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Innovative Railway Stations

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Abstract. In relation to modern demographic trends, evolving technologies and environment-friendly solutions increases the potential of rail considered as sustainable form of public transport. Contemporary tendencies of designing railway stations in Europe are focused on lowering energy consumption and reducing carbon emission. The main goal of the designers is to create a friendly and intuitive space for its users and at the same time a building that uses renewable energy sources and minimizes negative impact on the environment by the increase of biologically active areas, reuse of rainwater and greywater, innovative heating and cooling solutions and reduction of energy losses. The optimisation of a life circle in railway architecture introduces new approach to passenger service. Examples mentioned in the content of this article help to synthesize changes in approach to the design within the context of sustainability.

1. Introduction

The beginning of the twenty-first century has been defined by rapid transformations, technological advances, urbanization growth and climate changes. These trends affect almost every aspect of the world including transport in general and rail transport in particular.

In 2011 the European Commission published the White Paper Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system which is the official transport policy of the European Union. One of the stated objectives is: "By 2050, complete a European high-speed rail network. Triple the length of the existing high-speed rail network by 2030 and maintain a dense railway network in all Member States. By 2050 the majority of medium-distance passenger transport should go by rail"[1]. Railway system is appreciated for its ability to transport a large number of passengers and at the same time lowering pollution levels and reducing traffic jams in cities. Even though traveling by rail is considered to be a sustainable form of public transport, railway stations have significantly high energy consumption and large carbon footprints.

The revival of railway passenger traffic during the last few decades led to the construction of new railway stations in Europe as well as refurbishment and development of many historical terminals. Changes have been driven by the evolving needs and expectations of users. New approach to design is focused on efficient form of station in accordance to its surroundings creating, on the other hand, a gateway to the city. Terminal is no more just an impressive building, but it is a kind of a square covered with a massive canopy full of natural light, attractive facilities and new functions where users are well-oriented, well-informed and safe. This space is also a core of the communication linking different transport modes into an integrated interchange [2].

Modern railway stations are focused on minimising passenger services. Waiting room is mostly combined in the main hall, ticket offices are supplemented and even replaced by ticket machines, virtual information (infobox) take space of traditional information service, storage lockers instead of places of left luggage offices, and for smaller stations vending machines instead of dining options. The only remaining constant element are public toilets.

The most impressive European stations carried out in this model are Liège-Guillemins (Santiago Calatrava/ 2013), Rotterdam Centraal (Benthem Crouwel Architects/ 2014), Amsterdam Bijlmer ArenA (Nicolas Grimshaw/ 2007), Crossrail Canary Wharf Station in London (Foster + Partners/ I stage 2015/ end planned for 2018), Main station in Berlin (author: Gerkan, Marg and Partners/ 2006), Main station in Vienna (Atelier Albert Wimmer/ 2014), and in Logroño (Abalos+Sentkiewicz Arquitectos/ 2011) [3].

Small railway stations are different from those big terminals by their scale, amount of connected public transport modes and parking lots. Their big asset is an ability of introducing innovative trends in the design philosophy consistent with the principles of sustainable development.

2. TGV line Ren-Rhône (France) - LGV Rhin - Rhone

The TGV line Ren-Rhône (LGV Rhin - Rhone) is considered to be an example of the most environmentally-friendly railway line in France. It is the first subsidiary line in France that has no origins in Paris. It aims to fill the missing high-speed linkage from Spain through France to Germany and Switzerland. The first 140 km has been opened on the 11th of December 2011 [4].

Localization studies had been ongoing since 1993 but its construction plan was finally approved in 2002. The initial phase of the project was dedicated to find the most optimal route variant, with the reduction of range and cost of collisions with valuable ecosystems and groundwater reservoirs. As a result the line was kept away from built up areas. Relatively low environmental impact on human habitats (mainly noise and vibration) have been observed. Optimization of its course was also carried out in terms of land macronillisations, construction of bridges, viaducts and tunnels to be implemented, consequently limiting the necessary cost to minimum. The construction of the TGV line in France is perceived as a strong factor stimulating the economic development of the adjacent region. It was therefore assumed that the locations of two new terminals, Besancon Franche-Comte TGV and Belfort-Montbeliard TGV, should initiate technology parks planned there. Both stations on the LGV Rhin-Rhone line are located in the vicinity of the expressway. Besancon FC TGV has also been linked with a regional line to Besancon city, while Belfort-Montbeliard TGV is at the intersection of the TGV line and Belfort-Delle line. The Besancon Franche-Comte TGV is located near the village of Auxon-Dessus, 10 km from Besancon city. It is a TGV interchange hub including regional line, regional buses, taxi, parking for bicycles and car parking for 1,000 seats. It occupies an area of 6 hectares with a station building of 2,555 m2. The Belfort-Montbeliard TGV station is located near the village of Meroux, 15 km from Montbeliard and 10 km from Belfort. It is a TGV interchange hub including a reactivated regional line, regional buses, taxi, parking for bicycles and car parking for 1200 seats. Total area of the station building is 3,000 m2 [5-6]. Each of this investments cost about 26 million euro. Both projects are innovative in urban planning and architecture design. They set new green trends in the approach to public transport and were designed by the French company AREP, headed by chief designer Jean-Marie Duthileul.

