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A SELECTION ANALYSIS OF SOLUTIONS FOR TEMPORARY TRAM TRAFFIC ORGANISATION EMPLOYED IN WROCLAW

Summary. Urban transport plays a massive role in the proper functioning of cities [1, 2]. Prioritisation of public transport [3] is an attempt to fight growing traffic congestion, which has a noticeable impact on people's comfort of living, especially in large cities [4-6]. Shaping the road environment to improve the quality of functioning of public transport means that the management of urban infrastructure cannot cause difficulties. The continuous execution of construction works in Wroclaw has forced the ordering party to introduce temporary, and often complicated, traffic organisation solutions. The primary goal is to ensure the most efficiency for public transport users while maintaining the smoothness of private transport. This article presents solutions to temporary tram traffic organisation used in Wroclaw. The frequency and effects of the applied solutions were analysed using examples of completed and planned tram investments in Wroclaw. The reasons for the applied solutions and possible directions for further analyses were considered.

1. INTRODUCTION

In accordance with the policy of sustainable transport, passenger public collective transport is expected to play an increasingly important role in opposition to individual transport. Due to the possibility of the relatively fast movement of large streams of passengers, public transport is of great importance within urban agglomerations and highly urbanised areas. Public transport must meet not only the condition of profitability (price) and comfort but also, above all, operational reliability in order to constitute sufficiently attractive competition for individual transport. The operational reliability is defined as the ability of a system to perform operational tasks without downtime caused by failure in the assumed period of time and under established conditions. At the same time, it is closely related to three basic characteristics: reliability, maintainability, and the ability to provide logistic support (supportability) [7]. In the case of urban transport, the above term means the reliability of infrastructure and rolling stock.

Over the last few years, the following improvements have emerged in the public transport industry:

- devices for de-icing the contact line used to protect the contact lines with a special anti-icing agent (preventive action) and to remove the layer of ice that has already appeared on the contact wires (intervention action) – Cracow Municipal Transport Company JSC,
- green wave for tram transport – in Warsaw,
- bainitic cast steel used in turnout structures, characterised by high durability and resistance to operational wear – invented by Kolejowe Zakłady Nawierzchniowe "Bieżanów" Ltd.,
- light rail transit systems – developed by ArcelorMittal,
- autonomous trams – a research and development project aimed at increasing driving safety implemented in cooperation with Newag SA, Cracow University of Technology – Institute of Rail Vehicles, Cybid Ltd., Cracow Municipal Transport Company JSC, and Medcom Ltd.,

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- a new generation of medium-floor trucks aimed at reducing the total weight of the trucks and using a solution that facilitates service and repair work – a project implemented by Modertrans Poznań Ltd. in cooperation with the Faculty of Machinery and Transport of the Poznań University of Technology,
- Medcom Ltd. power electronics:
    - energy recuperation systems of the E-recycler series that allow the recovery and storage of electricity generated during braking and its subsequent use to accelerate the vehicle again – in Warsaw,
    - operation systems powered by battery energy, owing to which trams can travel up to 3 km without a traction power supply – in Cracow,
    - power supply systems for Moderus Gamma trams manufactured by Modertrans Ltd. using silicon carbide technology – in Poznań,
- track lubricators with a power supply system, online technical condition monitoring system, audio and video noise monitoring system, rainfall sensors, sensors for detecting passing trams, and elements supplying lubricant to the rails – implemented by ZUE JSC for Warsaw Trams Ltd.,
- the marking of tram switches with a QR code, the development of a reading system, and the recording of data controlled by the infrastructure manager through a mobile application – developed for Wroclaw Municipal Transport Company Ltd.

The abovementioned improvements show how much emphasis is placed on the development of public transport. The common goal of city authorities is not only to introduce innovative technological solutions but, above all, to achieve the constant maintenance of the infrastructure, which involves constant renovations and modernisations. The main challenges related to such actions are to continue prioritising public transport and to maintain its uninterrupted operation.

