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The concept of an integrated rail transit system in Radom with tram-trains

Abstract: The article presents the concept of an integrated rail transport system in Radom, based on classical and dual-system trams, taking into account the role of regional rail in servicing urban and agglomeration transport. The development of the concept of the tram network in Radom was presented and then the analysis of the conditions for the development of urban rail transport was made. The article is a synthetic description of the author's version of the city transport service model, with an emphasis on the integration of various transport modes, as well as technical, operational and organizational aspects essential in planning the connection of the tram and railway layout in Polish conditions.

Keywords: Tram-train; Urban rail transit; Radom

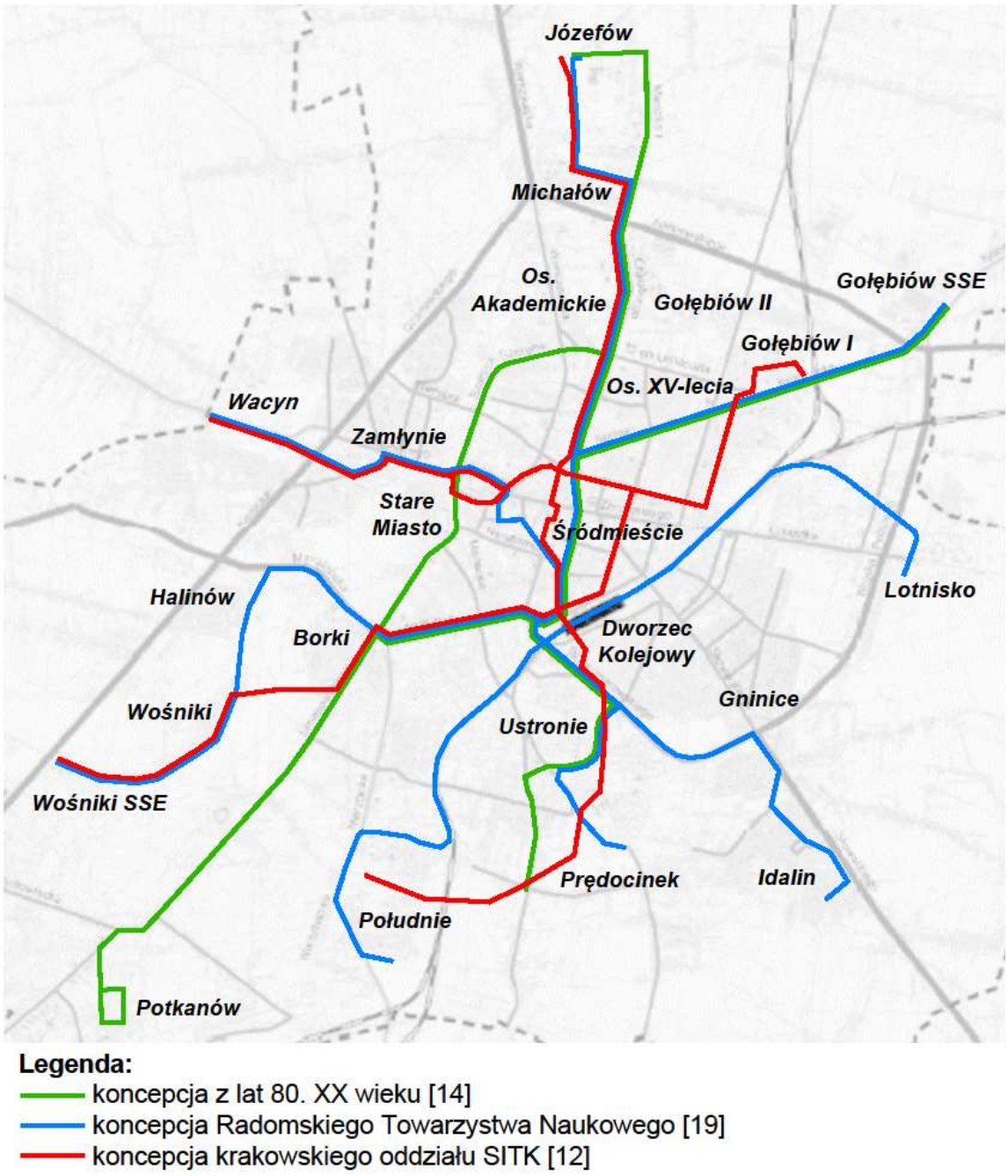
Introduction

Radom is the 14th city according to the number of residents in Poland (215,000 in 2017), and in Radomski Functional Area, there are 375,000 inhabitants. people (2014) [15]. At the same time, it is the second city by population (after Bialystok), a Polish city with urban collective transport based solely on buses. Due to the rapid development of industry and the rapid (threefold) increase in the number of inhabitants of Radom in the second half of the twentieth century, it turned out that bus transport may be insufficient for servicing the city and electrification of the main transport corridors will be necessary. The concept of launching trolleybus or tram communication dates back to the 1950s. From the 1960s, the concept of a tram route connecting Gołębiów with Potkanow was developed [25]. Both parts of the city constituted important industrial areas and new housing estates were planned in their vicinity. Over the next several years, the concept of building a tram network was developed. A north-south route connecting Józefów, Michałów, Dworzec PKP, and Ustronie was introduced. Through the downtown area, the trams had to travel along Traugutta Street - Mickiewicza Street or 25 Czerwca Street (formerly: 1 Maja Street) and along Limanowskiego - Mireckiego - Szarych Szeregów streets (formerly: Dzierżyńskiego - Mirecki - Gwardii Ludowej). In this way, the concept of a tram network was promoted, supported by Radom scientists (Prof. Kelles-Krauz) and subjected to further detailed analyzes in the 1970s and 1980s [18]. The socio-economic crisis of the 1990s caused the postponement of the construction of the tram network for an uncertain future.