Great emphasis was put on environmentally-friendly solutions. Both terminals have a built-in, closed rainwater circuit. This water is collected from paved surfaces through drainage ditches and stored in underground reservoirs to be further distributed by a drainage system placed under parking spaces. It is also being used to water trees, flower beds and decorative greenery (only locally occurring vegetation). In the Belfort-Montbeliard TGV's car park there are 550 trees, 1,400 bushes and 43,000

other plants. Due to the location of the Besancon FC TGV station on the forest clearing, it was designed in such a manner that it prevents a significant number of trees from being cut down. Only 188 out of the 306 trees growing in the area had to be logged. Parking lots are located directly at the entrances to both stations, therefore more frequently and more intensively used, have concrete pavements. Secondary parking spaces are made of semipermeable layers (clay mixed with coarse gravel).

Figure 1. *Besancon FC TGV (D.Załuski).* Additional thermal insulation delivered by its green roofs and the shape of the building itself.

Figure 2. *Belfort-Montbeliard TGV (D.Załuski).* Distinctive form of the tube made of laminated wood covered with galvanized steel helps to reduced energy consumption.

Belfort-Montbeliard TGV is heated by geothermal pumps placed up to 100 m below ground level whereas Besancon FC TGV has a furnace for crushed, waste wood from surrounding forests. Both buildings are additionally powered by solar panels of approximately 300 m2 each (13% of the demand for Besancon FC TGV and 20% in Belfort-Montbeliard TGV). At the same time water is heated in solar collectors located on the roofs (30% of annual demand for hot water at Besancon FC TGV and 50% at Belfort-Montbeliard TGV) [5-6]. In both cases subterranean air chambers were designed under the roofs. Thanks to this solutions, significant savings on the air conditioning have been achieved. Besancon FC TGV Station has an additional thermal insulation delivered by its green roofs and the shape of the building itself which is completely submerged in the ground from the south side. On the other hand the distinctive form of the Belfort-Montbeliard TGV tube station is made of laminated wood covered with galvanized steel. The social and technical parts are also located in a partially hidden underground section. Thanks to these solutions, energy consumption was reduced by 38% compared to traditional SNCF rail stations [5-6].

Both buildings construct a form of a bridge over the platforms designed to make pedestrian traffic the most intuitive as possible and as short distance as possible. Due to the increased passenger traffic, the Belfort-Montbeliard TGV train station functions as a service-wide passageway also working as a waiting room. Basic services such as a ticket and train station, café and newspaper stands, public toilets and vending machines have been designed at both stations.

Both TGV's terminals where the first stations in France that received the HEQ certificate, an award for the highest quality pro-ecological technologies and minimal negative influence on the environment during the construction process.

3. Accrington Eco Station (England)

The new station building at Accrington in England opened in October 2010 as a part of an "Eco Station" project. Key partners involved in the process were: Lancashire County Council, Northern

Rail, Network Rail, the East Lancashire Community Rail Partnership and Hyndburn Borough Council. The station was designed by a team of SBS Architects, Cyril Sweet Quantity Surveyors, Halcrow Yolles Structural and Services Engineers and contractor Strategic Team Group. The project was also the first completed part of SusStations (Sustainable Stations) initiative that is part funded through the European Union's Interreg IVB program. The Eco Station has achieved an 'Excellent' BREEAM rating (Building Research Establishment Environmental Assessment Method) and has also achieved an 'A' rating for its energy performance. Energy use at Accrington was halved what is a substantial reduction [7]. The investment costs were around 1.5 M EUR [8].

Figure 3. *Accrington Eco Railway Station* (SBS ARCHITECTS LTD. 2010 from [9]. Application of a local stone integrated the building with architectural heritage of the historical part of the city and helped to reduce transportation needs in terms of range and costs

During the preparation of this investment wide range of public consultations was carried out including 547 face-to-face interviews with passengers waiting to join trains at the station. Accrington is a medium sized station (about 240,000 passengers per year).The fieldwork research was also based on counts of passengers, cars and bicycles to establish an optimal volume of the infrastructure[7].