2. PUBLIC TRANSPORT IN WROCLAW

Wroclaw is one of the largest cities in Poland [8]. The tram network in Wroclaw comprises 21 tram lines. The total length of the tram tracks in Wroclaw is 203 km of single track. Due to the extremely extensive network of tram tracks, the city authorities started an investment project [9, 10].

Municipal Transport Company Ltd., the tram track authority in Wroclaw, has been implementing a tram infrastructure modernisation program since 2020. TORYwolucja includes renovations of tracks and traction networks. The purpose of TORYwolucja is to conduct year-round work on improving the condition of the tram infrastructure, from current repairs to major renovations. However, the enormous pace of work is associated with many complications. The main problem is the change in traffic organisation introduced for the needs of the renovation. The contractor's task is to plan the renovations in such a way that it is the least burdensome for all users. The temporary traffic organisation is considered both in terms of functionality for road traffic (cars, buses), rail traffic (trams), and pedestrian traffic.

As part of TORYwolucja, only in 2021 alone, 19 investments were completed, 70 switches were replaced, 80 million PLN was allocated to track infrastructure, and 11.2 km of tracks were renovated and built. According to the map depicted in Fig. 1, 10 tasks were completed in 2020, 21 tasks were implemented in 2021 (including two tasks continued in 2022), and 16 more tasks were planned for 2022.

The number of tasks performed requires carefully considered decisions and elaborate plans for temporary traffic organisation.

3. TEMPORARY TRAFFIC ORGANISATION

Temporary traffic organisation is determined on the basis of consultations and the multi-level coordination of offices. It is conducted in a way that minimises the resulting traffic difficulties as much as possible.

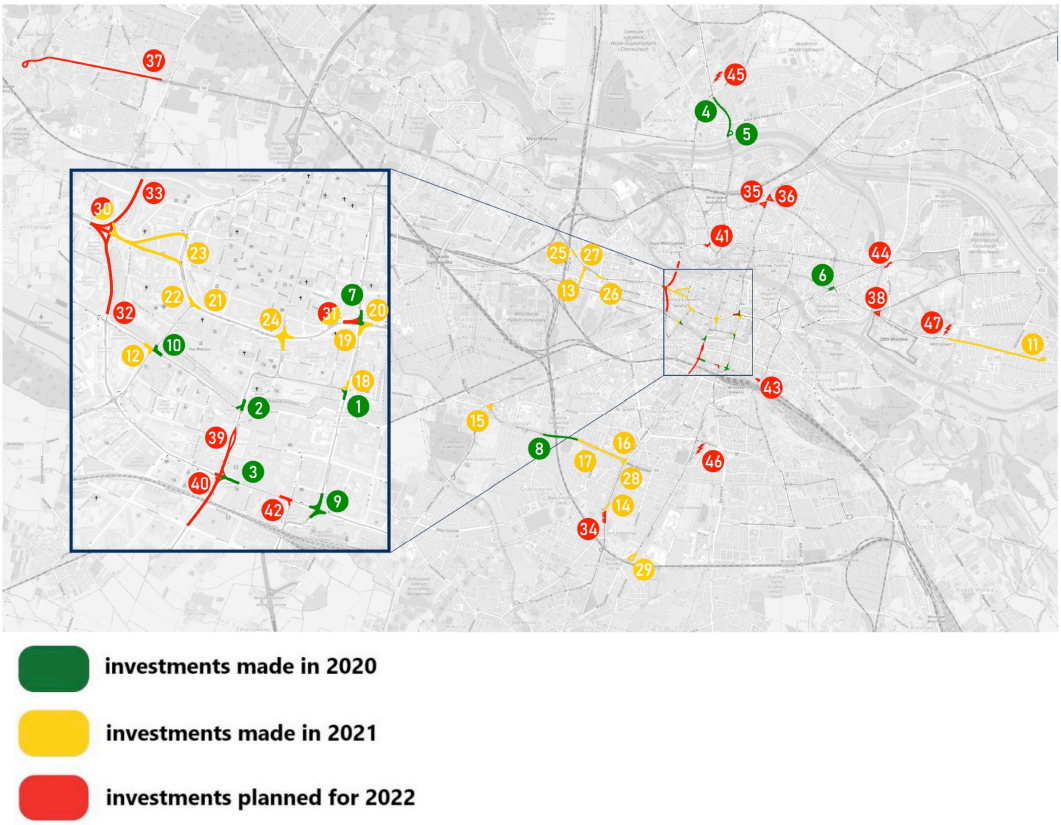

Fig. 1. Modernisation tasks carried out from 2020-2022, divided by year

Each renovation task should be considered individually. All arrangements are made, among others, with the following organisations:

