


## Using virtual reality for the visualization of microscopic simulation in the field of transport systems: Case study

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### ABSTRACT

Visualization and presentation of simulation experiment results in a virtual reality environment offer a highly attractive and understandable way to present them. Its realisation in the field of transport systems is not easy. Currently, several solutions exist for creating specialised graphic programs, and the paper aims to determine whether a more straightforward solution exists. As a simulation tool, the program Tecnomatix Plant Simulation will be considered, as it has the ideal prerequisites for the field of transport systems. At the same time, it is suitable for creating transport microsimulation models but lacks the necessary blocks for modelling and simulating transport processes. The goal will be to design the procedure to develop a simple methodology for microsimulation models in the field of transport systems and present their results in immersive virtual reality using a head-mounted display.

**Keywords:** visualization, transport, microsimulation, virtual reality.

### INTRODUCTION

Virtual reality (VR) has huge potential for road transport and transport systems, and this potential is constantly developing. In the context of transportation, VR can play a decisive role in advancing various aspects that contribute to the creation of innovative, sustainable cities [1]. Its main task is to create a visual experience using a special display device, such as a head-mounted display (HMD) [2].

In general, the primary effort of VR is to provide the most faithful presentation of spatial models and scenes, enabling movement in three-dimensional space and providing an immersive experience. In the context of road transport and transport systems, the mentioned properties of virtual reality are desirable and a major reason it can be used in road transport.

These facts explain why many scientific works focus on virtual reality in road transport. Virtual reality enables a better understanding of how transport processes function [3]. It makes it possible to realise new types of traffic research

[4], to analyse individual transport systems from different points of view [5], to solve the organisation of transport, or to investigate and analyse the behaviour of road users [6]. VR can focus more on researching the behaviour of a specific group of participants in transport processes, such as pedestrians [7]. Great potential can be realized through the use of VR in the transport sector, particularly for improving safety [8]. The results of the current research activities show that VR is a tool with high potential to support traffic studies [9].

From the perspective of transport systems, the added value of virtual VR lies in its ability to represent spatial and temporal relationships in a realistic and interactive form. Compared with conventional two-dimensional visualisations, VR enables users to perceive traffic situations at human scale, assess visibility and conflict points, and better understand the interaction between vehicles, pedestrians, infrastructure, and traffic control elements. This is particularly beneficial for safety assessment, communication of design alternatives, and the presentation of simulation results [9, 10].

The importance of virtual reality in road transport is increasing due to its connection to computer simulation. The computer simulation method is currently one of the critical analytical tools in the field of transport systems [10]; therefore, its integration with VR is a logical outcome of its further development. Computer simulation, extended by virtual reality, is a critical research methodology for modelling and analysing transport systems [11]. The combination of computer simulation and VR is highly important, especially in microsimulations. According to Hasan et al. [12], microscopic traffic simulation (MTS) is the emulation of real-world traffic movements in a virtual environment using various traffic entities (e.g., vehicles and pedestrians). Visualization of MTS results in a virtual reality environment, which can be achieved using other procedures.

Zhou et al. [13] visualized simulation experiments in 3D using the CORSIM program and EON Studio, a software platform for creating virtual reality. The key to this approach is the translation of network geometry and traffic data, which is realised using a specially designed middleware program. Chun et al. [14] conducted a study documenting the application of a microscopic simulation model developed in VISSIM, combined with VR4MAX, to create an interactive virtual reality model. They used this approach to analyse the current and future traffic flows in East Pilgrim Street in Newcastle. As can be seen, both examples rely on simulation and graphics software to transform the obtained results into VR. However, this approach may be one reason many experts and researchers in the field of transportation hesitate to use VR.

Current simulation tools aim to make the entire process of using computer simulations and VR in the field of transport as simple as possible for users. That is why they are already starting to offer direct VR support or a direct connection to graphics software for creating VR and presenting simulation results. Among these examples, we can mention the cooperation between the VISSIM /VR Design Studio software [15]. For almost 30 years, Vissim has been one of the leading tools for traffic microsimulation [16]. However, it is not the only one. There are also other similar solutions [17].

