16.7 Hz and 25 kV 50 Hz. In July 2016, NS ordered a total of 109 units to handle IC trains on the Amsterdam – Rotterdam – Breda and Hague – Eindhoven routes starting from 2021. These will be 5-cars and 8-cars trains, 49 and 30+30 units respectively, with 256 and 417 seats. The operator ordered EMUs in a two-voltage version: 1.5 kV DC and 25 kV 50 Hz, and a 3-voltage (additionally 3 kV DC, ICNG-B), which can operate within the domestic railway network and on a high-speed line (HSL Zuid), with the option of entering the Belgian railway network. One of the elements in the certification process is the testing in a climatic chamber at Rail Tec Arsenal in Vienna. EMUs have been equipped with the domestic ATB-EG, Belgian TBL1+ and ETCS security systems. The operational tests of the ICNG (InterCity Nieuwe Generatie) EMU designated as 3100 (5-cars), 3200 and 3300 (8-cars) series were commenced in June 2020 (unit 3108) [28]. ICNG deliveries were planned to start in January 2020, and commencing operation was planned for 2021, however, due to the COVID-19 pandemic, these dates were postponed. Similar units were ordered by FS during the Expo Ferroviaria trade fair in Milan in August 2016, under a contract valued at EUR 900 m. for the supply of 150 EMUs. The implementation of the first part of the order, namely the supply of 47 units, commenced in early 2019. The FS version designated as ETR.103 was a single system (3 kV DC) and a 3- and 4-cars unit, with a maximum speed of 160 km/h, with 227 and 305 seats, respectively. The regions of Abruzzo (4 units) and Emilia Romagna (27 units) were the recipients.

In mid-December 2020, Alstom was awarded a contract for the design, construction, and maintenance of the third underground line in Toulouse, 27 km long, worth almost EUR 470 m. Moreover, 28 train sets (with an option of extending to an additional 25 trains, totalling EUR 713 m.) were ordered. The vehicle design was based on the Metropolis construction platform. The 21-station line will serve employees of the aviation sector (Toulouse is the location of the main EADS group centre, which manufactures civilian and military aircraft as part of the Airbus consortium). The transport capacity of the line is estimated at 5,000 people per hour in both directions, with an option to increase this number to 10,000. The contract covers the provision of an efficient, proven Alstom system solution – namely, Metropolis trains, the Urbalis™ 400 CBTC system that enables automatic train running (without drivers), and Hesop™ power substations with energy recuperation. The scope of the contract also covers platform doors as well as the provision of a dynamic load signalling system and Appi-track – a rapid track laying system. The contract also

provides for a 6-year maintenance period (extendable to 12 years). Some of the subassemblies will be manufactured in Toulouse (electrical equipment) and Tabres (mechanical elements), and a total of 80% of the man-hours devoted to order processing will be completed in France, with 55% in Occitanie. New jobs at Alstom's suppliers will be created in Toulouse, as well as throughout France for the purposes of the installation, infrastructure, and commissioning of individual systems. The Alstom Konstal S.A. plant in Chorzów will significantly contribute to the implementation of this project. As a Rolling Stock Integration Unit, the plant will be responsible for some of the engineering, the entire production, serial tests, commissioning and transport, as well as the in-warranty repairs of 28 trains of two cars.

2.3. Bombardier

In Poland, Bombardier operates plants in, among others, Wrocław (former Pafawag), which manufactures Traxx locomotive bodies, and ZWUS in Katowice, designing and producing traffic control devices. Selling the division responsible for the railway industry to Alstom enabled the company to focus on, among others, manufacturing jet aircraft for business clients. Alstom's acquisition of Bombardier Transportation assets will allow the French concern to advance to the second place in the world (after the Chinese CRRC) in terms of rolling stock and general railway manufacturing. Up until the 1990s, Pafawag Wrocław was the main manufacturer of electric locomotives and EMUs for PKP. However, the economic transformation after 1989 (decline in PKP orders) and the lack of capital to initiate the production of modern rolling stock resulted in the need to find a foreign entity (Adtranz in 1997, acquired by Bombardier in 2001) to enable the production output to be maintained. Bombardier's showcase products are currently electric and diesel Traxx locomotives used by Polish operator both in passenger and freight transport, domestically and internationally.

Traxx locomotive bodies are manufactured by Bombardier in their own plant in Wrocław, with 2,400 units already built. The locomotives are transported by road to a plant in Kassel, Germany, where their final assembly takes place. The Bombardier (now Alstom) plant in Wrocław uses industrial robots, among others, to weld metal (Fig. 3).

One of the latest solutions used by the manufacturer is an optional feature called the *'last mile'*. It eliminates the need to use an additional diesel locomotive on non-electrified railway network sections (e.g. industrial or port sidings, etc.). The feature involved equipping a locomotive with a low-power diesel engine and a fuel tank. The Traxx platforms, i.e.

multi-system electric locomotives or their diesel version, have been in production for 18 years and their design enables vehicles to be tailored to the individual demands of a given operator, e.g. by installing domestic traffic safety systems.



Fig. 3. Industrial robot for laser welding at the Bombardier plant in Wrocław [photo M. Kaczanowski / Bombardier, 07.06.2017]

Bombardier Transportation is a division of the concern that employs 40,700 people (with its headquarters in Berlin) and exports its own products, such as rolling stock, railway traffic control systems, comprehensive transport systems, e-mobility technologies, and maintenance services to over 60 countries (Fig. 4). The Polish branch comprises plants in Katowice, Łódź, Warsaw, and Wrocław, and employs almost 2,800 people. Altogether, Bombardier, with its seat in the Canadian city of Montreal, manages manufacturing and engineering plants in 28 countries, and operates in such sectors as transport, business and aircraft manufacture and design, aviation structures, and engineering services. Bombardier shares are traded on the Toronto Stock Exchange (BBD). In the fiscal year that ended on 31 December 2018, Bombardier reported a revenue of USD 16.2 bn. The concern employs 69,500 people within 4 fields of activity.



Fig. 4. Traffic safety system test stand at the Bombardier ZWUS plant in Katowice [photo M. Graff, 30.05.2017]

At the end of February 2019, the Canadian-German rolling stock manufacturer Bombardier and the French leasing company Akiem signed an agreement regarding the order of 20 Traxx DC3 locomotives for the Polish market, which was part of an overall plan involving the supply of 33 Traxx AC, DC, and MS locomotives that was to be completed in the period of 2019–2021. Akiem representatives also stated that, by 2020, their own rolling stock assets would consist of a minimum of 180 locomotives, of which 55 were intended for operation within the Polish railway network and for use in dealing with cross-border traffic. For rolling stock maintenance, Akiem, employs a network of specialised service centres (MGW Service). As the owner of 440 locomotives and serving approximately 50 customers that operate in the field of freight or passenger transport in most European countries, the Akiem Group generates revenues of EUR 140 m. The company belongs to Transport et Logistique Partenaires and DWS, and employs about 150 people in France, Italy, Germany, Sweden, and Poland in its leasing and maintenance departments. For operators which use Traxx locomotives, is offered the supply of spare parts, maintenance, and servicing. Akiem has decided to open an office in Warsaw in order to support the development of both Akiem and MGW Service in Central Europe.

2.4. Alstom and Bombardier Transportation merger

At the end of July 2020, the European Commission approved Alstom's plans to acquire the Bombardier Transportation concern. This meant the formation of the second largest railway sector manufacturer in the world, after the Chinese giant – CRRC [8, 10, 15]. The European Commission approved the acquisition (subject to numerous conditions), including the sale of shares in:

- Bombardier Transportation: high-speed V300 Zefiro trains, currently operated by FS;
- Alstom: the Coradia Polyvalent unit family, manufactured in the electric, diesel or electric, and diesel hybrid versions.

According to the EC, including M. Vestager, EC Executive Vice President and Commissioner for Competition, the merger of both companies is beneficial since a new, strong concern will be formed on one side, with the activities of other entities, e.g. Siemens or CAF, both of whom manufacture similar vehicles (locomotives, MUs, high-speed trains, railway I&C, etc.) not being endangered. In other words, there will be no situation where one concern monopolises the market and adversely impacts the potential implementation of future innovations and

the purchase prices of new vehicles. In February 2020, Alstom announced a plan to acquire 100% of Bombardier Transportation's shares, offering from EUR 5.8 to 6.2 bn. According to the agreement with Bombardier Inc. and CDPQ (*Caisse de Dépôt et Placement du Québec*), which at the time held 32.5% of all Bombardier Transportation shares, CDPQ will become the largest shareholder in the Alstom concern (17.5% of shares). Furthermore, CDPQ will invest approx. USD 2 bn in Alstom, plus an additional EUR 700 m. Moreover, the French industrial group Bouygues will become an Alstom shareholder (10% of the stocks). EC concerns regarding the merger of both companies were associated with several aspects of the original purchase proposed by Alstom, including:

- high-speed trains, in the field of which the new entity would become an undisputed market leader with a significant standing, although it should be noted that similar rolling stock is manufactured by Siemens or CAF, hence the reservation may only concern the market position;
- classic rolling stock (MUs and locomotives), in the case of which the new entity would gain a strong position, in France and Germany in particular;
- railway I&C – Alstom and Bombardier currently have a significant share in the aforementioned supply segment, therefore difficulties will arise for other vendors to participate in tendering procedures that involve ensuring ETCS compatibility with older (legacy) traffic safety systems. This situation could potentially lead to a reduction in the role of smaller companies to being sub-suppliers;
- urban signalling systems (trams and underground): The EC found that the proposed transaction would not raise concerns in terms of competition in the field of signalling systems for urban rail vehicles, although it should be added that Bombardier had not previously expressed interest in this segment.

To alleviate the EC's concerns regarding the impact of Bombardier Transportation's acquisition on the European railway market, Alstom has committed to several key initiatives, including [4]:

- Bombardier Transportation's contribution to the V300 Zefiro high-speed train and the transfer of an intellectual property licence to Hitachi in the case of the train developed jointly by Hitachi and Bombardier to be offered in the rolling stock tender for the British HS2;
- production lines, together with Coradia MU patent rights (electric, including multi-system and diesel-electric), plus the plant in Reichshoffen in France that belongs to Alstom;
- production lines, together with Talent 3 MU patent rights and the plant in Hennigsdorf, Germany that belongs to Bombardier;

- access to specified interfaces and certain devices that are part of onboard signalling systems and train control management systems (TCMS) developed by Bombardier.

According to Alstom, the acquisition of shares in the Bombardier concern was to take place in mid-2021 – subject to approval by the relevant regulatory authorities, including the European Commission, with each of the authorities having its own time frame. Originally, the EC's decision was to be announced in mid-July, but was postponed to late July 2020. One of the EC's control instruments is the option to initiate a 4-month investigation in the case of serious doubts regarding suspected infringement of competition. A similar investigation by the European Commission prevented the merger between Alstom and Siemens in February 2019. This came about because the German industrial union IG Metall called upon the German government to investigate the deal. As a result, in February 2019, the Commission blocked the previously proposed merger between Siemens Mobility and Alstom, saying that the companies did not come up with sufficient remedies to address EC concerns regarding competition in the signalling system and high-speed rolling stock markets.

However, there are several factors that differ between the two transactions. Above all, the Alstom-Bombardier merger is a smaller-scale transaction than the proposed one with Siemens, which some analysts believe could have resulted in a 70% share of a single entity in the rolling stock or automation market. Moreover, the transaction is technically an acquisition – not a merger, based on more complementary than competitive elements – Bombardier is a smaller player, e.g. in the case of high-speed trains, and had formed consortia in this field with other companies, like Hitachi in Italy and Siemens in Germany. The decision of the Commission faced a critical response, of e.g. SCI Verkehr, which raised an argument of concern for jobs in the plants of both Bombardier and Alstom in Germany and France, as one of the objectives of the Bombardier takeover. Furthermore, SCI Verkehr claimed that, currently, ten of the biggest global railway equipment manufacturers already supply 77% of the world's new rolling stock. The leaders are:

1. CRRC, a holding from China with virtually a monopoly over the Chinese market, although the entity often forms consortia with western entities for the purpose of tendering procedures in China;
2. Alstom – after acquiring Bombardier Transportation;
3. Transmashholding (TMH), Russia, a leader in the post-Soviet area (rolling stock on 1,520 mm gauge), although the company also wins other contracts (e.g. the supply of 1,300 passenger carriages for Egyptian railways) [30];
4. Siemens Mobility, an engineering company operating in the rail sector. It is present in almost all continents, and is responsible for, among others, the recent revival of urban rail transport in the USA. The enterprise has increased its revenue and profits in recent years;
5. Trinity Industries, a US holding operating in the transportation, power and construction industries; the company has recently supplied significant numbers of freight wagons;
6. Stadler, Switzerland – which is successful owing to, among others, the manufacture of Flirt sets that are used in Europe and North America;
7. Hitachi Rail, an engineering concern from Japan, also present in Europe (recent contracts for British and Italian railways);
8. Greenbrier Companies, a carriage manufacturer from the USA, which sells its products mainly in Europe and South America³;
9. Wabtec from the USA, after acquiring GE Transportation.