- The ordering party (in this case, Wroclaw Municipal Transport Company Ltd.),
- The Road and City Maintenance Authority[2],
- The Department of Municipal Engineering[3] (Wroclaw City Hall), which organises alternative transport (e.g. the introduction of a bus in place of a tram).

Creating the *concept* of traffic organisation is the responsibility of the designer commissioned to prepare the design documentation. However, only the traffic organisation *design* is the basis for its implementation in the field. It is worth noting that the commissioning of the traffic organisation *design* is usually the responsibility of the construction contractor. During the preparation of each investment, multiple variants of traffic organisation are analysed. During the stage of writing auction documents, such as the general terms and conditions of the contract, the ordering party (in this case, the Wroclaw Municipal Transport Company Ltd.) notifies the contractor of what conditions must be met. These stages are often very complicated.

3.1. Possible solutions

Temporary traffic organisation is an extremely complex topic. Of course, the larger the city, the greater the challenge to choose the best solution [11]. Each city develops its own transport policy. Generally, the most common solution for temporary traffic organisation during renovations is the diversion of tram routes and the suspension and (where practicable) the relocation of tram stops [12, 13].

[2] Zarząd Dróg i Utrzymania Miasta
[3] Wydział Inżynierii Miejskiej

Each renovation is a challenge for the contracting authority, designer, construction company, contractor, and offices approving design solutions. Everyone assumes some responsibility for the decisions and actions taken. Temporary traffic organisation is an extremely complex problem. This article focuses on the analysis of solutions for tram traffic only.

The basic solutions carried out in Wroclaw include the complete exclusion of tram traffic, the installation of a temporary turnout in a classic track, the installation of a temporary overlapping turnout, and triangular maneuvers. One of the solutions used during renovations carried out in Wroclaw is presented below.

3.2. The case study of temporary traffic organisation for the replacement of turnouts at the junction of the Zwierzyniecki Bridge

The task was scheduled to be implemented from June to September 2022. The order was for the replacement of the track surface of the entire tram junction at the intersection of Zwierzyniecki Bridge at A. Wajda Street and A. Mickiewicz Street (Fig. 2). The main goal was the maintenance of tram traffic to Biskupin (a district of Wroclaw).