However, it is still a solution that, despite the attractiveness of the final result, is difficult for many potential users to use. Therefore, the question is whether there is another solution that would enable easier creation of traffic simulation models

and their visualization in VR. A large number of simulation software on the market have built-in VR environments and allow the creation of traffic simulation models with some modifications. Therefore, the application of the Tecnomatix Plant Simulation program will be described in more detail in the presented research, with a focus on its modification to enable the visualization of microscopic simulation models in VR.

## MATERIAL AND METHODS

The creation of microsimulation traffic models in a virtual reality environment is often realised according to the methodology presented in Figure 1. As part of this methodology, a microscopic simulation model is required in the first phase. For this activity, several classic, tried-and-tested simulation programs can be used, such as Vissim or CORSIM.

### Visualization and simulation of traffic processes

Visualization and simulation of traffic processes are highly effective approaches for solving a wide range of transport tasks and problems. Traffic engineers use it to understand the processes under study better, gather information, and search for new solutions. From the perspective of detail, microscopic, mesoscopic, and macroscopic transport models are distinguished (Figure 1).

The VR graphic output was created in the second phase. As can be seen, the visualization is achieved using other software tools and data obtained from the simulation program designed for the transport field. The most important step of this phase is “generating graphic output in VR”, and its detailed development and description are presented in Figure 2.

This process is difficult to generalize because it varies across software tools. In many cases, this methodology is why visualizing the results of microsimulation models in virtual reality is often not implemented.

## BACKGROUND

According to [18], five primary categories of virtual reality can be distinguished (Figure 3). Each category offers different applications and benefits

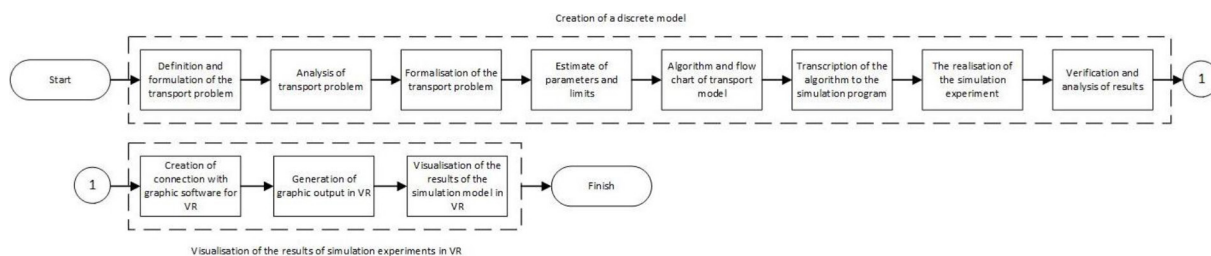


Figure 1. Creation of microsimulation transport models in the environment of virtual reality

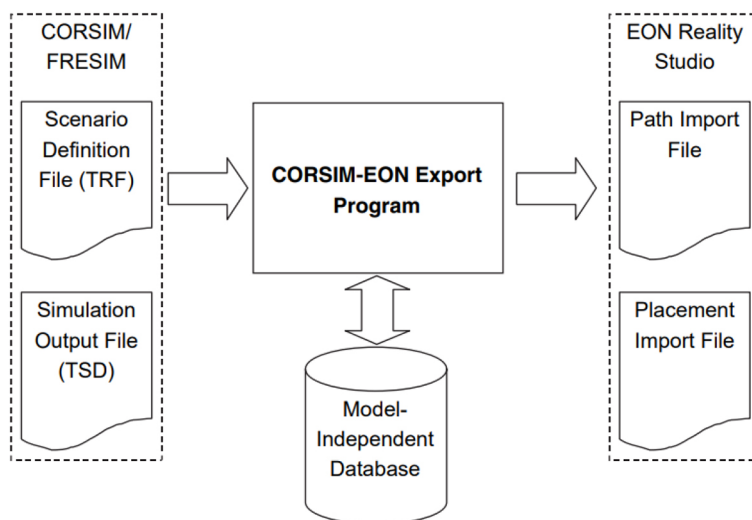


Figure 2. Generation of graphic output in VR – a sample [13]

in the transport sector. The immersive (absorbing) virtual reality has a great perspective in combination with the computer simulation method.