It is estimated that the railway market consolidation index has increased relative to 2017, with the 10 largest manufacturing increasing their share in the global market from 73% to 77% in 2019. A formal conclusion of the purchase and sale agreement covering the acquisition of Bombardier Transportation from Bombardier Inc. and CDPQ was announced by Alstom in mid-September 2020 [5]. The transaction was closed in Q1 2021, after the regulator's approval. A price range reduction by EUR 300 m. to approx. EUR 5.5–5.9 bn was achieved, excluding all further downward adjustments associated with the net cash protection mechanism. According to Alstom's top management, the acquisition could amount to EUR 5.3 bn, compared to the EUR 5.8 to 6.2 bn range announced on 17 February 2020. The financing structure remained unchanged, and CDPQ will become Alstom's largest stakeholder, with a share capital of 18% and voting rights. It is expected that the transaction will provide a double-digit increase in profit per share in the second year after closure and enable the maintenance of Alstom's Baa2 credit rating.

The price was reduced from a range of EUR 5.8 bn to 6.2 bn agreed in February 2020 due to the opera-

³ Greenbrier Companies acquired the former plant – Fabryka Wagonów (Carriage Factory) Świdnica and is currently producing freight carriages for both Polish and foreign markets.

tional performance of Bombardier Transportation, the COVID-19 pandemic, and broader market conditions, excluding any further downward adjustments associated with the net cash protection mechanism [3]. Currently, Alstom is expecting this figure to further decline to EUR 5.3 bn, based on the estimated potential post-closure adjustment and a commitment related to this mechanism. Bombardier Transportation reported an adjusted EBIT loss (operating profit before taxes and interest) of USD 383 m. for Q2 2020, which was announced on 6 August, after recording revenue of USD 1.5 bn for this period. Adjusted EBITDA (operating profit before depreciation of fixed tangible assets and amortisation of intangible and legal assets) amounted to USD -350 m. for the quarter, reflecting the lower production output that came about because the operations in key locations in Europe and North America were suspended due to the COVID-19 pandemic.

Alstom confirmed its objectives of achieving operating cost synergy of EUR 400 m. per year from the 4th to the 5th year after the acquisition and after restoring Bombardier Transportation's margin to a standard level in the average term. According to Éric Martel, Bombardier's CEO, the revenue from the aforementioned transactions will enable it to commence the transformation of the group's capital structure and focus on its financial balance by repaying its debts, and allow it to fully utilise the potential of in-house employees and maintain its leading position in the field of manufacturing business jets.

After receiving information about Bombardier's financial results, including the adjusted EBIT loss of USD 383 m. in Q2 2020, Alstom modified the purchase price of the Canadian company [6]. Bombardier described the EBIT loss as well below expectations, but one that reflected the additional burden of USD 435 m., primarily resulting from increasing engineering, certification and modernisation costs associated with numerous projects at a late stage, mainly in the United Kingdom and Germany. Alstom's management still believes in strong, strategic rationale behind the acquisition of Bombardier Transportation, and assumes that its profitability and commercial results will be restored. However, the announced Q2 data indicated unexpected and adverse events regarding Bombardier Transportation's condition. The company is currently facing challenges, especially relative to information available prior to the announcement from February 2020, when the acquisition was planned. According to Bombardier's management, the prospects for transport remained positive and the company reported an order portfolio of USD 33.7 bn. In addition, with plants returning to standard operation, it was assumed that production would accelerate in the second half of 2020 and reach the 2019 level in Q4.

It was also expected that the delays in engineering and manufacturing associated with COVID-19 would be eliminated in 2021. Moreover, a newly appointed team was authorised to conduct deep changes in company practices during the first quarter of 2020. The team was to assess both the management processes (organisation) and vehicle engineering, and to answer questions regarding the factors generating excessive costs. This would enable appropriate corrective measures to be undertaken. It should be noted that Bombardier Transportation has recently reported delays in the supply of Talent 2 EMUs for Abellio Rail in Baden Württemberg and Talent 3 EMUs for Southwest German Transport (Sweg), as well as Aventra EMUs for the Crossrail line in London, London Overground and Greater Anglia, and the South Western franchise. The loss of USD 350 m. was associated with the delays in fulfilling project deadlines and contributed to an adjusted EBIT loss of USD 230 m. in Q4 2019.

Alstom itself reported a 27% decline in the sales in Q1 (from 01.04 to 30.06.2020) of the financial year 2020–2021 due to the Coronavirus pandemic [9]. During this period, the volume of sales dropped from EUR 2.05 bn, to 1.5 bn, although the volume of orders increased by 2%, from EUR 1.62 bn in the same period in 2019–2020, to EUR 1.65 bn. The accounting relation relative to current accounts in this period was 1.1, and the order portfolio remained at a level of EUR 41.2 bn as of 30.06.2020. Despite the latter, the company maintains a positive approach and expects that its business activity will be back to normal relatively soon after the pandemic. According to Henri Poupard-Lafarge, the company's CEO, Alstom's operating activity was maintained thanks to remote work, but there was a certain negative impact on the operation of the company's plants and supply chain. Despite the crisis, Alstom's commercial activity remained stable. Orders continued to come uninterruptedly from operators in Africa, the Middle East, and Central Asia (rolling stock), Taiwan (Taipei underground), Mexico, China, USA, Greece (mixed supplies), Europe and the USA (signalling systems). The decline in sales was caused mainly by the slowdown during the COVID-19 crisis shutdown, especially in terms of rolling stock manufacturing. Services were less affected by reduced train traffic, while signalling systems suffered from installation rate slowdown. As of mid-July 2020, Alstom's operations returned to normal and the supply chain was resumed in line with the manufacturing output. In late June 2020, Alstom also announced the acquisition of Ibre, a manufacturer of cast iron and steel brake discs, which is a significant expansion of the Alstom in Motion (AiM) Strategic Plan.

Ibre employs around 30 people in its headquarters in Sens, Bourgogne Franche-Comté, and reported a turnover of approximately EUR 10 m. in 2019. According to

Alstom's management, the continued COVID-19 crisis is likely to adversely impact the financial results in the 2020-2021 fiscal year, including the accepted order volume, net income, free cash flow, and sales volume, although it is currently impossible to accurately estimate the aforementioned factors. In the aftermath of the current crisis, Alstom expects a rapid rail market recovery, supported by a solid foundation and growing demand for sustainable mobility. Therefore, the objective of a 5% annual average growth rate in the period from 2019–2020 to 2022–2023 should be only slightly impacted by the temporary slowdown in the company's activities, and the 2022–2023 objectives of a 9% adjusted EBITA margin and a change in the net income into free cash flow above 80% should be achievable. Alstom's management believes that, owing to the strong liquidity, the demonstrated operational capacity and profitability, as well as the rapid launch of the cost and cash containment plan, the company is prepared to survive the crisis and to take the opportunities in the thriving railway market – as well as to contribute to the transition to sustainable transport systems.

In late January 2021, Alstom completed the Bombardier Transportation acquisition process [1, 2]. The combined group employs 75 thousand people in 70 countries, generates a revenue of approximately EUR 15.7 bn, has assets worth EUR 71.1 bn, boasts extensive research and development assets, and has manufactured a total of 150 thousand vehicles, which makes it the second largest entity in the world in terms of revenue. The holding is primarily present in Europe – France, Italy, and Spain, but also in India, South-East Asia, North Africa, and Brazil. The previous Bombardier Transportation was present in such markets as the United Kingdom, Germany, the Scandinavian countries, China, and North America (USA and Canada). In total, the merged concern has access to 75% of the original equipment manufacturer (OEM) market. The reference price set at EUR 5.5 bn falls within the lower part of the EUR 5.5–5.9 bn range announced in mid-September 2020. The total sales revenue was set at EUR 4.4 bn, thus less than the previous estimates, due to the unfavourable market conditions (Bombardier Transportation's negative net cash position at the end of December 2020 and other contractual adjustments), as well as Bombardier's doubts regarding certain provisions governing the takeover. Bombardier Inc. expects that the net inflows will amount to approximately USD 3.6 bn, including USD 600 m. for Alstom shares, which will be redeemable as of late April 2021, and the obtained funds will be assigned to debt repayment. The acquisition of Bombardier's shares was financed by:

- the issue of preemptive rights to the amount of approximately EUR 2 bn, completed in early December 2020;
 - part of the EUR 750 m. priority bond issue completed in mid-January 2021;
 - increasing the reserve capital for CDPQ and Bombardier Inc. subsidiaries to the amount of EUR 2.6 bn and EUR 500 m., respectively.
- Alstom has confirmed its objective of generating EUR 400 m. of annual cost synergies by the 4th or 5th year and restoring Bombardier Transportation's margin to a standard level in the average term. Alstom intends to finalise the sale of some assets, following the requirements of the European Commission regarding acquisition approval. Alstom's North American HQ will be located in Montreal, Quebec, Canada, and will manage all regional operations and establish a research centre for engineering and design based on Quebec's strengths in terms of innovation and sustainable mobility. Both Alstom and Bombardier had their own manufacturing plants in Poland, but it should be noted that these are complementary – not competing – entities. For example:
- the Konstal plant in Chorzów is an Alstom division specialising in underground train manufacturing, although it also produces trams and, recently, EMUs of a maximum speed of 160–200 km/h (order for NS and FS). In 2000, this plant supplied Metropolis trains for the underground rail system in Warsaw, and trams for the Katowice, Warsaw, and Gdańsk transit systems;
 - the former Bombardier plant in Wrocław manufactures bodies for Traxx locomotives. These are also operated by Polish operators;
 - the ZWUS Katowice plant manufactures I&C hardware and software for rail communication systems;
 - the trams that were supplied by Bombardier (MPK Kraków was a big client) were assembled using the carrier's own capacities and resources, without launching a new assembly line or opening a new plant.
- It should be added that both companies also have other plants in Poland, which, however, operate outside the railway industry. Thus, as separate entities, there was no competition, but rather complementation. What is more, Bombardier has supplied numerous Traxx locomotives to Polish rail entities, while the Prima locomotives developed by Alstom are used in France and outside Europe rather than in Poland. The tram market case was similar. In Poland, although this market segment is dominated by Pesa, some contracts were awarded to Bombardier and Stadler, with Alstom virtually withdrawing from it after 2000. Moreover, Pesa and Newag dominate the Polish market of diesel and electric multiple units (due to, e.g. the price criterion being a key factor), although Stadler has recently been awarded an increased number of contracts.

2.5. H. Cegielski FPS

H. Cegielski FPS (Railway Vehicle Factory), which is a separate section of the former H. Cegielski concern (a company involved in marine engine manufacturing, among others), currently produces – or modernises – passenger cars for PKP IC. Until the beginning of the 1990s, the Poznań-based manufacturer, however, produced electric and diesel passenger locomotives for PKP. Unlike Pafawag, the plant from Poznań has not been supported by foreign entities, therefore, the stated intentions to commence the production of MUs or trams have not yet been implemented. H. Cegielski FPS conducts repairs and modernisations of diesel locomotives operated by Polish operators.

After completing a 3-year restructuring programme in March 2020, H. Cegielski FPS announced that [17]:

- plant sales increased 5.5 times, to a value of PLN 213 m. in 2019;
- a net profit increase was reported for the second year in a row – PLN 2.7 m. in 2019;
- EBIDTA (operating costs excluding depreciation) amounted to PLN 13 m.;
- TSI (Technical Specifications for Interoperability) requirements were implemented in the manufactured passenger carriages;
- the order portfolio amounted to approx. PLN 1 bn;
- FPS put in place a new production, planning, and logistics organisation;
- adequate financing of implemented projects was ensured;
- co-financing from the National Centre for Research and Development for development projects to the amount of PLN 34.2 m was obtained;
- ERP (enterprise resource planning) was introduced in 2018. This is a recognised system for the effective management of resources.

H. Cegielski FPS sp. z o.o. is currently owned by the Polish Industrial Development Agency (PL: Agencja Rozwoju Przemysłu), and proper collaboration with banks and insurance companies makes it possible to secure contract liquidity. In late May 2019, PKP IC decided to modify the contract with H. Cegielski FPS, which provided for the supply of 55 passenger cars. The contract was expanded to include an extra 26 units (total contract value of PLN 697.3 m.) [33]. The ordered cars are approved for traffic within the railway network of Poland, as well as the Czech Republic, Germany, Austria, Slovakia, and Hungary. The manufacturer selected DB Systemtechnik – a notified body (NoBO) to conduct the process of approval for operation, to verify the fulfilment of requirements for individual subsystems or interoperability constituents (e.g. compatibility with existing infrastructure), and

to issue the required verification certificates (a car certification process is first implemented at the engineering and manufacturing stage, and covers the selection of proper subassemblies and materials, as well as appropriate technologies). Technical and operational tests of the carriages were conducted on an experimental track in Velim, Czech Republic, which provided the possibility of supplying the traction line with several types of voltage (3 kV DC, 15 kV 16.7 Hz, 25 kV 50 Hz). This enabled the study of, among others, the impact of a given voltage type on the carriage's electrical system. In mid-January 2020, the operator announced that static tests of the bodies were ongoing and crash tests had been completed. The carriage entry into service permit procedure changed in mid-June 2020 and is now conducted under the supervision of the European Railway Agency and not the Polish Office of Rail Transport (PL: Urząd Transportu Kolejowego/UTK) [71].