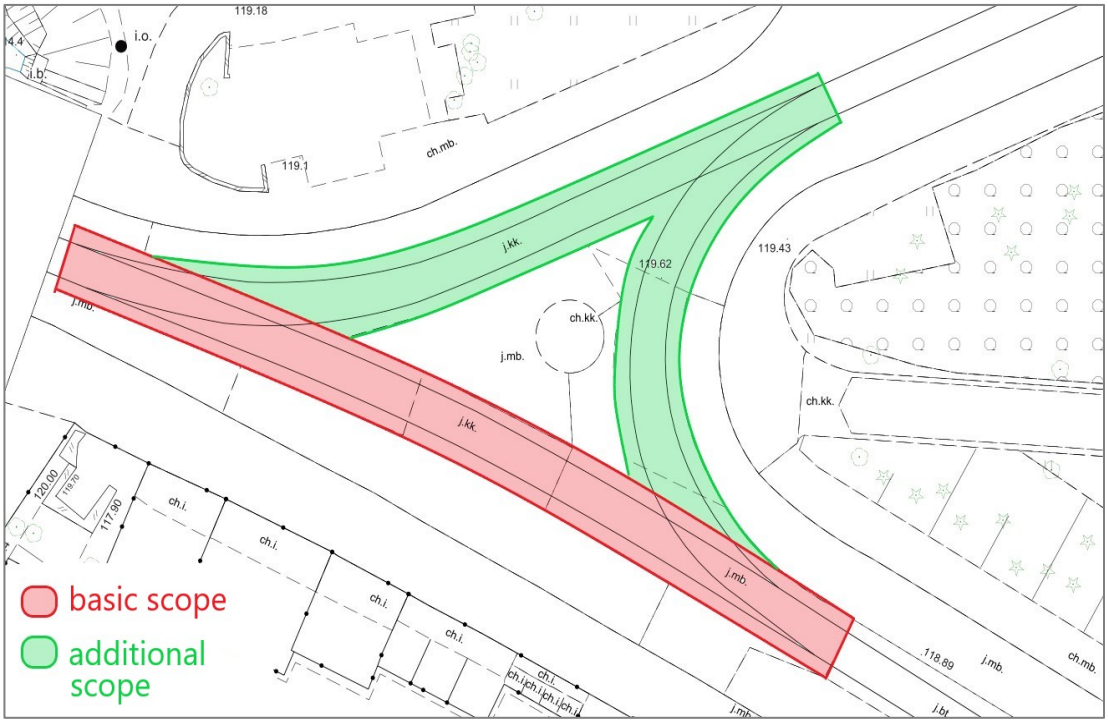

Fig. 2. The scope of the task of replacing turnouts at the junction of the Zwierzyniecki Bridge

The subject of the contract has been divided into the following stages:

1. Stage I (Fig. 3, Fig. 4) – the execution of all construction works related to the replacement of the turnout from the side of the Zwierzyniecki Bridge, including:

a) Stage Ia – the replacement of the entry switch BN309/1,
b) Stage Ib – the replacement of the exit switch BZ309/1.

The solution requires the installation of an overlay turnout or the arching of the track in order to lead the tram traffic “upstream”. The installation of another entry switch enabling the tram to return to the correct track is possible only after the Zwierzyniecki Bridge in the suggested location as below (Fig. 3).

A detour (Fig. 5) through A. Mickiewicz Street was planned for both of the above stages in order to maintain tram traffic on the Reagan Roundabout-Biskupin route.

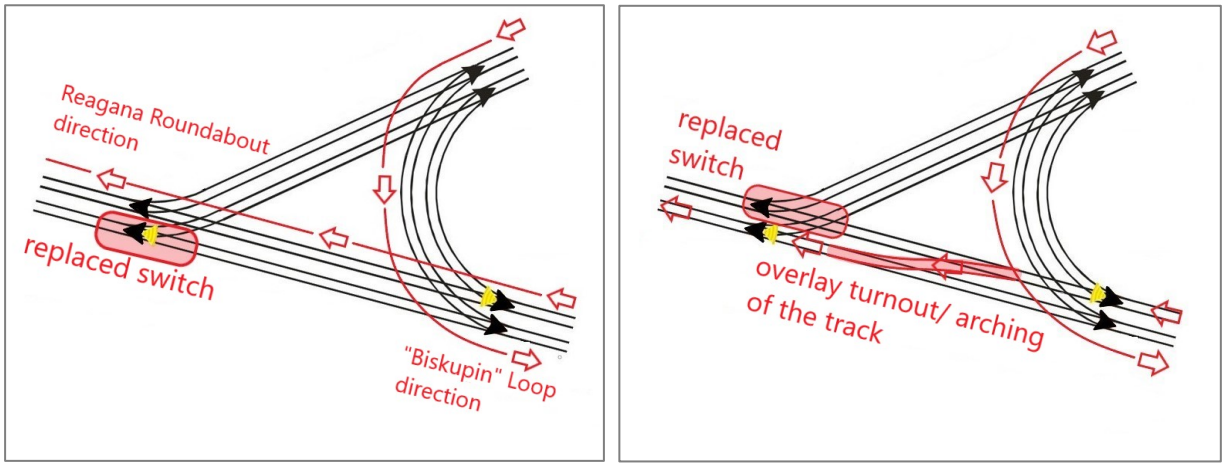

Fig. 3. Stages Ia and Ib of the task of replacing turnouts at the junction of the Zwierzyniecki Bridge