An absorptive effect on a user characterises immersive virtual reality. It means that when using it, there is a feeling that the person is directly part of the action (the simulated process). Individual functions are monitored in the direct first person; the user can move within the virtual reality and is surrounded by the fact in a 360° range. For its realisation, a unique display device is usually needed, placed on the user’s head. Most often, it is a device in the form of viewing glasses or a special helmet that must also be able to display the third dimension. In addition, the user must have additional controllers equipped with special sensors for pointing, moving, and possibly manipulating objects in the virtual space.

### Visualization and simulation of traffic processes

Transport systems are particularly suitable for VR applications because they are dynamic,

spatially distributed, and strongly dependent on human movement, perception, and decision-making. Many transport-related problems are linked to visibility, orientation, reaction, and interaction in space and time, which are difficult to evaluate using static representations alone. In addition, real-world testing in transport is often costly, time-consuming, or unsafe, whereas VR makes it possible to verify alternative layouts, traffic regimes, and user responses in a controlled and repeatable environment.

The combination of immersive virtual reality and computer simulation in the field of transport is a highly effective tool for visualising the results of simulation experiments and analyses (Figure 4). A user can monitor the simulated traffic processes directly in the first person. During the presentation, a user can move frequently, change the point of view, and monitor the results from a specific position.

A frequent shortcoming of this solution is that it is impossible to monitor additional indicators, such as graphs and tables, within the visualization. This is primarily because if the

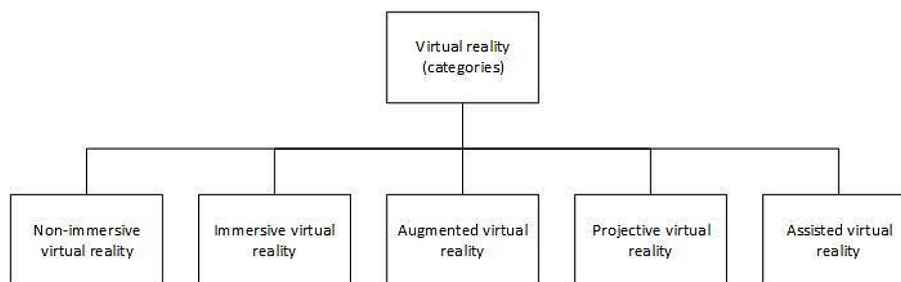


Figure 3. Categories of virtual reality [18]

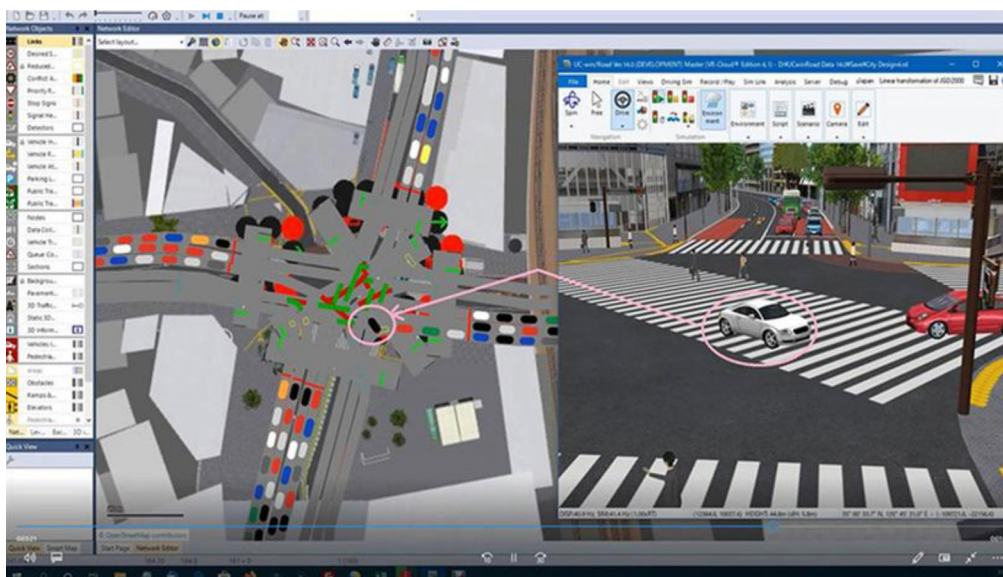


Figure 4. Presentation of the output of the simulation experiment for immersive reality in the field of transport obtained by the combination of VISSIM /VR Design Studio [15]

final immersive display is realised using additional graphics software, it usually cannot display graphs, tables, and other data in sync with the ongoing output in the immersive virtual reality environment.