According to the contract concluded in November 2017 with FPC, PKP IC completed the acceptance of modernised 2nd-class cars worth PLN 410 m. [62]. The contract stipulated that the contractor conducted P5 repairs, along with modernisation and P3 repairs of 111A cars (174A after modernisation). The P5 repair also involved the installation of 25AN bogies with significantly more advantageous travel properties, relative to older-type bogies (e.g. 4ANc). FPS completed the contract 5 months prior to the deadline, and the modernisation involved the installation of air-con, electric sockets, route displays, contained waste storage, 6-seat passenger compartments, cellular signal amplifiers, and devices providing wireless Internet. The new rolling stock started running in December 2018. PKP IC assigned the modernised carriages to run on the following routes:

- IC Bolko on the Szczecin – Lublin – Szczecin route,
- IC Gryf on the Szczecin – Olsztyn – Szczecin route,
- IC Drwęca and IC Jeziorak on the Olsztyn – Poznań – Olsztyn route,
- IC Albatros on the Gdańsk – Szczecin – Gdańsk route,
- IC Żuławy on the Szczecin – Olsztyn – Szczecin route,
- IC Mewa on the Warsaw – Szczecin/Gorzów Wlkp. – Warsaw route,
- IC Mamry on the Wrocław – Białystok – Wrocław route,
- IC Szygar and IC Morcinek on the Wrocław – Lublin – Wrocław route,
- IC Jagiełło on the Lublin – Kraków – Lublin route,
- IC Hetman on the Wrocław – Lublin/Hrubieszów – Wrocław route,
- IC Korfanty on the Wrocław – Katowice – Wrocław route,

- IC Pomorzanie on the Gdynia – Wrocław – Gdynia route,
- IC Starzyński on the Warsaw – Terespol – Warsaw route,
- IC Zielonogórzanie on the Warsaw – Zielona Góra – Warsaw route;

and also in the near future:

- Szczecin – Trójmiasto (Tricity) – Olsztyn – Białystok,
- Wrocław/Zielona Góra – Poznań – Gdynia/Olsztyn – Białystok,
- Kraków/Lublin – Katowice – Wrocław – Zielona Góra – Szczecin – Świnoujście,
- Przemyśl – Lublin – Warsaw – Bydgoszcz – Gdynia/Piła – Kołobrzeg/Gorzów Wlkp.,
- Suwałki – Białystok/Lublin – Warsaw – Poznań – Szczecin/Gorzów Wlkp./Zielona Góra.

The construction of 8 passenger carriages ordered by the Ministry of National Defence, which was commissioned in 2020, was an unusual order for FPS. At the end of 2018, H. Cegielski FPS was also the only contractor to place a bid in the tender for the modernisation of ten 1st-class carriages of the 145Ab type with managerial compartments, involving a conversion to restaurant cars [63], which includes the current P5 repair and later P3 repair, with a unit value of PLN 6.13 m. and PLN 153.3 thousand, respectively, with a 36-month warranty. Because the budget allocated by the operator was lower than the price offered by the moderniser, PKP IC decided to accept FPS's terms (the tender decision date was postponed twice). One of the reasons behind the modernisation of the 145Ab cars was frame deformations and body fragment detachment in the Bautzen 89 carriages, manufactured by the East-German producer, VEB Waggonbau Bautzen. These faults practically determined that they had to be scrapped [29]. It should be added that DR acquired similar carriages in 1984 (DB designation – WRm¹³⁰). However, their operation ended a few years ago, probably for similar reasons to those in the case of the PKP carriages. PKP IC received the modernised restaurant cars in early November 2020 [57]. The moderniser installed 12 tables and 36 seats in the carriages.

In early December 2019, PKP IC concluded a contract with FPS, valued at PLN 90.3 m. gross, for the updating of 13 SM42 diesel locomotives [18]. The entire undertaking was financed under the Operational Programme Infrastructure and Environment 2014–2020, under the following project titles:

1. Time for new connections – modernisation of carriages and locomotives for PKP Intercity S.A.
2. Accelerating comfortably – modernisation of carriages and purchasing locomotives for PKP Intercity S.A.

In the spring of 2018, the operator signed a contract with the Centre for EU Transport Projects (PL: CUPT) for the co-financing of the aforementioned project to the amount of PLN 653.8 m., with a completion time of 24 months. According to the agreement, the SM42 series was to be rebuilt into two-unit vehicles that were capable of supplying the hauled passenger carriages with electricity. The locomotives were to obtain microprocessor controls, new diesel engines with lower fuel consumption and an overall better performance, and the driver cabins were to be fitted-in accordance with the principles of best ergonomics.

2.6. Newag

Newag, which is the former ZNTK Nowy Sącz, was acquired and recapitalised by an investment fund in 2005. The flagship vehicles manufactured by Newag are the Impuls MUs (electric, diesel, hybrid) for Polish regional operators (Fig. 5), Griffin electric locomotives for passenger traffic, and Dragon electric locomotives for freight trains. Besides the 3 kV DC version, Newag has also developed 15 kV 16.7 Hz and 25 kV 50 Hz options. Newag also exports to Italy (Impuls EMU, Vulcano DMU) and carries out repairs and modernisations of electric and diesel rolling stock – as well as of passenger cars owned by Polish operators. The entity forms consortia with other manufacturers (Siemens, Stadler) for the purpose of tendering procedures organised in Poland and abroad.



Fig. 5. Impuls MU body, Newag [photo M. Wojtaszek, 27.12.2016]

In late September 2020, the Nowy Sącz-based manufacturer published a financial statement for the first half of 2020 (with some data of a preliminary nature) [11, 12]:

- achieved profit is 4 times higher relative to January – June 2019 – PLN 62.1 m. and PLN 12.4 m., respectively;
- difficulties associated with shipping Impuls 2 EMUs of the ETR322 series to the Italian operator

FSE were reported – units will be handed-over in the first half of 2021 (planned for 2020);

- 4% higher sales revenues – i.e. PLN 569.3 m.;
- EBITDA⁴ value of PLN 111.9 m., which is 154% higher, resulting from a more favourable distribution of sales plans according to the producer;
- the dividend paid to shareholders is higher;
- total order portfolio value of PLN 2.4 bn;
- the hybrid unit presented at the Trako 2019 trade fair is a new type of vehicle, and the first orders for the unit have already been placed.

At the end of November 2020, Newag announced that a 245 m long test track, with the possibility of supplying three types of voltage – 3 kV DC, 15 kV 16.7 Hz and 25 kV 50 Hz, was put into operation within its own site [50]. The overhead catenary system is connected to a transformer station, which enables voltage change. The entire system allows the testing of vehicles supplied with voltage other than 3 kV DC, which is used to power the PKP network. Newag launched a similar track with regard to multi-system vehicles or ones manufactured for export. It should be added that a similar track can be found at the Stadler Siedlce plant, with the aforementioned manufacturer carrying out export orders for operators from EU countries.

2.6.1. Locomotives

In mid-September 2020, Newag sent the first EU43 Dragon locomotive in the dual-system version (3 kV DC, 25 kV 50 Hz), manufactured for PKP Cargo, to be tested on the experimental track of the Railway Institute in Węglewo near Żmigród (Fig. 6) [42]. The contract for the supply of 31 vehicles was concluded in September 2019 during the Trako trade fair. According to the agreement, 7 locomotives were to be equipped with an approach module (low-power diesel engine), and the remaining 24 units were to be dual-voltage versions. The requirement for adaptation to operate under a 25 kV 50 Hz voltage arises from the need to acquire vehicles capable of moving over the southern part of the railway network in the Czech Republic and Slovakia, which is electrified with alternating current (the northern part is powered by 3 kV DC voltage). Newag intends to deliver 12 dual-system Dragon units in 2021 and 12 in 2022.

At the beginning of October 2020, the first of the 5 ordered Dragon 2 E6ACTab locomotives was delivered to Rail Capital Partners (RCP), a leasing company. The entire contract was to be completed by the end of 2020 (2 vehicles received per month) [13]. The value of the new locomotives was PLN 78 m., which

amounts to PLN 15.6 m. for 1 unit. RCP intends to acquire a total of 50 locomotives in the coming years.



Fig. 6. A Dragon ET43-001 locomotive (Newag; 3 kV DC, 25 kV 50 Hz) during technical and operational tests on the experimental track in Cerhenice near Velim, Czech Republic [photo J. Navratil, 24.01.2021]

In late February 2020, the President of the Polish Office of Rail Transport approved the E4DCU “Griffin” from the EU160 series for operation by PKP IC, in accordance with TSI requirements. The approval is valid indefinitely, without operational restrictions (Fig. 7). The locomotives received a certificate confirming their compliance with the ETCS Baseline 3.4.0 level 2 system, which is a pan-European Train Control System in terms of rail transport interoperability. The certificate enables trains to be freely run within the railway networks of individual countries within the EU, without a requirement to stop at national borders and replace drivers or locomotives. The high power of these locomotives – 5,600 kW, enables the easy movement of passenger trains weighing 800 t with a speed of up to 160 km/h. In February 2020, ready vehicles from this series were presented at the central station in Nowy Sącz (8 units in total), and the technical and operational tests were conducted in September 2019 at the track of the Railway Institute in Węglewo near Żmigród. The entire batch was delivered to the PKP IC Central Department and it will ultimately replace the EP09 series in driving passenger trains (EIC, IC, TLK). At the end of June 2020, PKP IC received the last Griffin (EU160 series) manufactured under the basic order covering 20 locomotives and signed in May 2018, valued at PLN 367.6 m. (PLN 18.4 m. per 1 locomotive). Furthermore, an option included in the contract provided for the supply of another 10 vehicles. This was exercised; therefore, the contract value increased to PLN 551.4 m. (loco-

⁴ Earnings before interest, taxes, depreciation, and amortisation.

motive unit price remained unchanged), so Newag supplied another 10 locomotives (30 vehicles in total) by the end of 2020.



Fig. 7. Griffin EU160-008+007 locomotives (Newag) owned by PKP IC, at Szeligi Station of CMK (Central Railway Main Line) [photo S. Dębski, 11.03.2020]

It should be added that the locomotives were supplied efficiently, at an average of 5 locomotives per month, and the contract was completed in 25 months (2 years) from the date of signature. In late November 2020, the manufacturer announced the delivery of the last Griffin (EU160-030) locomotive for PKP IC [36]. The operating plan for Griffin locomotives assumed the use of the vehicles for driving IC and TLK trains solely for domestic traffic purposes and on the following lines, starting from the beginning of July 2020:

- TLK Kiev Express on the Warsaw – Kiev – Warsaw route, Warsaw – Dorohusk – Warsaw section;
- IC Zielonogórzanin on the Warsaw – Zbąszynek – Warsaw route;
- IC Mewa on the Warsaw – Szczecin – Warsaw route;
- IC Gałczyński on the Warsaw – Szczecin – Warsaw route;
- TLK Staszic on the Warsaw – Kołobrzeg – Warsaw route;
- IC Noteć on the Warsaw – Piła – Warsaw route;
- IC Czartoryski on the Lublin – Zbąszynek – Lublin route;
- TLK Zamoyski on the Piła – Lublin – Piła route;
- TLK Chełmianin on the Warsaw – Chełm – Warsaw route;
- TLK Kochanowski on the Chełm – Bydgoszcz – Chełm route;
- TLK Mierzeja on the Lublin – Kołobrzeg – Lublin route, Kołobrzeg – Bydgoszcz – Kołobrzeg section (seasonal);
- TLK Wetlina on the Poznań – Lublin – Poznań section (seasonal);
- TLK Latarnik on the Poznań – Białystok – Poznań section (seasonal);
- TLK Warta on the Warsaw – Poznań – Warsaw route.

PKP IC decided to gradually decommission its EP09 series locomotives, the full withdrawal date being 2027, due to, among other reasons, high P4 repair (revision) costs compared to the EP07 series locomotives. The decision was motivated by the discovered design errors, namely, poor selection of elements transferring tractive and braking forces from the bogies to the body, which led to a lower durability of the main mechanical subassemblies. Although the EP09 series was subjected to major overhauls (P5 level) and modernisation, the fundamental shortcomings were retained or half-way solutions were applied. The faster wear of the mechanical subassemblies in EP09 also stems from the fact that the series was intended for operation at a maximum speed of 140 km/h, which was later increased to 160 km/h – but without significant revisions of the locomotive's design. In addition, the operational characteristics of the EP09 locomotives arise from the rather short times-to-repair, and with a daily mileage ranging from 500 to 1,000 km, individual units would soon qualify for a third major overhaul. Although PKP IC planned a more extensive modernisation of the EP09 series, the idea was ultimately abandoned in favour of purchasing next-gen locomotives.