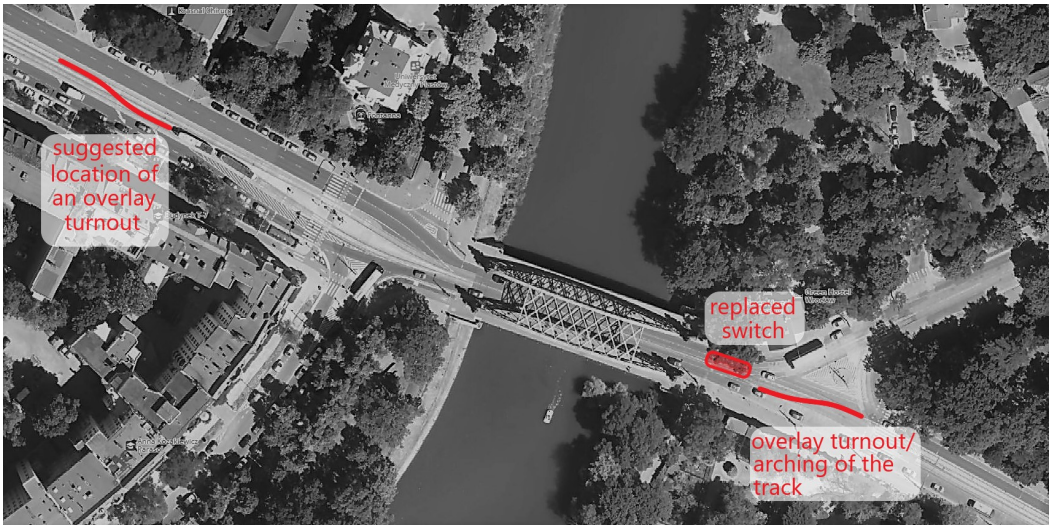

Fig. 4. Suggested location of the overlay turnout for Stage Ib

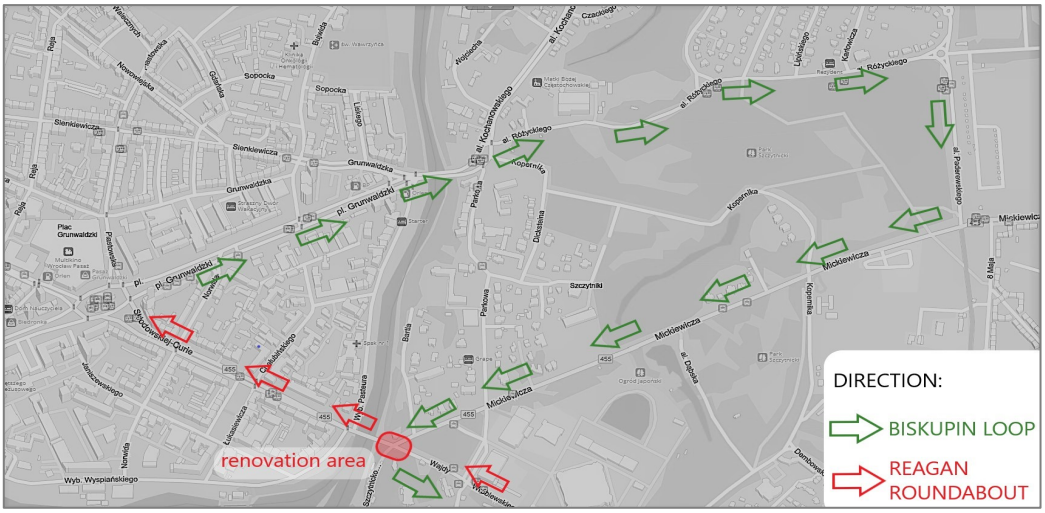

Fig. 5. The detour through A. Mickiewicz Street in order to maintain tram traffic on the Reagan Roundabout-Biskupin route