Based on the mentioned facts, the research hypothesis was presented: whether it is possible to create a microsimulation model of the transport process in an available simulation software tool, which can display the results of simulation experiments in an immersive way and at the same time will display additional information about ongoing processes in the form of graphs, tables, etc. The mentioned idea also supports the claim that Table 1 provides an overview of VR support in the most commonly used simulation software for creating traffic microsimulation models.

As Table 1 presents, VR in microsimulation models is not new and is supported. However, support is mainly provided through specialized graphics programs for creating virtual reality.

This is often why VR is not commonly used in the presentation of microsimulation models.

At the same time, there is a question of whether it is possible to present information about simulated traffic processes in a VR environment. The ideal solution is to create a microsimulation transport model and display it directly in a virtual reality environment.

A microsimulation model is particularly suitable for VR because it represents the transport system at the level of individual entities and their interactions over time. This level of detail makes it possible to observe vehicle movements, pedestrian behaviour, signalling logic, and local conflicts in a natural three-dimensional environment, which improves the interpretability of model outputs. When microsimulation is connected with VR, the user can not only observe the system from different positions and scales, but also compare scenarios more intuitively, interact with the presented model more naturally.

**Table 1.** Overview of possibilities of visualization by VR in the selected microsimulation software

Software	Support of VR	VR in an external program	External program	
Vissim	no	yes	VR4MAX	
Aimsun	no	yes	Unity	Unreal engine
SUMO	no	yes	Unity 3D	
Corsim	no	yes	EON reality studio	

## RESULTS

Based on previous research [19], the Tecnomatix Plant Simulation software was chosen to create a visualization microsimulation traffic model. Although it is not a simulation tool primarily intended for traffic modelling and simulation, its blocks and tools, as confirmed by previous research, fully support such use. At the same time, the mentioned simulation program offers excellent support for presenting the results of simulation experiments in a virtual reality environment. At the same time, as one of the few simulation systems, it does not require secondary graphics software to generate virtual reality for visualisation.

A general methodological procedure was proposed for presenting microsimulation results in a VR environment using the Tecnomatix Plant Simulation program (Figure 5).

The stated methodological procedure constitutes a scientific hypothesis that will be further verified in this research paper. It consists of four substeps created by a pair of smaller partial steps. The methodology is designed to be applied to other simulation software that supports the simulation of transport processes. Subsequently, virtual reality can present the obtained results. A microsimulation traffic model can be created in the Tecnomatix Plant Simulation program by combining available blocks and reprogramming missing functions and rules in the SimTalk program. This basic model needs to be further graphically modified to be visualised in a virtual reality

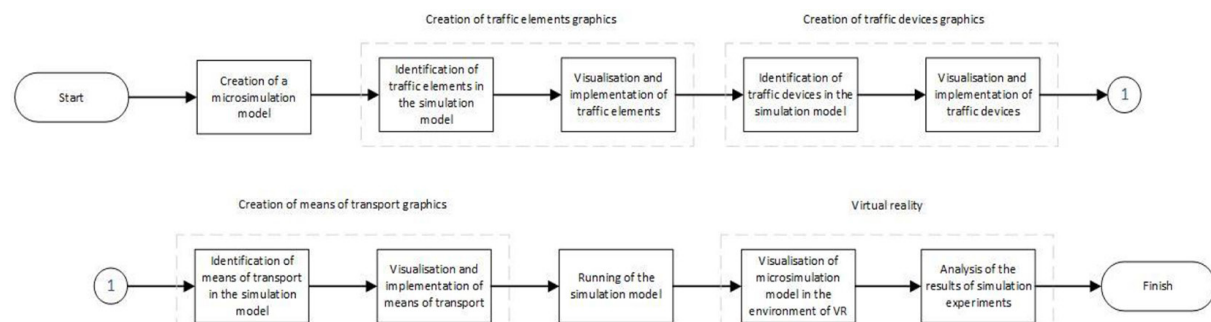
environment. Specifically, it changes the default graphic presentation to correspond with simulated reality or entities. For this reason, it is necessary to create customised blocks focused on transport elements, equipment, and means of transport.