The Study of conditions and directions for spatial development of the Radom Commune of 1999 included only a general record of the possibility of organizing the Fast Regional Rail system (SKR) using a light rolling stock - a bus or tram [13]. In later versions (changes from 2011 and 2014) there were no longer any general entries about trams. In 2002, the concept of launching light rail vehicles (the so-called Fast Railway Tram) appeared between the Gołębiów housing estate and the South housing estate on the urban section of railway line No. 8 [27]. The option of further development of the route by sections into the housing estates was adopted, which could be the first step to introduce dual-system trams. In the article [5] from 2003, the authors proposed a modification of the concept from the 1980s,

mainly due to the closure of large industrial plants. However, the basic backbone of the connections has been preserved. In 2013, the Radomskie Towarzystwo Naukowe (RTN) presented the proposal of a tram network as a component of the Radomski Innowacyjna's project. It was a response to the possibility of financing its construction from funds obtained under the Territorial Contract for the Mazowieckie Voivodeship. The city authorities, however, referred to this idea with great distance [26] RTN concept assumed the construction of the north-south line from Józefów to Ustronie (Prędocinek) in the first stage, which was in line with previous studies. According to preliminary analyzes of transport accessibility within this single line, there would be 80,000 people (over 1/3 of the city's inhabitants) [28]. The concept provided for further stages of network development, including the option of launching dual-system trams on the route: Airport - Railway Station - South housing estate, using the existing railway line, along with the construction of new tram tracks as the final sections of the route [23].

In 2014, the Kraków branch of SITK developed the concept of an integrated public transport system in ROF (Radom Functional Area), which presents variants of urban transport system development based on trams or buses [15]. The tram network has been modified both in the city center (running the lines of Focha and Piłsudskiego Streets instead of Mickiewicza Street) and in the southern direction (servicing Ustronie and Południe with one tram route). In the first stage, the north-south route from Józefów through Śródmieście, the PKP railway station, Ustronie, and the Południe estate should be implemented. In the study resigned from the use of the railway line for inner-city transport. Figure 1 presents a composite map of three main concepts of tram networks from the 1980s [18], through the RTN proposal [23], to the development of the Krakow branch of SITK [15]. Attention is drawn to the compliance of the north-south route on the section from Józefów to Śródmieście and further on Ustronie, with the lack of compliance for the way of operating the South estate and passage through the downtown area (although the route within Mickiewicza Street most often appears in all concepts from the 1970s).



1. Comparison of various concepts of the layout of tram routes in Radom. Source: own study based on: [5], [15], [23] on the foundation [21]

Analysis of conditions for the development of rail transport in Radom

The functional and spatial structure of the city in the current (2017) administrative borders was shaped mostly in the twentieth century, as a result of the rapid development of industry and the construction of housing estates on the north-south axis, partly referring to the diametrical route of the railway line (line No. 8). The majority of high-rise multi-family housing is concentrated in two areas (units): north (Michałów, Gołębiów I and II, Nad Potokiem estates) and south (Ustronie, Prędocinek, Południe I and II estates). The buildings are located a few hundred meters from the railway line No. 8, and there are no stops on the same line that would allow organizing transfer nodes. Additional stops are planned as part of

the modernization of the line. On the east-west axis, single-family housing predominates, with a small multi-family share (e.g. the Zamłynie, Glinice, Sadków and Kaptur estates). Plans for the construction of the first tram route in the north-south relationship presented in [15] and [23] are consistent with the conclusions drawn from the analysis of the functional and spatial structure and directions of the city's development.

The urban structure of the inner city itself was formed in the 19th century and the beginning of the 20th century. The concept of the city center does not coincide with the oldest part of the building, which is rather the periphery of the city center. Such a structure has a specific impact on justifying the selection of major public transport routes, which cross a relatively extensive downtown with various corridors, but its central part excluded from vehicular traffic (Żeromskiego Street) is relatively poorly available for public transport. Hence, most of the modern concepts of the tram route in the city center of Radom assumes a transverse intersection of Żeromskiego Street in its central part (near the City Hall). Regardless of the corridor, one should take into account the dense nineteenth and twentieth century eternal tissue of downtown Radom, well preserved and undamaged during wars, where the tram line is a challenge in itself. However, according to the author, it is not possible to condition the routing of a tram route of general urban importance from the occurrence on its route of single objects (buildings) and collisions with other routes.

The collective transport system in Radom consists of 26 lines, with 14 of them belonging to medium and high-frequency lines (running at least three times per hour at peak and off-peak), which are the main links on the north-south axis. Lines No. 7 and 9 with the highest frequency (every 10 minutes on business days) coincide generally with the planned layout of streetcar lines, omitting the differences in the route leading through the strict downtown. None of the lines runs, however, on the route exactly coinciding with the Michałów tramtrain route - Ustronie. The common section of lines 7 and 9 in the city center is its communication backbone, but the service of the eastern part of the downtown (east of Plac Konstytucji 3 Maja) rests on the north-south bus lines running on ul. 25 June (lines 3, 4, 13, 23). The main interchange in the city is Plac Dworcowy located in front of the Radom railway station. In addition, in the downtown area, there are several other transfer nodes of lesser importance (due to the dispersion of communication routes in the center). The most important of them are the intersection of Malczewskiego / Kelles-Krauza / Struga, the square of Kazimierza Wielkiego, the intersection of 25 Czerwca / Struga). The city is a railway node that is important in the entire country, although due to the infrastructure it has relatively few long-distance connections. The (2017) modernization of the most important railroad route No. 8 on the section of Czachówek Płd. - Radom, which after modernization is to provide access to Warsaw in about 75 minutes for the fastest trains [22].