2.6.2. Domestic contracts – multiple units

In early October 2019, the local government authorities of the Pomorskie Province decided to exercise the option for the supply of another four 5-car Impuls EMUs, pursuant to the contract concluded in 2018 and valued at PLN 246 m. (with an option right) [36]. It was initially planned to acquire 5 EMUs, but the positive experience with the new vehicles and the opportunity to receive additional funds resulted in the decision of the Marshall's Office to exercise the option. Impuls 2 units are used to run on the Słupsk – Trójmiasto – Elbląg route, and in the future, after electrification, also in the Pomorska Kolej Metropolitarna (Pomeranian Metropolitan Railway) network. All Impuls units were supplied in Q1 2020.

In mid-November 2018, a contract between the Marshall's Office of the Lubuskie Province and Newag for the supply of two 3-car diesel multiple units valued at PLN 43 m. (PLN 14.3 m. per vehicle), with a delivery deadline by the end of 2020, was concluded [51]. The vehicles, handed-over in mid-November 2020, satisfy TSI requirements and are fitted with ETCS and PZB traffic safety devices, which lets the units enter the DB network to the first border station [64].

In October 2019, Łódzka Kolej Aglomeracyjna (Łódź Metropolitan Railway) received the last of the fourteen ordered 3-car Impuls 2 EMUs [31]. The price of the entire contract amounted to PLN 267 m. (PLN 19.1 m. per EMU), with a co-financing of PLN 164.5 m. (62%) from the EU's Operational Programme

for the Łódzkie Province. As of December 2019, it was possible to make the routes and connections listed below available to the public:

- Łódź Chojny – Łódź Olechów – Łódź Widzew;
- Skierniewice – Łowicz – Kutno (number of connections – 26 per day);
- Łódź Fabryczna – Skierniewice: an increase in the number of scheduled connections from 16 to 38;
- Łódź – Tomaszów Mazowiecki: an increase in the number of trains from 2/day to 20/day;
- Łódź Fabryczna – Piotrków Trybunalski: 1 additional pair;
- Łódź – Sieradz: the maintenance of 33 current connections, despite the ongoing route renovation;
- Commencement and termination of connections to/from Łowicz and Kutno at Łódź Widzew;
- Łódź Widzew – Łódź Chojny – Łódź Kaliska ring line: 85 trains/ daily;
- Łódź Widzew – Łódź Stoki – Zgierz and Łódź – Łowicz: no changes due to renovation works carried out by PKP;
- Łódź – Warsaw: 9 train pairs on weekends;
- Łódź Fabryczna – Radomsko: 1 extra pair/day.

In December 2019, a contract for the supply of eight 2-car Impuls EMUs was concluded between Newag and the Marshal's Office of the Lubelskie Province. It was priced at PLN 146.6 m. (unit price of PLN 18.3 m.) and has a completion deadline of December 2021 [49]. The contractor also offers a 64-month warranty. In late September 2020, Newag presented one Impuls diesel MU for Koleje Wielkopolskie (Greater Poland Railways), which was sent to undergo technical and operational tests on the Railway Research Institute track in Węglewo near Żmigród [43]. The operator subsequently ordered four 36Wehd vehicles, pursuant to a contract signed in September 2019 stipulating an option right for two more vehicles [35]. The purchase of four vehicles was co-financed under WRPO (Regional Development Programme for Wielkopolska) 2014+ ("Development of public mass transit in Wielkopolska through the purchase of diesel rolling stock"). The contract value was PLN 94.9 m. (unit price of PLN 23.7 m.), the provided co-financing was to the amount of PLN 66.4 m., and the delivery time was 410 days for the first two DMUs – and 500 days for the other two. Koleje Wielkopolskie intended to assign the new vehicles to run on the Poznań to Wągrowiec, Gołańcza and Wolsztyn routes. The manufacturer granted a 48-month warranty for each vehicle. The operation of the new DMUs commenced in early November 2020 [61].

At the end of August 2020, Koleje Dolnośląskie (Lower Silesian Railways) concluded a tender for the purchase of two hybrid MUs equipped with electric

and diesel drive [47]. The Nowy Sącz-based manufacturer was the only bidder in the tender, and price was the most important criterion. The purchase value for hybrid vehicles was estimated at PLN 56.3 m. or PLN 28.1 m. per unit, which is 50% higher relative to DMUs and 30% relative to EMUs. The delivery date was set at 18 months, and the contract includes an option right for 6 more vehicles and the option to order them within 12 months of concluding the contract. In mid-July 2020, Newag also concluded a contract with the authorities of the Zachodnio-Pomorskie West Pomeranian Province for the supply of several hybrid units [44]. The contract involved the supply of two Impuls 2 units of the 36WEh type, with an option right for ten more similar vehicles. The base contract was valued at PLN 40 m., and the additional order was valued at PLN 200 m.

At the end of February 2020, when the operator selected Newag's bid (the only bidder), the tender for the supply of rolling stock for SKM Warszawa was settled. The contract was signed in early April 2020 [22, 34]. In total, Newag's bid covered 21 vehicles, including 15 units – 85 to 95 m long (5 cars) – and 6 units – 70 to 77 m long (4 car), together with P1 and P2 maintenance (100% overhauls) as well as P3 and P4 maintenance (60% overhauls) for 7 years. Newag's bid's value is PLN 543.0 / 667.9 m. net / gross, including the purchase of new vehicles valued at PLN 452.7 / 556.8 m. net / gross plus PLN 77.6 / 111.1 m. net / gross for maintenance. SKM also allotted PLN 779.3 m. for the purchase of new rolling stock. Project completion was set at November 2022 (delivery of the first 2 vehicles was to take place within 23 months of the signature of the contract).

The rolling stock availability factor was determined to be 97%. The manufacturer granted the operator a 4-year warranty for the aforementioned vehicles. The EU funding of PLN 202.6 m. obtained in 2018 came from the Operational Programme Infrastructure and Environment for 2014–2020 Priority V: "Development of rail transport outside of TEN-T". At the same time, it was the largest contract signed to date by both the manufacturer and the operator. In mid-November 2020, the EUR 46 m. (PLN 202.6 m.) co-financing under the Cohesion Fund was approved by the European Commission [74].

In late September 2020, Newag received information from the local government authorities of the Małopolskie Province (Lesser Poland Voivodeship) regarding their intention to exercise the option right for the supply of 2 more Impuls vehicles, pursuant to an amendment to the contract of June 2020. The contract initially provided for the supply of 7 × 4-car Impuls EMUs [45, 68]. Therefore, the contract value increased by PLN 44.78 m. to PLN 199.41 m. (approx. PLN 22.2 m. per vehicle). The time frame for the

delivery was set for the years 2021–2022. The vehicle purchase obtained EU funding from the European Regional Development Fund. The operator – Koleje Małopolskie (Lesser Poland Railway) – intends to use the vehicles on the following routes:

- Koleje Małopolskie connections;
- SKA2: Skawina – Kraków Gł. – Sędziszów;
- SKA3: Kraków Gł. – Tarnów;
- it is also possible to operate the vehicles on other routes, e.g. SKA1: Wieliczka Rynek Kopalnia – Kraków Gł. – Kraków Lotnisko (Cracow Airport);
- alternatively, the vehicles can be assigned to handle transport to Chrzanów, Oświęcim, Wadowice, and Zakopane;
- Kraków Gł. – Nowy Sącz / Krynica Zdrój;
- Przewozy Regionalne connections;
- Kraków Gł. – Katowice.

In early November 2020, Newag handed over 2 SA140 (222Ma type) DMUs to the local government authorities of the Podkarpackie (Subcarpathian) Province, who will offer the vehicles to the Polregio carrier under a lending agreement [69]. The contract for the supply of vehicles was concluded in late July 2019 [48]. Similar vehicles are already in use in the Podkarpackie railway network. They will soon be incorporated into the Podkarpacka Kolej Aglomeracyjna (Subcarpathian Metropolitan Railway), which handles metropolitan and suburban traffic within Rzeszów, including the civilian airport in Jasionka. The aforementioned project was co-financed from EU funds. The manufacturer supplied the new vehicles with a 60-month warranty. Besides diesel vehicles, Newag was to also supply 3-car EMUs from the Impuls 2 family, which will also be operated within the PKA project. The Impuls 2 units will be compatible with the ETCS level 3 system. The value of ordered electric and diesel vehicles exceeded PLN 200 m. In late October 2020, Newag handed over five of the eight three-carriage Impuls 2 EMUs of the 36Wedb type and EN63B series [72], with the remaining vehicles supplied in mid-December [75]. Until the construction of a new servicing and repair centre in Rzeszów, the Polregio depot in Przeworsk was selected as the Impuls maintenance location (it is an adaptable facility where the EN57 undergoes maintenance).

2.6.3. Export contracts – multiple units

In December 2015, Newag concluded a framework agreement for the supply of 15 × 3-car Impuls 2 36WEb EMUs for Ferrovie de Sud Est from Italy. In

signing this, Newag agreed to supply the 5 first units within 12 months of the date of signature (Fig. 8). The first manufactured EMU was supplied in September 2016 in order to conduct technical and operational tests on the experimental track at the Railway Research Institute in Węglewo near Żmigród. The testing of a second unit and other EMU vehicles manufactured for Koleje Małopolskie took place in late November 2016 at the station in Nowy Sącz. At the turn of November and December 2016, an Impuls 2 was sent to Florence, Italy (HQ location of the ANSF – Italian ORT), where Italcertifer⁵ commenced dynamic EMU tests within the Italian railway network. In mid-July 2017, the manufacturer submitted technical documentation regarding the vehicles in order to obtain an entry into service permit (initially a temporary one – in December 2017). Because FSE changed ownership (in August 2016, the FSE infrastructure was taken over by FS to cover FSE's debts), the contract performance was temporarily suspended.



Fig. 8. Impuls 2 36WEb-003 EMU (Newag) for the Ferrovie del Sud Est carrier at the premises of the Railway Institute in Węglewo [photo M. Graff, 06.09.2018]

A complete set of dynamic tests required to obtain ANSF approval was conducted from February to June 2018. A set of documents was submitted in February 2019 and ANSF issued an entry into service permit certificate in mid-May 2019. The public presentation of the vehicle took place in Bari (capital of the Apulia region, where FSE operates) in June 2019. The planned operation of the Impulse units commenced in September 2019, on the Bari – Putignano route. FSE decided to expand the contract by exercising two options: the first covering 6 EMUs signed in May 2019, and the second one concluded in April 2020 and covering 4 units, with a unit price of PLN 17.9 m. and a delivery time frame of 18 months. It should be added that FSE is already operating 27 DMUs of the ATR220 series, manufactured by another Polish producer – Pesa, supplied in the years 2008–2010.

⁵ Italcertifer offers all basic services in terms of certification and inspection that are required to obtain an operational permit covering railway parts, subsystems, vehicles and infrastructure in accordance with domestic (Italian) and European requirements, especially TSI.

Operational issues of the EP09 series

The design of the 104E locomotive (later known as the EP09 series) was developed in the years 1979–1980, as a result of collaboration between OBRPS Poznań (currently, Rolling Stock Institute “Tabor”) and the Rolling Stock Institute in Novocherkassk (USSR). A design speed of 140 km/h was adopted at the engineering stage but the speed requirements were increased to 160 km/h at the request of PKP, even though the project had reached the stage of constructing prototypes in 1986–1987. A characteristic feature of the first 7 vehicles was the electrodynamic (ED) brake setting – when braking at a speed of 160 km/h, it would activate at only 140 km/h. Currently, in all units, the ED brake works over the full travel speed range. The longitudinal dynamics of the locomotive were also an issue from the very start of operation, and a characteristic pulsed jerking would appear at travel speeds in the range of 100–120 km/h. This could be felt in the first (and sometimes the second) car behind the locomotive. Such a longitudinal force peak has an impact on the structure. Engineering practices have demonstrated that increasing forces relative to the loads assumed in the design does not have to result in sudden cracking of welded steel structures, however, excessive forces appearing in the course of operation can weaken welded joints and individual structural components, which in turn may lead to fatigue cracking. The effect was thought to be due to the two oblique traction pull rods (front and rear) that were used in each of the bogies. The design of the system is such that only one of the pull rods of a given bogie (tension) would work in a given travel direction.