### Creation of a graphic form of traffic models

The process of creating the traffic model graphic form is conditioned by modifying (customising) the block used in the simulation program. We talk about blocks or groups of blocks that represent mobile entities (individual participants in simulated traffic processes) (Figure 6). Subsequently, a group of objects is also created, containing blocks representing transport elements and equipment, and the number of these blocks depends on the scale of the developed microsimulation model.

By modification of the graphic form of blocks, the principle must be applied that the software structure of the existing block has not been interfered with. If it is necessary to add missing properties or rules to the block, we can use additional programming if the program allows it. However, the simulation program must allow such a change, as does Tecnomatix Plant Simulation.

The graphic visual for the blocks must represent individual entities at an appropriate level of detail. Once again, the program Tecnomatix meets this condition. It has suitable functionalities that allow modifying the dynamic block’s default form to the required form (Figure 7). For this, we can use a proper 3D model in the appropriate format.



**Figure 5.** Procedure of the microsimulation transport model presented in a VR environment

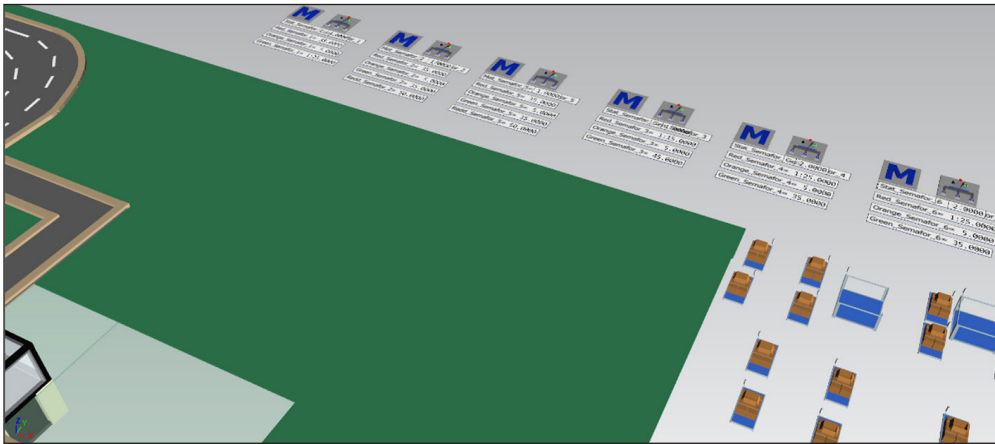


Figure 6. Presentation of the group of blocks „Method“presenting light signalisation

This will ensure that the individual entities are graphically represented during the simulation experiment with appropriate forms and visuals (Figure 8). At the same time, the methodology also requires modifying other blocks that generate entities in the simulation model (pedestrians, traffic elements, means of transport). This procedure can modify the complex vision of the simulation model to the form that sufficiently corresponds to the real environment and processes (Figure 9).

### Visualization of the microsimulation model in virtual reality

In the presented research, the Tecnomatix Plant Simulation program was used in version 14.2. This program does not directly support the visualization of simulation models and experiments in a virtual reality environment. But this deficiency can be solved using the virtual reality bridge software „moreViz“.