In the area of the city, the line runs from the north along the Gołębiów I and Nad Potokiem districts, then connects with line 26 to Łuków and leads along the southeastern edge of the city center as a de facto city railway midway line, to the southern periphery of the city, where east of the estate Południe separates into two lines: continuation of line 8 to Kielce and Kraków, and line No. 22 to Tomaszów Maz. On the urban section of line no. 8 stops are planned: Żółkiewskiego, Kozienicka, Sycyńska (and reserve space for the Żeromskiego stop), located essentially in places of two-level crossings of the main streets over the tracks [9]. Although the very route of the diametral line through the city area in the north-south relation seems advantageous for the possibility of using it for agglomeration transports, due to the large average distances between stops and the distance from dense buildings, railway transport could not play an independent role in inner-city transport [1]. However, railway stops could be interchange points for other means of transport and, as such, be included in urban transport. It should be recalled the previously described proposals for using the line in a dual-system tram system, but without further developing the concept [27], [23]. In the railway

system of the city, there is also a railway siding for the Radom airport, allowing direct connection with the Radom station. Due to the small passenger traffic at the airport (9,713 passengers throughout 2016 [24]) there is no justification for the rational use of the siding for regular passenger transport. In addition, the distance of the airport from the city center is small; there are also no major traffic generators justifying the development of rail transport in this direction.

Due to the relatively high unemployment in the city and the region (13.2% in Radom with an average 5.6% for the Mazowieckie voivodship - data for October 2017 according to the Central Statistical Office), a significant percentage of city residents work and commute in a weekly and daily cycle to Warsaw [12]). This fact will probably not change dramatically in the coming decades, because the capital's labor market will always be attractive, if only because of its size. Therefore, it is necessary to establish in the plans for the development of urban transport the connection of tram and bus lines with railway line No. 8 in a greater number of points than only at the main station Radom, to minimize the time of people traveling by train to Warsaw or other cities. Analyzing the existing plans and concepts, and drawing conclusions from the analysis of functional and spatial and transport conditions, you can define the following key problems (issues) to solve:

- way of servicing the inner city area (choosing the option of passing the route through the center),
- the manner of servicing housing estates,
- way of including the railway line into the agglomeration transport system,
- designation and design of interchanges,
- technical and functional integration of tram and railway subsystems.

Some of the above-mentioned issues have been addressed to a different degree and partly solved in the concept of commissioning trams in Radom [15], [18], [5], [23] and in other studies describing the possibility of implementing Western European experiences in dual-system trams (mainly German) in Polish conditions [3], [4], [6], [7]. According to the author, however, there are no studies on the comprehensive concepts of integrated rail transport in the city (and the Radom agglomeration), with particular emphasis on the feasibility of transfer hubs crucial for the functioning of the transport system.

The concept of urban rail transport development in Radom

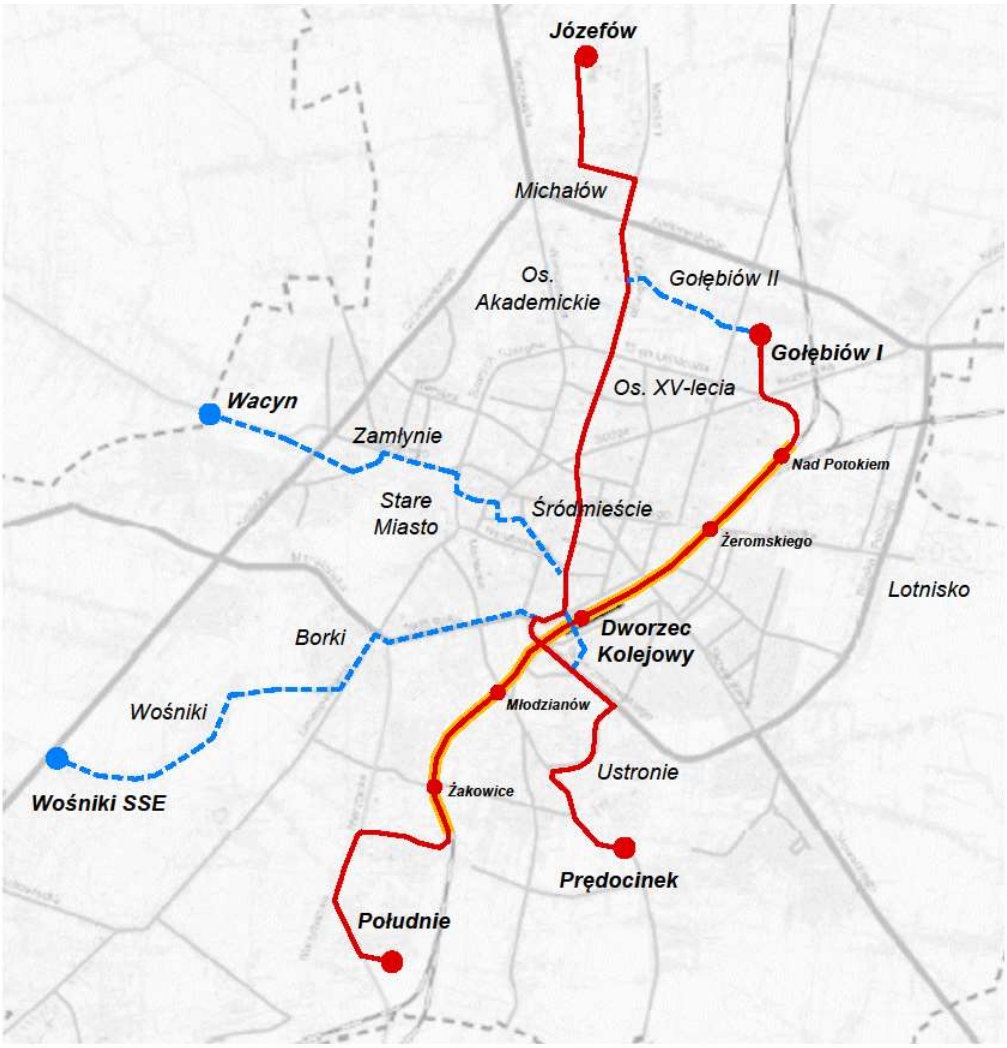
The concept developed under this article is a modification and development of the idea of a tram system in Radom with a dual-system tram, presented for example by RTN [23]. The author agrees with the complementarity of rail and tram systems. However, in order to specify this idea and develop a comprehensive concept, it was necessary to formulate some important preliminary assumptions:

- the basic skeleton of the urban rail transport network should be based on the north-south axis corridor connecting Michałów (Józefów) and Gołębiów in the north of the city with the South and Ustroń (Prędocinek),
- the system should be developmental and allow for further expansion, especially in the east-west axis,
- the main transfer hub should be realized at (at) the railway station of Radom station and provide maximum shortened pedestrian routes between different modes of transport for passengers moving in the main directions in the north-south axis,
- complementary transfer nodes should integrate stops on a cross-country railway line with tram and / or bus lines,
- use existing cross-country railway line for the needs of urban and / or agglomeration transport (via interchange junctions at railway stops and / or dual-system trams),

- steps should be taken to increase the accessibility of the central part of the city center (around Żeromskiego Street by the City Hall) and housing estates,
- both urban and agglomeration and feed traffic should be taken into account for regional and long-distance trains, especially those operating in the Warsaw - Radom - Kielce route, as well as Radom - Pionki - Dęblin,
- frequencies of trams were adopted on the basis of currently valid timetables [20] and studies [15] and were determined for 10 minutes each way for north-south relations (priority routes similar to routes of bus lines 7 and 9) and 15 minutes for supplementary routes (directions Wacyn, Wośniki, Gołębiów II); increase in transport performance in the city as a whole is estimated at 1.9% per annum [15].

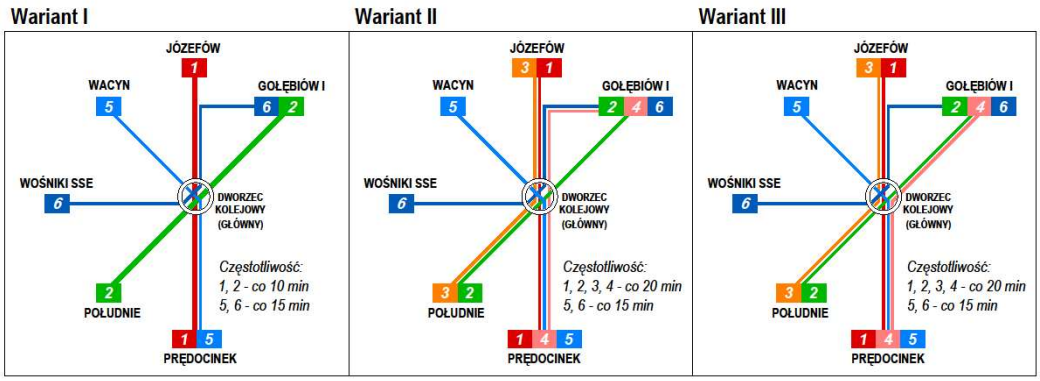
On the basis of the above-stated assumptions and previous concepts, the model for the development of the urban rail transport network is presented in Figure 2.The solution was to create a system of urban rail transport based on two basic corridors in the north-south axis:

1. route of the classic tram Józefów - Michałów - Śródmieście - Railway Station - Ustronie - Prędocinek, built from scratch,
2. route of the dual-system tram on the section Gołębiów - Śródmieście - Railway Station - Południe, using the infrastructure of the diametral railway line.



2. A model for the development of the urban rail transport network in Radom. Source: own study on foundation [21]

In addition, perspective directions for the development of the tram system to service the Gołębiów II, Wacyn and Wośniki settlements were marked. The key role in such a structure will be the area of the Railway Station (Main Railway Station), being not only the main interchange point but also the place of organization of the rail infrastructure node enabling the technical and functional integration of both corridors (for the implementation of the dual-system tram). Assuming the existence of two basic sequences intersecting around the Radom station, forming a structure similar in shape to the letter "X", three variants were proposed for creating fixed rail transport lines on this system (described below). Line layouts in three variants are shown in Figure 3.