In the second half of the 1990s, the issue of longitudinal dynamics concerning the locomotive, as well as increasing the durability and reliability of the drive unit (especially the traction gear) was addressed by numerous institutions, including OBRPS Poznań (the author of the design documentation – currently, the Rolling Stock Institute “Tabor” Poznań), Warsaw University of Technology, and Cracow University of Technology. Many solutions were proposed but most of them were never adopted in practice. A solution which many hoped would improve the longitudinal dynamics involved a change of the secondary suspension. Thus, a new body support system using large-size flexicoil springs was designed in 1994–1995. The positive outcomes of the tests carried out with the new solution enabled departure from a dropper system that required periodic adjustments and an inter-bogie coupling solution. Despite the positive operational test results (conducted by CNTK Warsaw, currently the Railway Research Institute), the pulsed jerking effect still occurred. The causes behind the problem have still not been identified to date, and the effect of cars being jerked about by the locomotive still appears. Until a few years ago, the intent was to modernise the vehicles to allow speeds of 180–190 km/h (which until recently was the

conventional vehicle approval limit) – raising the speed to 200 km/h would result in the approval for a high-speed vehicle, which would significantly increase project costs. The scope of changes was to be broad, and included increasing the traction power (new asynchronous motors) and ED braking power, the use of monoblock wheelsets, disc brakes, new shock absorbers, inclusion of impact energy absorbing elements, and a new frontal aspect to enhance aerodynamics. However, ultimately, due to the extensive scope and costs that were close to the price of a new vehicle, the project was abandoned.

2.7. Pesa

Pesa, formerly ZNTK (Rolling Stock Repair Plant) Bydgoszcz, was the first entity to commence the manufacturing of lightweight diesel rolling stock for Poland’s regional operators, as well as of electric rolling stock in which three-phase drive and other modern solutions were incorporated. The current offering of the company includes, among others, the Elf 2 EMU and Gama locomotives (electric and diesel) – Figs. 9 and 10. It seems that, apart from diesel rolling stock, the company’s success might have been determined by commencing the production of trams, initially for Polish carriers, and later for export. Some of the first foreign orders included contracts for Italian operators for the supply of 3-car Atribo DMUs (with Trenitalia as one of the clients). After the financial turmoil associated with entering the difficult German market (Link DMUs ordered for DB Region and other entities), Pesa was restructured, nationalised, and taken over by the Polish Development Fund (PFR). Currently, the Bydgoszcz-based manufacturer has a plant in Mińsk Mazowiecki, which carries out repairs of passenger trains, and deals with the servicing and maintenance of EMUs operated by selected carriers (including PKP IC and SKM Warsaw). The core of Pesa’s export production is 1,520 mm track gauge rolling stock (contracts implemented for LG, BC and UZ, as well as individual contracts for RZD and KTZ). Besides manufacturing vehicles, Pesa also repairs and modernises rolling stock (diesel locomotives, passenger cars).



Fig. 9. Gama 111Eb-001 locomotive (Pesa) at Pruszków Station
[M. Graff, 04.06.2021]



Fig. 10. Double-deck control carriage of the 316B type (Pesa)
[photo M. Graff]

In late September 2020, Pesa's management announced the completion of overdue contracts from 2014–2016 in Q3 2020, often with a loss [52]. The financial results of the manufacturer for 2019 were as follows:

- sales revenue – PLN 1.2 bn – 22% higher relative to 2018;
- production volume in 2020 was 60–70% higher compared to 2019;
- operational loss was reported; however, it was just partially of a monetary nature and did not result in a loss of solvency or a threat to continued operation;
- EBITDA (earnings before interest, taxes, depreciation and amortisation) for 2018 of PLN –508 m. was caused by increased risk and the need to create provisions for liquidated damages on account of potential contract performance delays, e.g. contract with SKM Warsaw, terminated in February 2020;
- EBITDA for the first half of 2020 amounted to PLN 10 m.;
- the order portfolio's value is approx. PLN 3 bn, with new orders being secured;
- access to bank financing was obtained only in 2020 (PFR financial aid was used previously), which should mitigate issues with orders for subassemblies and components, contributing to manufacturing smoothness;
- Pesa's audit for 2019 ended with a positive result;
- issues with financial liquidity have been eliminated and Pesa's financial situation is deemed stable;
- vehicles are manufactured in a timely manner;
- the company has been undergoing restructuring since 2017, which involves employment optimisation, administrative staff lay-offs, and potential employee transfers to manufacturing (e.g. recruitment launched) or support for people leaving Pesa;
- in November 2018, the Investment Fund for Polish Enterprises (FIZAN) took over the control of Pesa, while some part of the investment portfolio is managed by the Polish Development Fund.

2.7.1. Locomotives

In July 2020, Pesa concluded a contract for the delivery of a single Gama locomotive – in its electric ver-

sion, with an auxiliary approach engine in the 111Ed version, for Pol-Miedź Trans [37]. The contract value is PLN 14.39 m. net, and the time for completion is 24 months. The purchase was co-financed from EU funds within the framework of the “Purchase of new flatcars and a locomotive for carrying cargo in intermodal transport by Pol-Miedź Trans Sp. z o.o. in Lublin” under the Operational Programme Infrastructure and Environment 2014–2020 (application qualification process conducted by CUPT).

2.7.2. Domestic contracts – multiple units

In April 2019, the management of Koleje Śląskie (Silesian Railway) decided to expand a then-current contract by ordering two more 3-car vehicles. The last 4-car unit was received in early May 2019, and the last ordered Elf 2 EMU was supplied in late May 2020.

At the end of October 2019, the local government authorities of the Małopolskie Province concluded a contract with Pesa for the supply of four Elf 2 EMUs, valued at PLN 109.7 m. (PLN 27.4 m. per vehicle) [40]. The ordered units met the relevant TSI requirements and the contract value also covered the provision of maintenance services for 5 years, including maintenance at the P4 level. The new EMUs will expand the rolling stock assets already operated by Koleje Małopolskie, used for transportation within the Kraków metropolitan area and on outbound routes from the city to Tarnów, Sędziszów, Wieliczka, Balice Airport, and Skawina. The operator's managing authorities estimate the daily mileage of the already operated EMUs to be at 500 km, and that the operational availability indices of the new-gen units will reach a level of at least 98%.

In mid-February 2020, Pesa concluded a contract for the supply of five 5-car Elf 2 vehicles, with an option for two more EMUs for Poznańska Kolej Metropolitarna (Poznan Metropolitan Railway), namely, to offer transportation services on 9 outbound routes from Poznań to the stations of: Wronki, Kościan, Rogoźno, Nowy Tomyśl, Jarocin, Września, Gniezno, Grodzisk Wielkopolski, and Wągrowiec (by default, up to 50 km from Poznań) [54]. The contract was valued at PLN 127.45 m. (PLN 25.5 m. per vehicle), including PLN 48.75 m. co-financed (38%) from the EU's OPI&E 2014-2020 programme. The operator had its new vehicles supplied from June to December 2020. They satisfy TSI requirements and are suitable for installation of the ETCS level 3 system.

At the end of September 2020, Pesa signed a contract for the supply of five Elf 2 EMUs for Koleje Dolnośląskie, with a delivery deadline of July 2022 [79]. The contract is valued at PLN 145 m. (PLN 29 m. per unit), and it also covers vehicle maintenance at level P3 inclusive. In addition, it provides for an option of expanding the order to 25 EMUs, with

a deadline for exercising the option of 12 months from concluding the deal. PLN 85.1 m. (59%) for the purchase of the new rolling stock was allocated from the Centre for EU Transport Projects under the Project “Metropolitan Railway in Lower Silesia – purchasing rolling stock to handle passenger traffic within the Wrocław Functional Area”. The sections planned to make use of the new rolling stock are Wrocław – Jelcz Laskowice along two routes – via Wrocław Wojnów or Siechnice, with a possible extension to Oleśnica. Additional funds for the purchase of EMUs were obtained from two bank loans granted by mBank – the first loan of PLN 170.42 m. for purchasing the vehicles, and the second loan of PLN 58.75 m. on account of VAT.

2.7.3. Export contracts – multiple units

Another export contract carried out by Pesa is one for the supply of 3-cars ATR220Tr DMUs for several Italian operators [67]. One of them is Trenitalia, which had already concluded another contract for the supply of 14 additional vehicles in March 2018, by exercising the option right under the contract of November 2013. In total, the Polish manufacturer has already produced 85 vehicles of this series: 41 / 44 vehicles in the older / newer ATR220 / ATR220Tr version that are operated on local routes in the regions from northern Lombardy to southern Apulia. Currently, the ordered DMUs have been allocated by the carrier to run on Sardinia, which is the largest Italian island in the Mediterranean Sea. Vehicle deliveries were expected to end in January 2021.

In March 2019, Pesa concluded a first export contract for the supply of Elf 2 units (Elf.eu version) for RegioJet, an operators from the Czech Republic. The contract covered seven 2-car EMUs valued at CZK 1.5 bn (PLN 245 m., which is PLN 35.1 m. per vehicle), which are intended to run on regional lines in the Ústí nad Labem area [16, 41], as RadioJet was awarded a contract to manage the route for 10 years. The Elf 2 units for RegioJet will come in the dual-voltage version – 3 kV DC and 25 kV 50 Hz – with both voltages used in the region. It should be noted that ČD is ultimately planning a voltage conversion from 3 kV DC to 25 kV 50 Hz, which is used in the northern and southern parts of the country. The EMUs will be suitable for the installation of ETCS level 2 traffic safety system equipment. The Elf purchase contract also covered warranty repairs for 24 months and provided for the purchase of maintenance services. The EMUs will be operated on the following routes:

- Ústí nad Labem – Střekov (line U7);
- Ústí nad Labem – Úpořiny – Bílina (line U5);
- Most – Žatec (line U13);
- Most – Žatec / Bílina, Ústí nad Labem – Štětí and Teplice – Litvínov (some routes).

It should be added that this is the first RegioJet contract for the provision of public services in the Czech Republic. The units should be delivered and obtain an entry into service permit for both voltages by the end of 2021. The new Elfs will replace the previously operated VT628 DMUs purchased from DB. Pesa’s representatives noted that the Czech Republic is becoming a gateway to Europe for the Bydgoszcz-based manufacturer – ČD was the first carrier to order Link DMUs, and that experience was later used to win a contract with DB Regio for the supply of several dozen Link units, both 2- and 3-car.

In mid-July 2019, Pesa delivered the first 6-car DMU of the 760M series (or DP6), with a total power of 2350 kW, for Belarusian Railways (BC) (track gauge 1520 mm, Figure 11) [73]. BC ordered 6 similar vehicles as part of transport development in the years 2016-2020, and the funds were provided by state-owned banks as leasing. The manufacturer delivered 3 vehicles in 2019 and 3 in 2020. These are DMUs with each car resting on individual bogies (Jacobs bogies were abandoned). The vehicles are adapted for service on low platforms (additional step for passengers added). The 760M series is a step-up for the 730M/731M series, already delivered by Pesa to BC and already used by the operator to run on IC routes, especially on non-electrified lines (including from Minsk to Vilnius), e.g. Minsk – Grodno, Minsk – Polock, Mogilev – Gomel, Mogilev – Polock and others. Purchasing the DMUs is an element of a scheme aimed at departing from the use of classic trains (locomotive + car) on daily routes in favour of multiple units. Regular operation of the 760M series commenced in December 2019 on the Minsk – Orsha – Vitebsk route (the Minsk – Orsha section is electrified) as trains with a business class and a travel time of 3 h (296 km, not stopping at intermediate stations) or 3 h 16 minutes (with stopovers at Bogushevsk, Orsha, Talachyn, and Barysaw) [53]. It should be added that a classic night train journey on this route takes around 6 hours (it is necessary to change locomotives at Orsha). The DP6 series vehicles reach a maximum speed of approx. 140 km/h (speed on this route – 135 km/h). The DP6 has 311 2nd-class seats and 25 1st-class seats. Train occupancy varies from 70% to 100%. The trains are air-conditioned, have Wi-Fi access, sockets for charging mobile phones, vacuum toilets, and seats for people with disabilities. The approval of DP6 vehicles was based on the Technical Regulation TR TS 001/2011 of the Eurasian Economic Union, therefore, similar DMUs can theoretically be offered to carriers in Russia, Lithuania, Uzbekistan, Kazakhstan, or Moldova. The manufacturer will service the new vehicles for a period of 3 years. No option for purchasing more vehicles was granted.



Fig. 11. DMU of the DP6/760M-006 series (Pesa, 1520 mm), BC railway, Minsk suburbs [photo S. Badionkin, 04.09.2020]

Contracts for the supply for BC or an operator from a non-EU country cannot be co-financed from EU funds (OPI&E, CEF, etc.). It is therefore necessary to obtain financial aid in a different way, e.g. through Santander Group and KUKE (financing and insurance)⁶ [24]. The vehicles were purchased by a leasing company belonging to a state-owned Belarusian bank as the transaction guarantor. The Santander Group provided the Belarusian party with funds for financing the vehicle purchase, and KUKE is an entity supporting Polish exporters on behalf of the State Treasury. For this reason, the 6-year loan is insured, which protects the bank against defaults or delays in payments in the event of a commercial or political risk. In the case of the contract for DP6 vehicles, Pesa received EUR 32 m. from the Santander Group and KUKE. The Santander Group is a global leader in providing financing insurance services for export supporting agencies. It should be added that previous supplies by Pesa for BC in 2013, 2016 and 2019 were implemented in a similar manner.