The new “Eco Stations” concept is based on the enhancement of railway stations as an example of sustainable development within the local community. It was designed to demonstrate low environmental impact on every phase – design, construction and use. Material selection was based on region’s tradition, low or negative carbon footprint and low embodied energy. Local stone helped integrate the new building with the architectural heritage of the historical part of the city. In facts this solution helped to reduce transportation needs in terms of range and costs. Other significant solutions applied are as follows: crushed glass, sustainably sourced timber and eco-mix concrete. The station

idea has focused on saving on energy through the passive design of the building. A minimum requirement for structural steel has been achieved by the use of load-bearing masonry. Stone half of the building utilizes its mass and thermal properties to regulate temperature, whilst the roof and curtain walling façade placed at the south side of the building will maximize natural daylight and sun heat gains. The primary roof supporting structure is of seven curved engineered timber Glu-lam beams. It supports an aluminum roof finish with a maximal amount of insulation[9].

This English sustainable railway station has a non-heated hall (booking and waiting area) in order to reduce heat loss and take advantage of solar gain. Other environmentally-friendly features applied for the energy conservation running costs are active environmental systems like rainwater harvesting, solar hot water generation and solar photovoltaic technology.

Eco Station in Accrington is aimed at reducing the station's impact on the environment. On the other hand its passenger oriented approach is presented by providing an integrated ticket office, a modern waiting area, new public toilets, parent room, staff facilities and park and ride facility with 180 spaces.

4. Green Station Kerpen-Horrem (Germany) - „Grüner Bahnhof"

The first climate-neutral railway station in Germany was built in 2014. The "Green Station" in Kerpen-Horrem was the prototype of a concept called "Stations for the Future" (main architect Marc Ulrich/DB Station&Service). The objectives of the project were to increase passenger satisfaction and at the same time to reduce CO2 emission. The total investment adds up to 4,3 million Euro. It includes 0,9 million Euro funded as a part of the EU's "Sustainable Stations" project (SusStation), 1,3 million received from the Land's budget, 1.0 million from the national government, 1.0 million from transport associations and 0,3 million Euro from the Kerpen city's founds. General amount is about 20% higher than an average budget for a conventional investment with this dimensions [3].

The new terminal was built at the site of a demolished building, which was too expensive to maintain and did not meet modern standards. The new Horrem station is adjusted to actual ridership rate (about 12 000 passengers a day). Internal space has been limited to 620 m^2 with a waiting area of 250 m^2. Functional plan of this building consists of a hall, ticket service, commercial space of 70 m2, two restrooms and adjoining technical, administrative and social/staff areas [10].

Its structure is based on modules constructed mainly from glass, concrete, wood and stone. Prefabrication technique and large-scale formats enabled easier and shorter implementation at the building site. The load-bearing structure is made up of a single-span beam and steel legs supporting the top construction made of ribbed laminated veneer lumber. 340 m^2 of photovoltaic system has been situated on the roof to cater the demand of energy and heating at the station (31 000 kWh/year) and feed energy back into the public grid in case of a surplus. An assembled heat pump (geothermal system) delivers energy to heating or cool air appliances, depending on the needs [11].

To emphasize the public role of the hall it has a form of a pillar-free area with a large amount of natural light. The facade is made up of around 52% glass what provides transparency and gives good orientation to the users. By large-scale windows at the south side and stone walls from the north the ability to compensate energy in the building rises. The roof extends the outline of the building to provide proper shade. As an addition to daylight Green Station uses energy-saving LED technology controlled by an automatic switch which reacts to the fading light. In the close vicinity of the railway station the city has organized parking space as a park & ride for 1000 cars and 420 bikes, taxi stop and bus station [11]. Another green station is under construction in Wittenberg.

5. Innovative Railway Stations (Poland) – „Innowacyjne dworce systemowe – IDS"

In 2015 in Poland four Innovative Railway Stations were constructed in different locations taking places of the demolished oversized and ineffective terminals. Buildings in Mława, Ciechanów, Nasielsk and Strzelce Krajeńskie (author: Bartosz Szubski and Paweł Kośmicki/ PKP S.A. Design Department) are environmentally friendly objects of a new quality. Their design corresponds with Polish national railways renewal as well as with current world trends in architecture and with the idea of sustainable development. Parking areas in the surroundings of each building were designed as small park&ride.