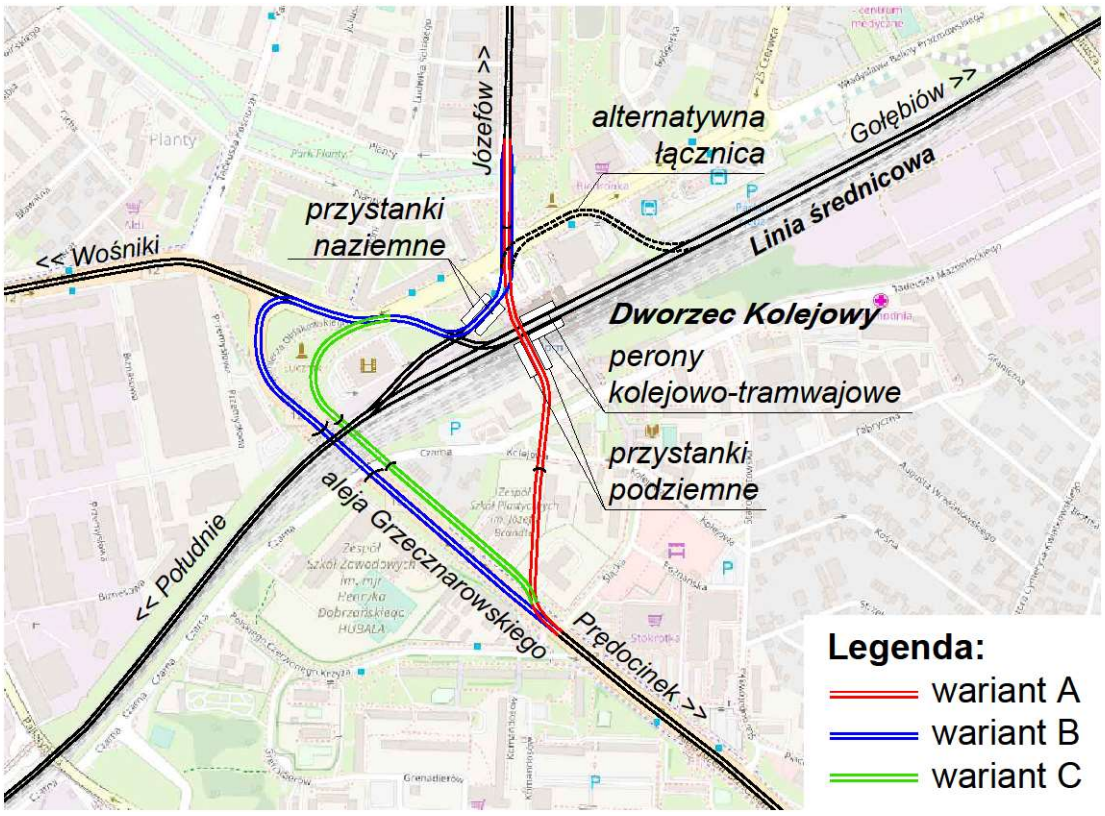
3. Proposed layouts of tram lines in Radom in three variants. Source: own study

The presented diagrams include supplementary routes to Wacyna and Wniczniki (lines 5 and 6), with identical mileage in each variant. The variant I: arrangement of two lines (1: Józefów - Prędocinek and 2: Gołębiów - Południe) separated technically from each other, without connections in a linear motion. In this variant, it is planned to separate line 1 of a typical city tram from line 2 of the light urban railway, with branches going deep into Gołębiów I and Południe housing estates. Assuming branching as tram routes, the dual-system fleet should operate on line 2. Such a solution does not require interchanges or transitional ramps (switchboards) between tram and railway systems in the vicinity of the Railway Station.

Variant II: arrangement of three lines (1: Józefów - Prędocinek, 2: Gołębiów - Południe and 3: Józefów - Południe). Lines 1 and 2 identical as in option I. Line 3 would be a solution typical for a dualsystem tram: on the section from Józefów to Dworzec Kolejowy the vehicles would use the urban tram route, and on the section from the Railway Station to the Southern housing estate from the railway infrastructure, ending with a tram route into the estate. Such a solution requires the construction of a switchgear and an access ramp between the tram and rail systems in the vicinity of the Railway Station. Variant III: arrangement of four lines (1: Józefów - Prędocinek, 2: Gołębiów - Południe, 3: Józefów - Południe and 4: Gołębiów - Prędocinek). Lines 1, 2 and 3 identical as in option II. Line 4 would be a solution typical for a dual-system tram: on the initial section of the Gołębiów I estate, run along the tram route, then to the Railway Station with the use of railway infrastructure, and then to Prędocinek again along the tram route. This solution requires the construction of switch gears and transitional ramps between tram and rail systems in the vicinity of the Railway Station. Due to the track layout of the Radom station and route of the dual-system tram on the northern side of the station, the passage to the south should be carried out without collision (otherwise the line would cross all tracks of the western station head Radom). In such a case,

it is proposed to run a turnstile with the passage of a tram route along Grzecznarowskiego Avenue (variants of crossing under the railway line are shown below).

The concept assumes three basic ways of passing the city tram line through the area of the Railway Station from the Śródmieście area (railway station square) to the area of the Ustronie estate (around Śląska Street / Grzecznarowski Avenue). The options are shown in Figure 4 and are described below:Variant A: crossing under the tracks of the diametral railway line by a tram tunnel under the platforms of the Radom station; the beginning of the tunnel on Traugutta Street and the ending on the south side of the station near Śląska Street; this is the most expensive option, treated as a targeted, prospective solution.