At the end of September 2020, the Bydgoszcz-based manufacturer delivered the last Link DMUs to DB Regio (Fig. 12). They were supplied to the Bavarian branch of the carrier (based in Kempten) [55]. In total, Pesa delivered 72 vehicles for DB (the framework agreements from September 2012 provided for a supply of up to 420 units), including 23×2 -car and 49×3 -car vehicles, designated as 632 and 633 series, respectively. The operator allocated the Link units to handle regional traffic in the regions of Dortmund / Sauerland, Frankfurt / Hesse / and Munich / Allgäu / Bavaria. Supplying vehicles to the demanding German market was a huge challenge for Pesa, and the difficulties that arose were solved by an established Polish-German group responsible for the entire contract – from the design through production to initial

approval of the vehicles. Link units were purchased by DB and NEB, while Regentalbahn ultimately withdrew from the deal due to the prolonged entry into service approval process (finally obtained in May 2018). The Link units purchased by DB have a maximum speed of 140 km/h, while the number of passenger seats varies from 110 to 160 (1st class – 12).



Fig. 12. DMU of the 633-001 series (Pesa) for DB Regio at the experimental track of the Railway Research Institute in Węglewo near Żmigród [photo M. Graff, 06.09.2018]

The essential difference between approving vehicles for traffic in Germany and in Poland is the vast experience of EBA, the German ORT, as well as long-standing regulations and procedures that have evolved (e.g. a fixed 3-year period from contract conclusion to final entry into service approval). In Poland, after the crisis in 1989, the state was practically unable to help domestic manufacturers (an example is the termination of electric and diesel locomotive manufacturing by H. Cegielski in 1994), and new entities after 2000 had to gain experience on their own, usually via the trial-and-error method, just like contemporary producers. These were largely new companies that had not been previously involved in the industry. Poland's accession to the EU in May 2004 provided an opportunity to receive EU financial support in individual fields of the Polish economy, including the railway sector, and a strong impetus to launch a broad railway modernisation scheme in Poland. This involved infrastructure overhauls and purchasing modern rolling stock.

The Bydgoszcz-based manufacturer tried to adapt to the situation, and the poor financial resources initially available to local governments and the lack of clear rules to be satisfied by new vehicles meant that both parties saved heavily with regard to the offered technical solutions, servicing and repairs. Pesa's entry into the German market, where any "shortcuts" were out of the question, and its encounter with EBA, i.e. very meticulous officials who thoroughly study a vehicle's technical documentation, was a great challenge. Fortunately, as

⁶ KUKE Finance, a factoring company, was established by the Export Credit Insurance Corporation (KUKE) in 2014.

shown in practice, it was ultimately overcome, despite numerous difficulties (e.g. issues with financial liquidity and, ultimately, nationalisation). It should be added that many manufacturers who have long been present in the German market, e.g. Stadler, Bombardier and Alstom, have experienced the effects of EBA's inquisitiveness. It should also be underlined that Pesa is currently the only manufacturer from Poland admitted to the German market. The experience gained in engineering and manufacturing Link units for this market will certainly pay off in the future and facilitate the preparation of new export contracts.

2.7.4. Rolling stock modernisation

At the end of July 2020, Pesa supplied 83 modernised 111A-20 non-compartment car to PKP IC under a basic contract signed in April 2018 and valued at PLN 312 m. [38]. The retrofitting was carried out by two Pesa plants – in Bydgoszcz and Mińsk Mazowiecki. A total of 245 cars modernised for the operator at the cost of PLN 1.03 bn was planned. A contract for another 42 car under the contract option was concluded in November 2018. It was valued at PLN 158 m. and provided for delivery in the second half of 2020. According to the contract, the modernising entity should also conduct P3-level technical inspections of cars. The “Accelerating comfortably” project is co-financed from EU funds. PKP IC intends to integrate the modernised carriages in the following trains:

- IC Albatros on the Gdańsk – Szczecin – Gdańsk route;
- IC Żuławy on the Szczecin – Olsztyn – Szczecin route;
- IC Jeziorak on the Olsztyn – Poznań – Olsztyn route;
- IC Ukiel on the Olsztyn – Zielona Góra – Olsztyn route;
- IC Stocznowiec on the Zielona Góra – Gdynia – Zielona Góra route;
- IC Gryf on the Szczecin – Olsztyn – Szczecin route;
- IC Drwęca on the Olsztyn – Poznań – Olsztyn route;
- IC Lednica on the Poznań – Gdynia – Poznań route;
- IC Bachus on the Gdynia – Zielona Góra – Gdynia route;
- IC Bolko on the Lublin – Szczecin – Lublin route;
- IC Szttygar on the Wrocław – Lublin – Wrocław route;
- IC Morcinek on the Wrocław – Lublin – Wrocław route;
- IC Jagiełło on the Lublin – Kraków – Lublin route;
- IC Hetman on the Wrocław – Lublin/Hrubieszów – Wrocław route;
- IC Mamry on the Wrocław – Białystok – Wrocław route;

- IC Rybak on the Białystok – Szczecin – Białystok route;

- IC Pomorzaniec on the Wrocław – Gdynia – Wrocław route;

and from August 2020:

- IC Gałczyński on the Warsaw – Szczecin / Gorzów Wielkopolski – Warsaw route;
- IC Mewa on the Warsaw – Szczecin – Warsaw route;
- IC Zielonogórze on the Warsaw – Zielona Góra – Warsaw route;
- IC Inka on the Warsaw – Lublin – Warsaw route;
- IC Czartoryski on the Lublin – Zielona Góra – Lublin route;
- IC Starzyński on the Warsaw – Terespol – Warsaw route;
- IC Żubr on the Warsaw – Piła – Warsaw route;
- IC Noteć on the Piła – Warsaw – Piła route.

Pesa also repairs locomotives, especially of the older type, which owing to their design simplicity is not difficult. In July 2020, Pesa and PKP Cargo agreed to reduce the number of ST44 level P5 repairs due to declining transport, which also means a reduction in the rolling stock demand [39]. The scope of repairs covers replacing the locomotives' diesel engines, while the number of vehicles will be reduced from 38 to 25. The deadline, pursuant to an amendment to the contract of May 2018, was extended until the end of May 2021. The contract value was PLN 116 m. Extending the contract performance date was also important for the modernising entity since the COVID-19 pandemic lasting for several months in 2020 disturbed the collaboration with vendors.

2.8. Siemens

Siemens, a global concern from Germany, although without their own plant in Poland, has established various consortia with other manufacturers, e.g. Newag, for the purposes of supplying rolling stock (e.g. the Inspiro trains for the Warsaw underground or exported Inspiro for the Sofia underground). Siemens has manufactured, among others, the Husarz (Taurus) locomotives for PKP IC and Vectron for PKP Cargo and DB Cargo Polska, primarily for use in passenger and freight transport between Poland and Germany (Fig. 13 and 14). It has also supplied Combino trams for MPK Poznań. Siemens, like Alstom or Bombardier, does not participate in tenders involving EMUs for Polish carriers because one of the key criteria is the vehicle price (and not e.g. operational availability)⁷.

⁷ Although Stadler participates in similar tendering procedures, it does so for only large carriers, e.g. PKP IC or Koleje Mazowieckie (an order for several dozen EMUs, with a minimum of 10 vehicles).



Fig. 13. Vectron locomotive driver cabin, Allach plant
[photo M. Graff, 27.06.2016]



Fig. 14. Vectron (Siemens) locomotives during assembly, factory Allach, Munich [photo M. Graff, 27.06.2016]

In mid-July 2019, PKP Cargo, which is the largest rail freight operator in Poland and the second biggest in Europe (after DB Cargo), received 3 new Vectron MS locomotives manufactured by Siemens Mobility. As a result, PKP Cargo's Vectron fleet has increased to 20 units.

In September 2015, the operator obtained its first 15 Vectron MS locomotives and it exercised an option for 5 more vehicles in January 2019 – six months later, it received the first 3 Vectron units, with 2 more handed over in early 2020. The purchased locomotives have a power of 6,400 kW, a maximum speed of 160 km/h, are equipped with the ETCS system and have been approved for operation on the railway networks of Poland, Germany, Austria, the Czech Republic, Slovakia, Romania, and Hungary. It should be noted that Vectron platform vehicles can run in as many as 18 European countries (depending on the locomotives being equipped with the approved national safety systems). PKP Cargo intends to use Vectrons

to handle routes within the New Silk Road (NSR) and the so-called Three Sea countries. A long-term goal of the operator is achieving the position of intermodal transport market leader in the Three Seas Initiative area and the EU NSR section.

Vectron locomotives are adapted to crossing European railway borders without stopping (a difference compared to e.g. the EU44 / ES64P4 locomotives operated by PKP IC). Eliminating the need to stop at the border shortens passenger train travel time by several minutes, and even up to half an hour for a freight train, while simultaneously lowering the costs involved in rolling stock operation and reducing the necessary driver work time. Over the last several years, Siemens Mobility has sold over 900 Vectron locomotives, and the supplied vehicles have already covered more than 215 million kilometres. Similar locomotives are operated within the PLK network (besides PKP Cargo) by DB Cargo Polska, Industrial Division and operators from Germany, the Czech Republic and Austria. Furthermore, a Vectron belonging to MRCE (a rented vehicle) heads trains owned by PKP Intercity. In order to present the aforementioned capabilities of Vectron locomotives, the manufacturer – in collaboration with the operator organised a test run in July 2019 on the Chojnów – Węgliniec – Bielawa – Horka route, across the Polish-German border (the train was headed by EU46-514), after the PKP-DB Bielawa – Horka border crossing was electrified in December 2018 (change of voltage 3 kV DC ↔ 15 kV 16.7 Hz on the German side).

In early July 2019, Siemens Mobility and Newag signed an amendment to the contract for the supply of 100 additional ETCS onboard devices for vehicles manufactured by Newag. It is an extension to the framework agreement between both companies regarding the supply of onboard devices. The new systems will be installed in, among others, Dragon 2 locomotives so as to gain approval for running on both Polish and other European rail systems. It should be added that, since 2016, Siemens Mobility has supplied almost 200 Trainguard ETCS onboard devices for locomotives and electric multiple units manufactured by Newag. Beyond this, the companies have signed an amendment to the applicable contract that extends the supplies by an extra 100 units. The supplied Siemens solutions are compliant with the latest European regulations in terms of ETCS level 3 baseline 3. Siemens onboard devices are also compact and virtually maintenance-free, and the German manufacturer has vast experience in integrating ETCS with the individual national safety systems put in place by EU operators. The currently valid amendment extends the contract validity date until the end of 2023 and leads to the unification of the onboard part of ETCS systems installed in Newag vehicles, while reducing the time required for their full implementation.

The metro in the capital of Bulgaria ordered twenty 3-car Inspiro underground trains for line no. 3, similar to their equivalents operated by the Warsaw underground. Underground cars were manufactured as a joint effort of Siemens and Newag, and the main and auxiliary converters were supplied by Medcom. The advertised technical data includes: carriage layout D-T-D, body sheathing – aluminium, track gauge 1,435 mm, total length 60,008 mm, maximum width 2,650 mm, floor height above rail head 1,100 mm, axle load 12 t, maximum speed 80 km/h, door width 1,400 mm, supply voltage 1.5 kV DC from an overhead contact line, and places for passengers: 110 seats and 617 standing spots. Train deliveries were to start in July 2018, pursuant to a contract concluded in 2015.

2.9. Škoda

Škoda, a manufacturer from the Czech Republic, supplied the EU/EP05 passenger locomotives produced under a Swiss license, which started electric traction in Poland. It also supplied the ET40 series for freight traffic. Currently, the Pilsno-based manufacturer is conducting a contract for the design and manufacturing of underground rolling stock for Warsaw, with manufacturing taking place in the Czech Republic (Figures 15 and 16).