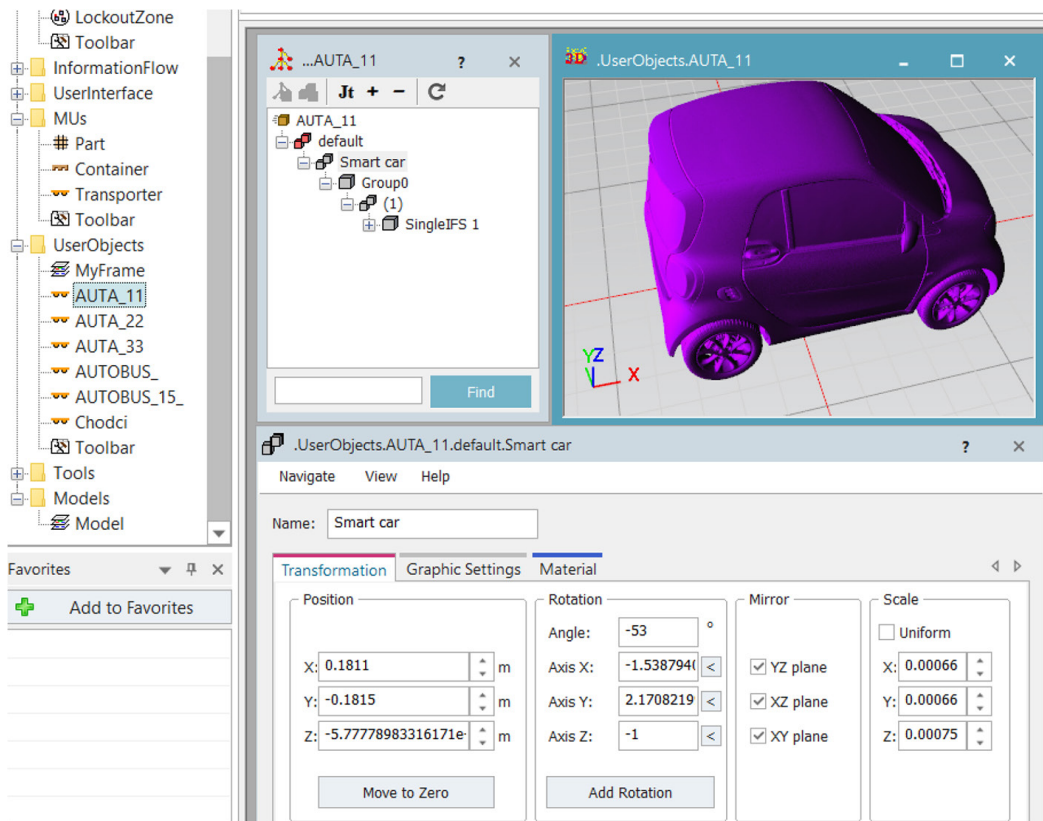


Figure 7. Sample of the modified block „Transporter“ for the need for virtual reality



Figure 8. Sample of the modified visualization of the block „Transporter“

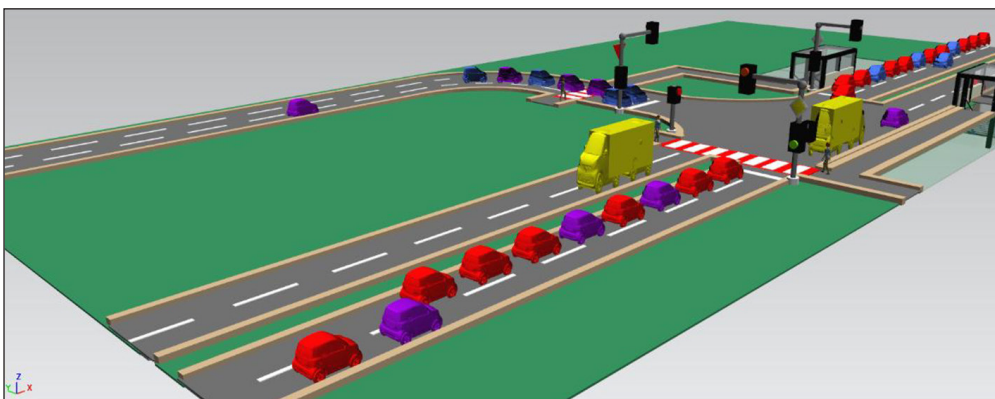


Figure 9. Overview of the visualization of the microsimulation model

### Use of virtual reality bridge software

Virtual reality bridge software „moreViz“ is a solution that enables the direct transformation of outputs from supported software into the virtual reality environment. The equipment used for the described research, the HTC Vive Pro, consists of

a headset with an AMOLED 3.5” display (resolution  $2880 \times 1600$ , frequency 90Hz) and two HTC Controllers (Figure 10).