4. Three basic variants of the route of the classic tram through the area of the Railway Station. Source: own study on foundation [21]

Variant B: crossing under the tracks of the diametral railway line with an existing road tunnel (ultimately road-tram) within Grzecznarowskiego Avenue, e.g. with the assumption of a narrowing of the avenue on the section from the intersection with 1905 Street to the intersection with Śląska Street. Variant C: crossing under the tracks of the diametral railway line with a new tram tunnel (built next to the existing road tunnel) within the Grzecznarowski Avenue.

Planned route and infrastructure for a dual-system tram

The concept assumes running a dual-system tram route according to the so-called "B" type model [1], in which the railway tracks are used in the city center area, and on the end sections, the vehicle enters the tram tracks. The final sections will be built specifically for a dual-system tram, but classic trams will be able to use them. Depending on the variant adopted, it may be a system with autonomous lines or integrated in technical terms. However, it is assumed to use a dual-system tram for the needs of the route of the railway infrastructure in the city area from the Gołębiów I housing estate to the Południe housing estate (where

connections between the tram network and the railway line would be located). Dual-system trams should be two-way and do not require the construction of tram loops. It was adopted as a rule to run dual-system trams on two tracks of the extreme Radom stations from the city center and then on the mid-range line. The above results from the demand for bringing the line closer to the city center, running it on the side of the station at which the main station is located, the possibility of making connections with the tram network in the vicinity of the station square and Gołębiów I and Południe housing estates. Providing convenient access to residents of housing estates for dual-mode vehicles is a chance for the entire project to succeed. The concept, therefore, envisages the construction of short one- or two-way street switches. On the railway line between Gołębiów and the South, it is postulated to create new stops for a dual-system tram. Ultimately, the following sections should operate on the railway section: Nad Potokiem, Żeromskiego, Dworzec Kolejowy (Main Station), Młodzianów, Żakowice. In addition, tram stops, including the final: Gołębiów I and Południe. The tram line in the northern part of the route should be introduced into the central part of the Gołębiów I estate along the street Olsztyńska, then crossing the street Struga and the estate park until the end on Orląt Lwowskich street, with the possibility of extending to Zbrowskiego street and the planned loop (ending) of the tram route servicing the estate Gołębiów II. The alternative route of the link could only begin after the viaduct of Kozienicka Street over the railway line and avoid the Gołębiów I estate from the north. Such a solution would not, however, ensure good accessibility to the residents of the blocks at Struga and 11 November streets.

In the southern section of the route, the junction should be introduced to the housing estate along the streets of Czarnoleska - Wierzbicka with the end of the route near the current bus terminus, where an integrated transfer node and P + R parking lot would be organized. Alternatively, the route of the link could be taken along Łąkowa or Sycyńska Streets. Regardless of the option chosen, the junction should provide services for both housing units: Południe I and Południe II without the need to organize transfers from buses to the tram. The detailed technical and operational analysis will show how the railway line and the Radom station will be adapted to the two-system tram. To ensure the readability of the communication system, fixed station edges of the Radom station should be assigned to the tram. With sufficiently long vehicle succession time, it may be sufficient to isolate only one platform edge (e.g. platform 1, track 7). With a shorter sequence time, in order to maintain a large capacity, it will be necessary to assign two lines to the two-system tram line at two different station tracks (e.g. platform 1, track 7 and platform 2, track 1). The choice of platforms results from the desire to shorten the time of access to the platforms from the station side. The use of platform 2 may be so much troublesome that regional and long-distance trains passing through Radom stop at it, which may be the cause of serious traffic conflicts resulting firstly from limiting the capacity of at least one of the two main tracks (track 1), and secondly from the necessity of cutting several station tracks (tracks 5, 7) by trams going down from the railway station to the urban tram system and vice versa. It will be necessary to rebuild the head of the south-western station Radom in order to enable the technical possibility of making such a connection. Due to the possibility of technical and operational problems on the head of the south-western station Radom, it is necessary to provide an alternative link to the city tram system with the track system of the station in the region of its north-eastern head (Figure 3). Such a solution would, however, involve the transfer of stops of at least some of the two-system tram lines from the platform zone to the Dworcowy Square, but would limit the reconstruction of the south-western head predicted in the basic variant.