2. Stage II (Fig. 6) – the execution of all construction works related to the replacement of the B309/2 turnout from the side of A. Wajda Street

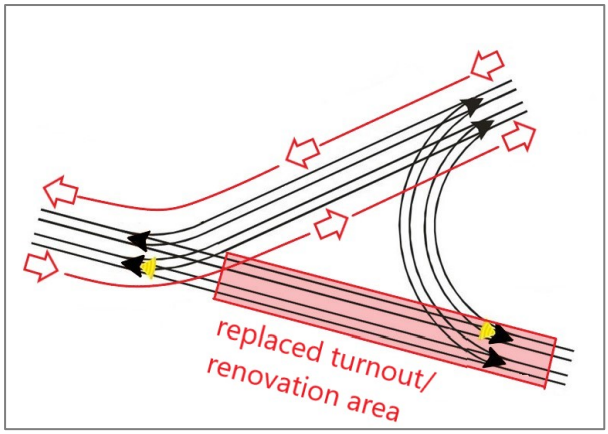

Fig. 6. Stage II of the task of replacing turnouts at the junction of the Zwierzyniecki Bridge

Due to the questionable condition of the existing B309/2 turnout, its half-replacement was abandoned. A temporary bus transport system was planned to ensure public transport to the Biskupin Loop.

3. Stage III – the execution of all construction works related to the replacement of the B309/3 turnout on A. Mickiewicz Street and the arcs connecting the turnouts along A. Wajda Street

Stage III constitutes an additional scope. The contracting authority will decide on its performance after reviewing the price offers of the contractors. For the above stage, a complete stop of the tram transport is planned on A. Mickiewicz Street.

3.3. Advantages and disadvantages of the applied solutions

The complete exclusion of tram traffic is a very radical solution but also the cheapest from the investment point of view. From the perspective of the contracting authority, this solution has the consequences of providing detours for tram transport and ensuring bus transport. The city authorities of Wroclaw take great care to ensure passengers are provided with the best information. With each renovation, the carrier's website and social media (e.g. Facebook) provide information on the designated detour routes and alternative communication [14, 15]. For example, information leaflets were handed out just before the start of the task of replacing the turnouts at the junction of the Zwierzyniecki Bridge (Fig. 7).

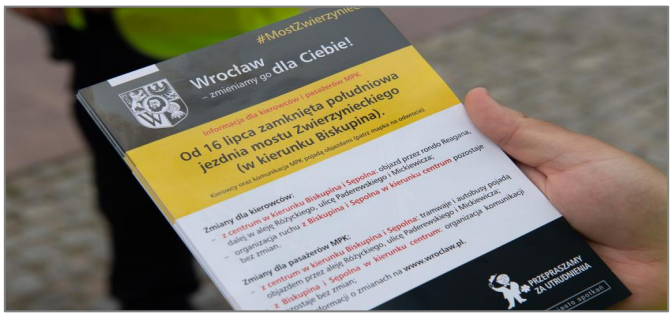

Fig. 7. A leaflet with information about changes in public transport distributed to the residents of Wroclaw just before the start of the task of replacing the turnouts at the junction of the Zwierzyniecki Bridge

The installation of a temporary turnout in a classic track is a relatively expensive solution due to the additional work related to dismantling a fragment of the existing track, constructing a temporary turnout, and assuring a power supply and track occupancy signalling. The main advantage is that this solution allows for a shift movement in and maintenance of tram traffic. Most trams can stay on their unchanged routes. From the passenger's point of view, the reduced frequency of trams due to the lower capacity of the renovated section is a disadvantage.

The installation of a temporary overlapping turnout [16] is a solution similar to the installation of a temporary turnout in a classic track. The main difference – which is an advantage – is a faster assembly process. The overlapping switch consists of segments (Fig. 8) that are mounted with bolts and anchors. However, this is an unusual solution. At the moment, only two companies offer their rental in Poland. The net cost of renting the set (two turnouts – right and left) is PLN 21,000, excluding transport and assembly.