Fig. 15. Aluminium body for a Warsaw underground train [photo M. Tobrman / Škoda]



Fig. 16. Animation of a Warsaw underground train [photo M. Tobrman / Škoda]

In late January 2020, the Czech concern Škoda (Škoda Transportation and Škoda Vagonka) and Metro Warszawskie signed an agreement valued at PLN 1.31 bn for the supply of 45 × 6-car trains (including 8 optional units). The ordered trains will be used to handle rolling stock on line no. 2, which is currently being expanded in both directions (western and north-eastern) and line no. 1, where, according to the operator intention, they will replace the currently operated series 81 cars of Soviet and Russian-built. The first Škoda trains should be delivered within 20 months of the date of the contract being signed, and the last train – within 53 months of the said date. The operator will receive funds for the purchase of new rolling stock from, among others, two EU aid programmes: “Construction of the 2nd underground line with associated infrastructure and rolling stock purchase – stage II” and “Construction of the 2nd underground line with rolling stock purchase – stage III”. When evaluating the bids of manufacturers participating in the tender, the committee considered such factors as price (50%), electricity consumption (24%), vehicle maintenance costs (22%) and environmental issues (4%). The metro fleet will be manufactured in Škoda plants in Ostrava (among others, bodies) and Pilsno (electrical and mechanical parts plus final assembly). They will be single-space trains, equipped with an energy recuperation system, adapted to transport physically disabled people. One of Škoda’s advantages were the long times between repairs equal to 130 days (4 months). In comparison, a similar index for Inspiro by Siemens is 2 months, Alstom’s Metropolis – 2 weeks and the 81 MMZ / Vagonmash series – 20 h. Although Škoda has not yet independently and serially manufactured underground car, it has been involved in underground rolling stock modernisation in Prague, Kiev and Tbilisi (cars of the 81 series, after modernisation of 81-71M), and has designed and manufactured Newa cars for the Saint Petersburg underground, based on the 6Mt series. Currently, the Czech company is the co-owner of a manufacturer from St. Petersburg – Vagonmash (51% of shares) that deals with the Kirov Factory (49% of shares).

2.10. Stadler

Stadler is an international concern from Switzerland and operates in the EU, North America, and several post-Soviet states. In 2007, Stadler constructed a completely new plant in Siedlce, Poland, and supplied its flagship product – the Flirt MU – to several Polish operators (via a framework agreement with Koleje Mazowieckie, Mazovia Railway). It is also currently implementing export orders for several European operators (track gauge 1,435 mm vehicles). Recent orders cover the supply of trams for

MPK Kraków. These are being manufactured outside the Siedlce plant, in Środa Wielkopolska, where the plant acquired from Solaris in 2018 is located. Although Stadler manufactures a wide range of rolling stock (underground, locomotives, high-speed trains), orders implemented in Poland involve only MUs and trams.

In mid-September 2020, Stadler commenced the production of 12 Flirt units (Fig. 17) ordered by PKP IC under a PLN 1.02 bn contract concluded in 2019. This also involves EMU maintenance for 15 years [60]. Manufacturing takes place in the plant in Siedlce, and each vehicle is assembled in the following manner:

- body installation – assembly of the electrical and pneumatic parts, insulation, and fastenings;
- installation of wall, floor, or ceiling elements;
- installation of vehicle lighting and equipment: – seats, tables, shelves, etc.



Fig. 17. The Flirt EMU of the ED160-10A series (Stadler), owned by Koleje Mazowieckie and used as a passenger train on the Sochaczew – Dęblin route, calling at Warszawa Wsch. Station [photo M. Graff, 15.08.2020]

Flirt bodies for all Stadler group vehicles are manufactured in Hungary out of aluminium. It is a process which is more difficult compared to the manufacturing of the bodies' steel equivalents (welding of aluminium elements must take place in an anaerobic atmosphere). Despite the greater thickness of aluminium sheets, owing to currently available technologies, the aluminium bodies are lighter than their steel equivalents. Moreover, the poorer acoustic wave conductivity of aluminium relative to iron / steel also means better acoustic insulation. Furthermore, the lower EMU mass means not only lower energy consumption, but also lower wear of the mechanical part of the railway infrastructure. Flirt units satisfy the current European crashworthiness (EN 15227) and durability (EN 12663) standards. Installation of the ETCS system in the ordered vehicles is also possible. After completing the manufacturing process, it is required for each vehicle to cover 150 thousand kilometres over 6-12 months as part of supervised operation. The manufacturer is planning to deliver the first units in the second half of 2021. PKP IC intends to initially

allocate Flirt units to run on routes in the Szczecin – Lublin – Kraków triangle, relative to such previous routes as:

- Warsaw – Bydgoszcz;
- Olsztyn – Warsaw – Kielce – Kraków;
- Gdynia – Bydgoszcz – Łódź – Katowice;
- Kraków – (on the CMK) Łódź – Kutno – Poznań – Szczecin.

For the purpose of implementing the PKP IC order, Stadler decided to construct a new, 165 m long production hall within the Siedlce plant, at a cost of PLN 44 m. The contract for the purchase of 12 Flirt units for PKP IC is part of a PLN 7 bn programme “PKP Intercity – Large Investment Railway”, which involves rolling stock renovation. The programme has been in place for several years and covers the acquisition of Pendolino, Flirt, and Dart units to handle EIP and IC routes. It includes the modernisation of already owned EMUs of the ED74 series (contract performed by Pesa for PLN 274 m.). The operator is also planning to purchase double-deck EMUs to handle the overburdened Warsaw – Łódź route, where the currently operated Flirt units run on double traction.

Another contract implemented by Stadler for Polish operators is one for the supply of a total of 71 units ordered in January 2018 by Koleje Mazowieckie (2 to 5 cars, 10 to 61 units, respectively) [65, 66] with a total value of PLN 2.2 bn (Fig. 18). The operator benefits from EU funding granted under the RPO WM (Regional Operational Project for the Mazowieckie Province) (subsidy of PLN 96.16 m.) and OPI&E 2014–2020 (subsidy of PLN 580 m.) under Measure 5.2 “Development of rail transport outside of TEN-T of the Operational Programme Infrastructure and Environment 2014-202” [14]. EU funding of a record-breaking amount of PLN 580.25 m was obtained. This covers 50% of the eligible expenditure amount. The new Flirt vehicles are compliant with the latest Technical Specifications for Interoperability (TSI). The entire contract has been divided into several parts that cover the purchase of 5-car EMUs with a total of 59 units:

- first part: 6 × 5-car vehicles running on the Łowicz – Sochaczew – Warsaw – Celestynów (Railway Line 6) routes, contract signed in May 2018, all vehicles already delivered and accepted;
- second part: 12 × 5-car EMUs for the Skierniewice – Warsaw – Mińsk Mazowiecki sections, contract value PLN 398 m. gross (co-financing from OPI&E 2014-2020 to the amount of PLN 126.05 m.), concluded in March 2019, 6 EMUs delivered (as of mid-September 2020);
- third part: 15 × 5-car EMUs, for the Góra Kalwaria / Czachówek – Warsaw – Modlin lines, conclusion planned in the near future;

- fourth part: 16 × 5-car EMUs, for the Warsaw – Tłuszcz section, conclusion also planned in the near future;
- fifth part: 10 × 2-car EMUs to run on the Radom – Dęblin / Skarżysko-Kamienna / Drzewica / Warka routes (Radom exit lines).



Fig. 18. Bodies of the first Flirt EMU for PKP IC, Stadler plant in Siedlce [photo M. Jarośnińska / Stadler, 12.08.2020]

The manufacturer offered not only to make the contracted EMUs and train the personnel (drivers, train managers, and auditors) but also to conduct 2 P4-level maintenance repairs and provide servicing, as well as to supply a post-collision (repair) package. Initial technical acceptance was conducted at the Stadler plant in Siedlce, followed by supervised runs (without passengers) and final acceptance in June 2020 at the Rolling Stock Repair and Operation Section, Warszawa Grochów. Maintenance and repair services will be provided for the new trains. In late June 2020, a contract with Stadler Service Polska for the construction of technical facilities, valued at PLN 20 m., was concluded at the Koleje Mazowieckie premises in Sochaczów [80]. A 2,500 sq. m hall will feature 2 service tracks, technical repair spaces, workshops, a warehouse, a social and office building, as well as track, road, and parking infrastructure. The possibility to expand the facility was also provided for, and the completion date is Autumn 2021. It is planned to conduct all running repairs and P1 to P3 maintenance services at this location. The entire facility will be located within the premises of the existing Koleje Mazowieckie Rolling Stock Repair and Operation Section, on the border of the city and municipality of Sochaczew. The acceptance of new Flirt units entails the decommissioning of previously operated EN57 units (non-modernised ones in particular). Modern rolling stock is also entering more lines, to-

gether with the modernised outbound lines running from Warsaw. The following lines are currently being reconstructed:

- LK (Railway Line) 8 on the Czachówek – Radom section, including the construction of a second track on the Warka – Radom section, as well as increasing the curve radii and enabling an increase in speed to 160 km/h along the entire line (Warsaw – Radom); the line has been partially approved for use and operation as of late June 2021 [70].
- LK 7, Warsaw – Otwock – Dęblin – Lublin: Otwock – Pilawa is currently being modernised – this involves the construction of a second track and increasing the speed to 160 km/h (this modernisation was at the partially completed stage as of August 2020) [58]. The Warszawa Wschodnia – Warszawa Falenica section still remains to be modernised.

Other outbound lines from Warsaw have been upgraded and adapted to a speed of 160 km/h, although such a value is rarely achieved in the course of operating EMUs in regional traffic due to the short distances between stops. In practice, the rational travel speed is 130 km/h, as this enables the capabilities of the new rolling stock to be utilised and the travel time to be shortened, while ensuring reasonable energy consumption.

The last contract performed by Stadler for Poland's operator is one signed in April 2019, and concerns the expansion of 10 Flirt EMUs operated by Łódzka Kolej Aglomeracyjna (Łódź Agglomeration Railway) – from the current 2-car to 3-car units. The vehicles are being rebuilt in the plant in Siedlce – the first unit was completed in late July 2020 [56]. The reconstructed EMUs will undergo tests on the experimental track at the Railway Research Institute in Węglewo near Żmigród. It should be added that the Flirt units ordered by ŁKA, unlike the other 2-car Flirt units manufactured by Stadler, received two drive bogies instead of one. This was to facilitate their expansion in the future. Vehicle expansion will result in an increased number of passenger seats – from 120 to 186, which will lead to a situation that some routes will require rolling stock to be serviced by 1 unit instead of the current double-traction service. The vehicle expansion process is conducted with financial aid from the Regional Operational Project for the Łódzkie Province.

Stadler's plant in Siedlce primarily manufactures MUs, including Flirts or GTW (*Gelenktriebwagen*; these MUs have a drive system located in a separate car, usually in the middle of the vehicle), and are either electric (including multi-system) or diesel driven – and supplied to the carrier market in Europe (1,435 mm track gauge). A list of Stadler vehicles manufactured in the Siedlce plant in the years 2017–2020 is provided in Table 2.

Table 2

List of Stadler contracts (MUs) carried out in the years 2017–2020 in Poland in the Siedlce plant

Operator	Country	Vehicle type	Number of units in vehicle	Drive	Voltage	Rail gauge [mm]	Number of vehicles	Production period
Arriva / Limburg	Netherlands	Flirt	2	electric	1.5 kV DC	1435	7	2016–2017
Arriva Limburg 3-system	Netherlands	Flirt	3	electric	1.5 kV DC, 3 kV DC, 15 kV 16.7 Hz	1435	8	2017–2018
Arriva Noordned	Netherlands	Wink	2	diesel	–	1435	18	2018–2020
SBH	Germany	Flirt 3 XL	3	electric	15 kV 16.7 Hz	1435	32	2020–2021
BW1	Germany	Flirt	5	electric	15 kV 16.7 Hz	1435	16	2017–2020
NSB Torske Tog Option 4	Norway	Flirt	5	electric, diesel	15 kV 16.7 Hz	1435	18	2017–2020
NSB Torske Tog Option 5	Norway	Flirt	5	electric	15 kV 16.7 Hz	1435	n/a	n/a
PKP IC	Poland	Flirt	8	electric	3 kV DC	1435	12	2019–2023
Koleje Mazowieckie	Poland	Flirt	5	electric	3 kV DC	1435	61	2019–2023
Slovenske železnice	Slovenia	Flirt	4	electric	3 kV DC, 15 kV 16.7 Hz, 25 kV 50 Hz	1435	11	2018–2021
Slovenske železnice	Slovenia	Flirt	4	diesel	–	1435	5	2018–2020
Slovenske železnice	Slovenia	Kiss	3	electric	3 kV DC, 15 kV 16.7 Hz, 25 kV 50 Hz	1435	10	2018–2021
Slovenske železnice	Slovenia	Flirt	3	diesel	–	1435	16	2019–2022
Slovenske železnice	Slovenia	Flirt	4	electric	3 kV DC, 15 kV 16.7 Hz, 25 kV 50 Hz	1435	10	2019–2022
GySEV	Hungary	Flirt	4	electric	25 kV 50 Hz	1435	10	2017–2018
East Anglia Abelio	Great Britain	Flirt	4	electric	25 kV 50 Hz	1435	21	2017–2019
East Anglia Abelio	Great Britain	Flirt	3	electric, diesel	25 kV 50 Hz	1435	14	2017–2019
EAV	Italy	Flirt	4	diesel	–	1435	5	2021–2022
FNM	Italy	GTW 4/12	4	diesel	–	1435	4	2016–2017
FNM	Italy	Flirt	4	diesel	–	1435	30	2020–2024
TPER	Italy	Flirt	5	electric	3 kV DC	1435	7	2016–2017