The program enables the presentation of models and simulation experiments in immersive virtual reality. It enables free



Figure 10. The headset used for virtual reality

movement in the virtual environment, zooming in on observed objects, and the use of means of transport (Figure 11). It allows monitoring of the partial results of simulation experiments (Figure 12). The user can monitor the running

transport process and, at the same time, view its characteristics in various graphs and tables. This information is presented online, synchronized with the graphical progress of the micro-simulation visualization.



Figure 11. The presentation in virtual reality

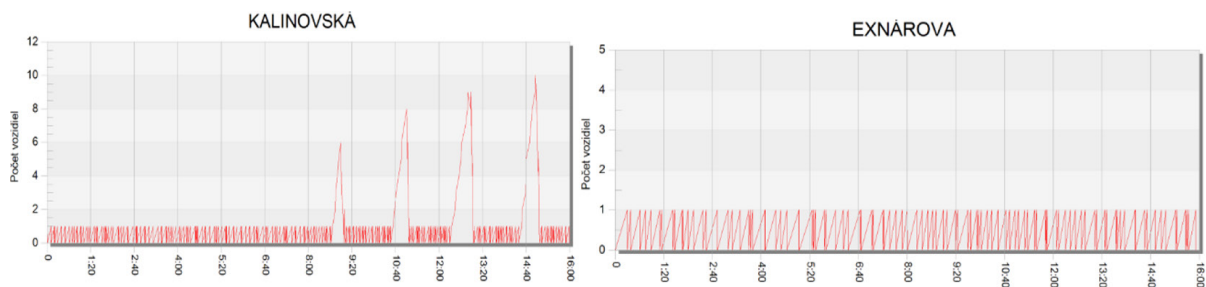


Figure 12. Sample of the partial results of simulation experiments

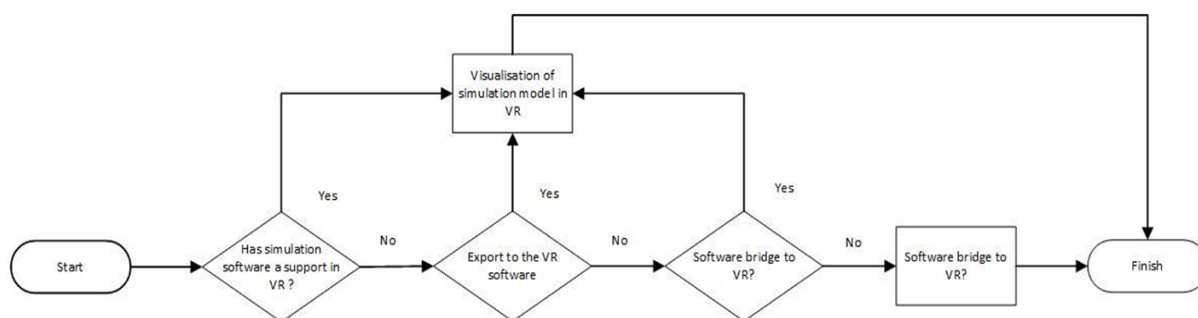


Figure 13. General procedure for microsimulation models visualization in the environment of VR

## CONCLUSIONS

Virtual reality offers a highly attractive and valuable way to visualize traffic models in the field of microsimulation. It allows the interactive form to monitor and analyse ongoing transport processes. A specific shortcoming is that not all microsimulation programs support presenting results in virtual reality.

Currently, there are no solutions that can eliminate the shortcomings mentioned above. However, each said solution always refers to a specific simulation tool. All known solutions can be summarised in the blocking scheme presented in Figure 13.

Many of the presented solutions currently emphasise the graphic side of the visualisation. This can be important from the presentation point of view. Still, if we want to use VR for the analysis and evaluation of microsimulation traffic processes, we need to find a suitable compromise. In addition to the graphic page, it is also required to present partial characteristics and parameters of simulated traffic processes.

For this reason, the research was conducted using a simulation program that provides robust support for presenting results in a virtual reality environment. The presented results confirmed that the Tecnomatix Plant Simulation program is a suitable tool for visualising microsimulation model results in VR. Thanks to the use of the software bridge tool provided by the program Tecnomatix Plant Simulation, the creation of a VR environment, as offered by other solutions (for example, Unity 3D or VR4MAX), is omitted. The software bridge enables direct connection of the simulation software to the HDM set, thereby visualizing the simulated transport processes in a VR environment.

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