Organization of dual-system vehicles traffic

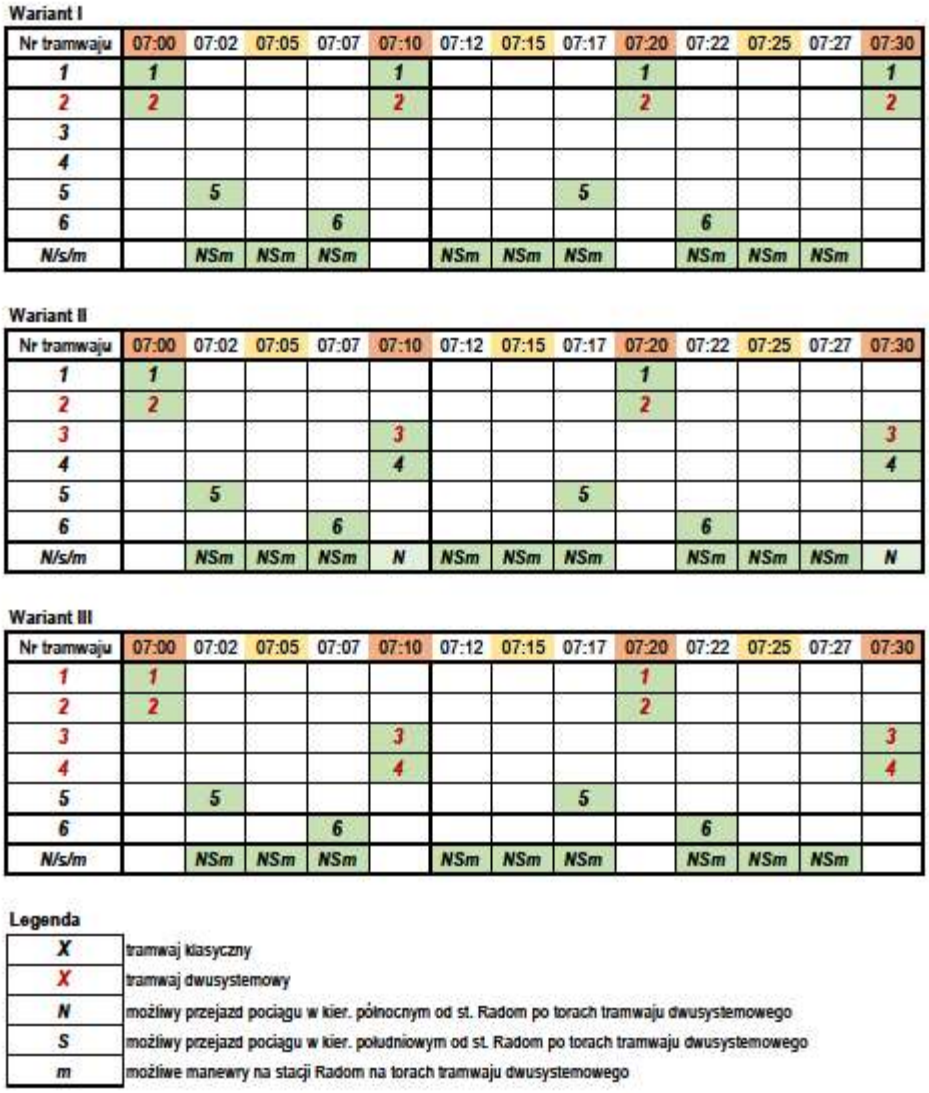
A dual-system tram would enter the railway tracks on the basis of a permissive signal on a semaphore operated by the Radom station's traffic controller, located in the LCS Radom

control room. The principles of vehicle movement between the railway and tram system in the conditions of Polish railway regulations have been described in the theoretical work in [16]. Traffic of tramway vehicles is usually run on visibility, but on the section of the railway line in Radom, the trams would move according to the indications of the semaphores of the three-point automatic line blockade (sbl). One of the key issues to solve is the organization of the movement of dual-system vehicles and the arrangement of timetables in such a way as to maintain the regularity of traffic This problem has been repeatedly analyzed, also in Polish publications [14], [2]. For a route with three hundred sbl, at the maximum permissible speed of 100 km / h and block intervals with a length of 700 m, it is possible to achieve a succession of 2.5 minutes when driving two-system trams to "green light" [16]. For a route with a three-block lock, at 60 km / h dual-speed vehicles, the expected follow-up time will be 3.5 minutes [1]. In relation to transportation needs in the Radom agglomeration, this is a sufficiently large interval.

Due to the mixed rail and tramway traffic on a relatively long section of the cross-section line, it would be worth considering the reconstruction of the linear block to four-level. Such a blockade would facilitate the operation of vehicles with different traffic parameters and different braking distances because the semaphores transmit more indications and are arranged at intervals of not more than half the braking distance valid for a given section (in the three-hundredth block the intervals are equal to the braking distance). The transition to a 4-level block would increase the throughput, but it would require the construction of more traffic control devices (semaphores, wheel sensors) on the line. By analogy to the frequencies currently running in Radom 7 and 9 bus routes [20] in relations similar to those to be serviced by the tram fleet, 10 min can be assumed as the peak frequency of vehicles for each of the four directions on which the route is planned tram from the Railway Station. Assuming even running a railway with a midline line of trams with a smaller succession time, e.g. 7.5 minutes, it still is a much lower frequency than is possible to achieve on a railway line with a three-speed blockade at a speed of 60 km/h.

Option II seems the most likely to be implemented than option III, because line 4 of Gołębiów I - Prędocinek would require a special and expensive technical solution for the transition from the Radom railway station to the Ustronie district, and would also bypass the city center (with the alternative tram route of the classic Józefów - Prędocinek with a branch towards Gołębiowa). In connection with the above, the northern section of the diametral line (together with the Radom station) would be less loaded than the southern section (south of the Radom station). From the point of view of a mixed rail and cross-street traffic on the mid-range line, it would be a good solution, because the risk of potential disruptions and traffic conflicts with regional trains starting in Radom and running to Warsaw would decrease and constitute the relative majority of regional connections [15]. Option II also provides the best service for the downtown area thanks to the highest frequency of courses on the most-loaded section: Dworzec Kolejowy - Centrum - Osiedle Akademickie. An important issue to be solved will be the transfer of delays from the tram system to the rail (and vice versa) by a two-system vehicle. This is a problem typical of this type of systems. It may be necessary to introduce, first of all, a cyclic or quasi-cyclic timetable, which regardless of the launch of two-system trams should be implemented in Poland in the same way as other EU countries [2]. Secondly, detailed regulations will be prepared for traffic on duty in the event of occurrence of traffic disturbances, taking into account the possibility of regional train shifts about 2 minutes earlier or later [16]. Thirdly, some changes in the infrastructure will be necessary to increase the flexibility of driving two-system vehicles (additional turnouts, track sections, sbl devices) - as described above. The construction of collision-free switchboards of the tram and rail network would be an extremely expensive undertaking. A much cheaper solution will be a properly arranged timetable and the organization of train traffic. A fragment

of an exemplary timetable of trams in Radom, taking into account the traffic of conventional trains on the railway line, is shown in Figure 5 (timetable was prepared for the Dworzec Główny stop team).