Figure 4. *Green Station Kerpen-Horrem* (DB Station&Service AG from [11]). Green roof and a photovoltaic system has been situated on the roof to cater the demand of energy and heating at the station

The main objectives of these investments were to minimize maintenance costs, maximize effectivity of utilization (new technologies, renewable energy sources) and create high-quality passenger service fully adapted for people with reduced mobility. As in German Green Stations, Polish IDS have been adapted to local needs and conditions and its size is adequate to a ridership rate. In order to improve the investment process, the target project is planned as standardized and repeatable what leads to more efficient documentation faze, preparation of investment and realization at the construction site. Implementation has to be fast - one year from the decision to official inauguration. Outside veneer in each location is diversified by material and color what allows to fit into the surrounding architecture and emphasize local characteristics.

The Innovative Railway Station's functional plan consists of three modules: passenger service, commercial area and open space covered by the roof. First one is dedicated to a heated transparent waiting room, public toilets and technical, administrative and staff areas. The second module is for commercial use (shop, newsagent, snack bar etc.) selected on the basis of a commercial potential analysis made for every location. The last space functions as a seasonal waiting room shaded and well protected from the rain by a large field of the extended roof. Under this canopy designers placed

bicycle racks, seats and vending machines as well as storage lockers and ATMs. Every IDS has a compositional dominant in a form of a seven-meter-tall clock tower firmly identified with traditional station buildings.

Figure 5. *Innovative Railway Station in Ciechanów* (D.Załuski**).** A seasonal waiting room shaded and well protected from the rain by a large field of the extended roof. Also a place for bicycle racks, vending machines, storage lockers and ATMs

Environmentally-friendly solutions applied in Poland are: extensive green roof for rain water retention, photovoltaic panels for lighting and supporting water heating, geothermal heat pumps, ventilation with heat recovery, rain water collection system and LED lighting activated by motion sensors. Outer illumination of the building intensifies before every arrival of the train at the station what increases safety and good orientation of the passengers. Architects made an effort to maintain the maximum number of existing trees (e.g. in Mława) or introduce plant replacement.

Figure 6. *Innovative Railway Station in Mława* (D.Załuski**).** A compositional dominant in a front view - a seven-meter-tall clock tower firmly identified with traditional station buildings. The maximum of existing trees have been maintained in Mława

The average cost of an Innovative Railway Station should not exceed than 1.5 million Euro and the maintenance costs should fall by 40% compared to demolished old terminals [12].

6. Results and discussions

All above-mentioned examples present how the way of thinking about public transport evolves. The development of railway stations indicates a new direction in the design. The main goal of the designers is to create a friendly and intuitive space for its users and at the same time an environmentally-friendly buildings that use renewable energy sources and minimizes negative impact on the environment.

Based on prototypes already existing it can be assumed that environmentally-friendly investments require long-term planning and farsighted approach. Increased construction costs can be discouraging if the prospective energy gains, ease of maintenance or reduced CO2 emission are not taken into account. Due to relatively short time of innovative railway stations' operation time, it is not possible to complete their full evaluation yet. However, many factors indicate their enormous success. The question arises if it is possible to implement green ideas on global scale?

The construction process of a completely new terminal allows to fully exploit the location advantages, exposure to sunlight and the topography. Building stations connected to the existing railway lines impose certain constraints. However, the most problematic are existing railway stations, which should be preserved for aesthetic or historical reasons. It is very difficult to apply some innovative technologies in an existing building without major interference into its structure. It is almost impossible to implement so many green solutions to match innovative railway stations.

Another issue to solve is an attempt to optimize the construction time through prefabrication and standardization of the objects. It is very difficult to use the same modules in a variety of locations due to cultural variations, regional materials availability, terrain conditions or even passenger flows.

The coming years will allow more comprehensive evaluation of completed investments, and will let the designers carry out further research that is still needed to make another step forward.

7. Conclusions

The rail industry is often perceived as a conservative way of transport, however there is a need to proceed with foresight. With the biggest number of people in urban areas than ever before, railway stations around the world need to adapt. Climate change seems to be a great purpose to look again at how we approach to station projects. Railway stations are not anonymous buildings, they are gateways to our cities and should reflect local needs.

The French TGV stations, English Eco Station, German Green Station and Polish Innovative Railway Stations IDS show that the energy use at stations can be substantially reduced. Renewable energy schemes can lead to creating low carbon stations. However, it is necessary to conduct a number of studies to obtain a global effect. It is the first stage of the development - making the necessary step into a greener future in the railway environment. As Brian Edwards wrote already in 1997: "Stations are an essential element of sustainable development, and combine environmental considerations with social and cultural ones. Their significance for the decades beyond the millennium is partly a result of this confluence of postmodern imperatives. In the new urbanity of the post-industrial age the station, with its democratic open structure, its public spaces inside and out, and its corridors of movement etched upon the face of the city, represents an important civilizing element"[13].

This 'new' thinking explains why national and regional authorities in Europe have already started to invest in an innovative programs alongside railway infrastructure.

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