[Source: M. Jarosińska / Stadler]

2.11. Greenbrier – Wagony Świdnica

The largest manufacturer of freight cars in Poland is the Wagony Świdnica plant, which, after acquisition and recapitalisation by the American Greenbrier concern, has become the largest rolling stock exporter in Poland in terms of production volume. The access to modern technologies that has been enabled by the new owner and the large unit contracts that have been won (which enables a reduction in unit price),

not only in Poland but also in several EU countries, North America, and the Middle East, are not without significance. Wagony Świdnica currently manufactures, among others, tankers for liquids (crude oil, petroleum products) and gases (propane, butane), coal wagon (coal, aggregate), flatcars, and car wagon, with 60% of the output being exported [81]. Starting in 1989, the plant has annually produced 1 thousand cars on average (approximately 100 per month or 3 per day), while the production capacity has amounted to

1.5–2.0 thousand per year. The plant, which has its own 50-employee engineering office, employs 1,600 people. According to the manufacturer's released business data, the order portfolio includes 27 thousand cars. Proof of its high manufacturing quality was the implementation of an order for an operator from Saudi Arabia⁸ – the supply of 1,185 carriages for transporting liquid sulphur. The manufacturer has developed new bogies with a maximum axle load of 25 t, while the produced cars are made of high-strength materials, which enables e.g. reducing the size of the main frame in tankers, while simultaneously increasing the liquid tank volume. Greenbier is also the owner of an overhaul plant in Oława and a repair plant in Tarnobrzeg. The Wagony Świdnica plant assembles [23]:

- container transport flat wagons – series: Sgnss 60', Sggrss 80', Sggss 80', Sggmrss 90', Sffggmrss – for FLA 2 X 40, FKA 2 X 50, FEA 2 X 60, FAA 40 UK;
- tanker wagons – series: Zags 53 m³, Zacens 73 m³, Zaens 73 m³, Zacens 79 m³, Zans 85 m³, Zacns 87 m³, Zacns 95 m³, Za(c)ns 97 m³, Za(c)ns 99.5 m³, 102 m³ –Z08D, Zags 102 m³, Zags 103 m³, Zags 106 m³, Zags 113 m³, Zags 116 m³, Zags 120 m³, Zags 123 m³;
- flatcars – series: Rijmmns 660, Sns-x, Rns 674, Rglns 673, Rns-z;
- coal wagons – series: JNA UK 42,9 Eamnos 57 m³ –E06A, Eamnos 57 m³ – E06B, Eamnos 72 m³ – E04E, JNA 60 m³, Eanos 82.5 m³;
- covered freight wagons with sliding side walls – series: Hbbillns, Rils-y 653, Habbii(II)ns 352, Habbii(II)ns (Habbiins) – H01A;
- dumping wagons – series: Tanpps 55 m³–T05A, H0a 55 m³, Falns 184 77 m³, Tanos 78 m³–T03A, Tadns 82 m³, Falns 85 m³, Falns 181 86.6 m³, Falns 87 m³, Tagnos 898 90 m³, IIA 90 m³, Tagnpps 95 m³ (length 14,800 mm and 17,170 mm), Tagnpps 102 m³, Uagnpps 105 m³, Tanoos 123 m³, Tagnpps 130 m³;
- covered wagons with foldable side walls – series: Shimmns S10B, Shimmns S10C, Shimmns ttu 724, Shimmns, Smmnps, Sfhimmns, Shmmns;
- car carriers wagons – series: Laaers L04A, Laadr, Laaers L02A, Laaers L07A, Laaers L08A;
- special wagons – series: Faccns (Xans), Faeprss (SSDT), SSDCT, for transporting railway sleepers for MRA UK;
- bogies – types: GB25RS, Y25Lsi(f)-DD1, Y25Lsi(f)-DC1, Y25Lsd-K/-K-V, Y25Lsde-K/-K-V, Y25Ls(s)d1-K, Y25Ls(s)(d)i(f)1-K, Y25Lsdi(f)-KB1, Y25Lsdi(f)-KC1, 25Lsd-KP1, Y25Lsdi(f)-KW1, 3ASL1o-K(V).

- apart from two-axle car wagons, other cars feature two 2-axle bogies each.

2.12. Zastal Zielona Góra

The Zastal Zielona Góra plant is a transformed entity that significantly reduced its production output after 1989 due to the collapse of the eastern (Soviet) market. Prior to 1989, the plant produced, among others, light diesel locomotives for operation on industrial sidings (the Ls60, SM03/SM04 series, 410D and 803D types) as well as 601W, 408W, and 401Wk coal wagons, 1R tankers, 14K covered wagons, and 1L coolers [25]. The plant has given up on manufacturing finished freight wagons in favour of producing class 1, 2, and 3 steel structures, in accordance with the PN-M 69008 standard, using unalloyed or low-alloy structural steel, including in particular:

- steel structures;
- structural elements of machinery and technical devices;
- girder structures, trusses,
- industrial systems,
- tanks, containers,
- belt and chain conveyors,
- environmental protection elements,
- landings, stairs, handrails,
- installation and welding instruments,
- construction fittings.

The Zastal plant makes use of such technological processes as sand-blasting, sheet metal cutting and bending, as well as hydrodynamic coating:

- **sand-blasting / shot-blasting:** steel structures are cleaned in two shot-blasting booths of the internal dimensions of chambers of 5 × 5 × 15 m and 6 × 6 × 30 m, equipped with abrasive material scraping and conveying machines;
- **sheet metal cutting (with propane and plasma) on a table of the dimensions of 3 × 12 m** as well as using two innovative Mitsubishi lasers with 1.5 × 3 m work tables. The cutting capacities are:
 - normal – 140 mm (propane) – 28 mm (laser);
 - stainless – 16 mm (plasma) – 12 mm (laser);
 - aluminium – 18 mm (laser).
 One of the lasers is equipped with an attachment for machining pipes and profiles. The capacities are:
 - min. / max. diameter 15 / 240 mm;
 - max. length 3,000 mm;
 - max. material mass 115 kg;
 - rotational speed 33.5 RPM.

⁸ Orders made by petroleum-producing countries from the Persian Gulf are characterised by the expectation of very high quality with regard to the supplied products, which is also appreciated in the form of high remuneration paid to the manufacturers.

Materials are also cut on a hydraulic guillotine and by band-saws, with the following cutting thickness capacities:

- sheet metal – on guillotines up to 3 m wide and 13 mm thick;
- sections – on band-saws with maximum cross-sections of 600 × 400 mm;
- **bending of sheet metal, workpieces, etc.:** on two hydraulic press brakes:
 - Durma – maximum bending length 3,050 mm, pressing force 320 t;
 - Baykal – maximum bending length 4,100 mm, pressing force 300 t;
- **hydrodynamic coating:** with primers and top coats.

2.13. Europejskie Konsorcjum Kolejowe WAGON in Ostrów Wielkopolski

The history of the Europejskie Konsorcjum Kolejowe (European Railway Consortium) WAGON in Ostrów Wielkopolski after 1989 is similar to that of Zastal Zielona Góra. Following the decline in transport in Poland resulting from the transition from the command and quota system to a free market, which led to a reduction in the volume of orders mainly from PKP, the company's management commenced restructuring. However, neither the accession to the mass privatisation programme in 1995 nor the transfer of 15% of the shares to the plant's employees a year later prevented the plant's bankruptcy in 2004. The bankruptcy trustee then sold the plant's assets to several companies, which enabled the formation of a new entity under the name of Kuźnia Ostrów Wielkopolski sp. z o.o., which manufactured metal elements for the railway (orders from, among others, PKP Cargo), shipbuilding, and machinery industries, and also provided turning, welding, and installation services related to steel structures. Since 2010, after being purchased by a new owner, the plant has been operating under the name "Europejskie Konsorcjum Kolejowe WAGON sp. z o.o.". Some of the facilities intended for office workers were not needed and were handed over to other entities from the education or healthcare sectors. The plant is a subcontractor for other railway industry enterprises, and it manufactures freight wagons and wagons bogies as well as parts, assemblies, and subassemblies for freight wagons, including those based on the ordering party's design documentation. The manufacturing portfolio offers the following freight wagons and wagons bogie series [26]:

- container flatcars – series: Sgnss-K 60', Sggmrss-K 80', Sggmrss-K 90', Sgns(s) 60', Sggmrss 80', Sggmrss 90', Sggmrss 104';
- coal wagons – series: Eaos, Eas, Es, Eamos, Eans, Eanos, Tamns, Eans-K, Eanos-K;

- dumping wagons – series: Fals, Falns, Tadns, Tads;
- flatcars – series: Rils, Res, Snpss, Scs, Shimms, Lgs;
- pocket wagons – series: Sdgmns, Sdggmrss;
- bogies for freight wagons of the following types: Y25 Ls(s)d1, Y25 Ls(s)1, Y25 Ls(s)d1-K, Y25 Ls(s)1-K, Y25/25t.

The entity also provides services in the field of overhauls and repairs at the P2, P3, P4, and P5 maintenance levels, as well as reconstruction and modernisation of all freight wagons types, including:

- coal wagons with normal (type E) and special (type F) structures;
- flatcars on normal (types R, K, O) and special (types S, L) bogies;
- tankers (type Z) – without tank repair and inspection;
- wagons with a retractable roof (type T);
- covered wagons with normal (type G) and special (type H) structures;
- special wagons (type U);

as well as repairs and regeneration of all parts, assemblies, and subassemblies for freight wagons, among others:

- complete bogies, bogie frames;
- wheelsets;
- full-bearing axle boxes;
- rolling stock running gear springing elements;
- draw and buffer gear;
- brake parts and air brake fittings;
- unloading mechanisms;
- external devices.

The plant also manufactures steel elements, and offers:

- design and construction of freight wagons, wagons bogies, as well as parts, assemblies, and subassemblies for freight wagons;
- development of complete technical documentation for freight wagons and wagons bogies – as required by applicable law;
- execution of freight wagons and wagons bogie prototypes;
- approval of the scope of testing required for obtaining EC Certificates with all research units;
- representation of clients in discussions with the President of ORT in matters related to obtaining Operation Approval Certificates for a railway vehicle type or a specific assembly, subassembly or element;
- representation of clients in discussion with Certification Bodies in matters associated with obtaining EC Certificates for carriages – structural subsystems and wagon bogies – interoperability constituents, pursuant to Directive 2008/57/EC (2001/16/EC) and the Commission Decision TSI WAG (freight carriages) and TSI NOI (noise).

2.14. Tabor Dębica

The youngest freight carriage manufacturer in Poland is Zakłady Produkcyjno-Naprawcze Taboru Maszyn i Urządzeń “Tabor” M. Dybowski Sp. J., established in 1993 and transformed into two entities in 2013 [76]:

- 1) Zakłady Produkcyjno-Naprawcze Taboru Maszyn i Urządzeń “Tabor” M. Dybowski Sp. J. – rail transport;
- 2) Tabor Dębica Sp. z o.o. – rolling stock manufacturing and repairs.

Tabor Dębica manufactures freight wagons such as:

- 438W and 438Wa coal wagons of the Eanoss series;
- 451Z flatcars of the Sggn series, 451Za of the Rbns series, 452Z and 453Z of the Res series;
- 455Va dumping wagons of the Fas series;
- 402Rc tanker wagons of the Zaces series;
- 441Sa cement-carrier wagons of the Uacns series;
- 455Zc high-temperature material wagons.

3. Conclusions

Rail vehicle manufacturers in today’s Poland produce locomotives and multiple units (diesel and electric) as well as underground trains for both domestic and foreign clients. Poland’s domestic manufacturers usually produce single-system locomotives and multiple units, sometimes diesel-driven. In contrast, the manufacturing of more advanced vehicles – multi-system locomotives or MUs, high-speed trains, and underground trains is dominated by international manufacturers who own plants in Poland and, owing to the ability to acquire or hold larger capital, are able to freely develop new technologies (e.g. production robotisation) that are currently unavailable to domestic producers. Nevertheless, contracts are awarded to virtually all companies. Therefore, each plant is engaged in the production process. Stimuli include the possibility of receiving EU funding for rolling stock purchases as well as the numerous modernisations of PKP infrastructure financed in recent years by the National Railway Programme and still carried out, also with EU financial aid. Freight carriages are also manufactured – mainly by the plants of large producers (Greenbier from the USA) and primarily for export.

A distinctive feature of the post-1989 Polish rolling stock industry is the significantly higher quality of manufactured vehicles, and exporting ready-made units is currently a natural process. However, before 1989, it was limited mainly to freight carriages and (to a lesser extent) passenger carriages.

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