A triangle maneuver is called a wye or triangular junction in railroad structures and rail terminology. This solution allows trams to travel in either direction by another track. Everything is done with the participation of employees who direct the traffic and ensure safety during such turns. The main advantage of this solution is that there is no need to install any temporary turnout and interfere with the existing track. There is only the cost of servicing by additional traffic control workers.

Fig. 8. The numbered segments of overlapping turnouts used during the task of replacing turnouts at the Borek junction

3.4. Frequency of the applied solutions in Wroclaw

Most tram investments carried out in Wroclaw are announced in the form of a tender procedure. Between the beginning of 2020 and September 2022, 42 renovation tasks were announced. They primarily concerned the replacements of turnouts; only a few were repairs of the route. During each of these investments, the solutions listed in Tab. 1 were applied.

Table 1
A list of tram investments and applied solutions for temporary traffic organisation

Task number	Solution			
	Temporary turnout	Overlapping turnout	Wye	Exclusion from traffic/detour
SUM	3	2	1	36

Tab. 1 presents the applied traffic organisation solutions for each tram renovation carried out from January 2020 to September 2022. It was necessary to trace each investment to collect this data. The terms of the investment were most often described in the tender documentation (general terms of the contract) announced by the tram infrastructure manager. They indicate a specific type of substitute traffic organisation that the contracting authority has planned and agreed upon with other authorities.

As can be seen from the table, during most of the investments, it was decided to completely exclude a tram track from traffic in a given section. Of the 42 tasks, only three had a temporary turnout installed, two had an overlapping turnout, and one had a triangle maneuver. Therefore, there is a noticeable tendency to close the entire section under renovation. This allows for the comprehensive implementation of the investment and, thus, better quality. Sometimes, the investor decided to install temporary or overlapping turnouts due to the need to maintain traffic (e.g. a connection to a tram depot) or because the work covered a very long distance and it was not possible to provide enough replacement buses. However, due to investment costs and, above all, short-term tasks, the track manager usually decided to turn off the tram traffic for the duration of the investment.

3.5. Solutions applied in other countries

Current information was gathered on the investments carried out in order to find examples from other countries. As a result of the review, it was found that city authorities usually decide to completely suspend tram traffic (and, very often, the road traffic in the area of the investment as well) in order to facilitate the project's implementation and ensure proper safety. This solution was used for tram track maintenance works in Hong Kong [17], Manchester, Sheffield [18], Melbourne (City of Stonnington) [19], Ballarat [20], and Nottingham [21]. In all cases, replacement buses were planned to help continue the journey.

4. CONCLUSIONS

Along with increased traffic in urban areas, competition between personal and public transport has arisen. The mass phenomenon of traffic congestion, which is mainly caused by the excessive use of personal transport, should be reduced by making public transport more appealing. The effective improvement and increased efficiency of the functioning of urban collective transport are associated with renovation activities.

This article draws attention to the manner in which tram investments are implemented using the example of Wroclaw. The scientific value of this article is related to the finding that the implementation of municipal investments is an extremely complex construction process that requires thorough consideration and planning. The above solutions do not form an exhaustive list but only indicate the multitude of possibilities. The performed renovations and the accompanying changes in the temporary tram traffic organisation should be planned while taking into account the functionality and comfort of all users, but special attention should be paid to users of public transport. Even during the renovation works, the use of public transport should not be a compulsion but a conscious choice [22-25]. Therefore, the temporary tram traffic organisation, which has a direct impact on public transport, should be organised in a way that encourages the use of public transport.

This is an interesting issue worth examining in subsequent publications. Therefore, it would be necessary to trace investments carried out in other cities and countries, determine the dominant form of temporary tram traffic organisation, and consider the reasons for which particular solutions are chosen. In addition, it would be worth performing an analysis of the relationship between the type of the scope of renovation – a turnout or a straight route – and the selected solution of temporary tram traffic organisation. However, due to the differences in tram track networks and the number of turnouts in other cities, such comparisons would be very complicated. It should be noted that the urban network determines the possibility of using certain temporary traffic organisation solutions.

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