Wariant I

Nr tramwaju	07:00	07:02	07:05	07:07	07:10	07:12	07:15	07:17	07:20	07:22	07:25	07:27	07:30
1	1				1				1				1
2	2				2				2				2
3													
4													
5		5						5					
6				6						6			
N/s/m		NSm	NSm	NSm		NSm	NSm	NSm		NSm	NSm	NSm	

Wariant II

Nr tramwaju	07:00	07:02	07:05	07:07	07:10	07:12	07:15	07:17	07:20	07:22	07:25	07:27	07:30
1	1								1				
2	2								2				
3					3								3
4					4								4
5		5						5					
6				6						6			
N/s/m		NSm	NSm	NSm	N	NSm	NSm	NSm		NSm	NSm	NSm	N

Wariant III

Nr tramwaju	07:00	07:02	07:05	07:07	07:10	07:12	07:15	07:17	07:20	07:22	07:25	07:27	07:30
1	1								1				
2	2								2				
3					3								3
4					4								4
5		5						5					
6				6						6			
N/s/m		NSm	NSm	NSm		NSm	NSm	NSm		NSm	NSm	NSm	

Legenda

X	tramwaj klasyczny
X	tramwaj dwusystemowy
N	możliwy przejazd pociągu w kier. północnym od st. Radom po torach tramwaju dwusystemowego
S	możliwy przejazd pociągu w kier. południowym od st. Radom po torach tramwaju dwusystemowego
m	możliwe manewry na stacji Radom na torach tramwaju dwusystemowego

5. An example of a tram timetable (including conventional trains on the railway line) for the Dworzec Kolejowy station. Source: own study

Integrated system of urban and regional rail transport

One of the assumptions of the concept is the integration of the tram system with the railway system, also in relation to agglomeration, regional and long-distance transport. The study [15] indicated the possibility of using the development of regional transport in the corridor Skarżysko-Kamienna - Radom - Warsaw to handle agglomeration travel, which after increasing the frequency of regional trains in this relation up to 30 minutes and shortening travel times will allow the joint dual integrated Radom train to create a coherent, integrated and an efficient agglomeration system for rail transport with a scale suitable for the city and the region. This system should be supplemented with agglomeration lines, e.g. to Pionki. However, one should be aware of the limited possibilities of generating demand by the surrounding towns, including Pionki (19,000 inhabitants in 2014). Therefore, the most appropriate will be the shaping of the regional connections, which will allow to efficiently

serve the Radom agglomeration and to use the possibility of integration with the Radom tram system, including the dual-system tram. In connection with the above, the following solutions are proposed:

- introduction of a cyclic or quasi-cyclical timetable (also for the purpose of ensuring the regularity of dual-system tram traffic);
- creation of an integrated regional transfer node at Radom station (Radom Główny);
- creation of integrated local interchanges and P+R car parks at railway stations in Radom and final stops of tram lines;
- extension of some routes of Warsaw-Radom trains to the Radom-Południe station (this would require construction of holding tracks, but would also shorten the time of station tracks at the Radom station, e.g. for the passage of dual-system trams); the postulate is in accordance with the one presented in [15];
- commissioning / improvement of bus transport from / to the centers of poviat cities in the Radom region, located a few kilometers from railway stations serving them; a prospective solution would be to build railway junctions from the nearest stations to the centers of such cities as: Szydłowiec (with extension of some routes between Warsaw and Radom to Szydłowiec), Przysucha and Kozienice (a new connection through Pionki or Garbatka-Letnisko or reactivation of transport on the Kozienice-route Bąkowiec);
- extension of some routes of the Skarżysko-Kamienna - Radom route to Pionki station (in order to provide better service for this city without creating new agglomeration lines).

In the future, further development of the integrated rail-tram system in the Radom agglomeration may be considered. The development directions may be two-system tram lines to the cities of the Radom subregion, e.g. to Pionki or to the Radom-Sadków Airport (if there is a need for such transport in the future)).

Summary

The planning of the tram network in Radom has been going on for over half a century. Previous attempts to implement, despite the basic north-south tram route in the main part of the route, have always been unsuccessful. Modern transport needs require greater integration of various transport modes. It has become crucial to combine seemingly separate systems, making use of fully existing infrastructure and relying on many years of experience of other cities and regions in Europe. The difficulty in implementing plans for the construction of two-system tram routes in Polish conditions results from several reasons, not much of which is technical and the majority of legal and organizational (technical problems were largely solved over the last decades of construction and operation of such systems in Europe, primarily in Germany), which is emphasized by the authors of many Polish studies in this field [1], [2], [3], [6], also published recently, such as [10]. The author of the latter clearly indicates problems with the homologation of an unusual dual-system vehicle, the lack of appropriate regulations and standards, and a conservative approach to understanding and separating the terms "railway" and "tram". The need to change the authorities' approach to designing less-conventional solutions in urban rail transport was also highlighted in [8], [11] and [17].

The dual-system tram, although it will not solve all of the city's transport problems, is an important element connecting its structure and enabling the efficiency of the transport system in the agglomeration to increase. Further research and conceptual work should include detailed technical and operational solutions of interchanges, variants of the passage through multi-family housing areas, a location of stop units, a specification of rolling stock and installation of control and traffic management systems.

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