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To cite this article: Jan Petru *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **236** 012033

IOP Conf. Series: Materials Science and Engineering **236** (2017) 012033 doi:10.1088/1757-899X/236/1/012033

Assessment of the transport routes of oversized and excessive loads in relation to the passage through roundabout

Jan Petru[1,2], Jiri Dolezel[2,3] and Vladislav Krivda[1]

[1]VSB – Technical University of Ostrava, Faculty of Civil Engineering, Department of Transport Constructions, Ostrava, the Czech Republic
[2]MORAVIA CONSULT Olomouc a.s., Olomouc, the Czech Republic
[3]Brno University of Technology, Faculty of Civil Engineering, Brno, the Czech Republic

E-mail: jan.petru@vsb.cz

Abstract. In the past the excessive and oversized loads were realized on selected routes on roads that were adapted to ensure smooth passage of transport. Over the years, keeping the passages was abandoned and currently there are no earmarked routes which would be adapted for such type of transportation. The routes of excessive and oversized loads are currently planned to ensure passage of the vehicle through the critical points on the roads. Critical points are level and fly-over crossings of roads, bridges, toll gates, traffic signs and electrical and other lines. The article deals with the probability assessment of selected critical points of the route of the excessive load on the roads of 1st class, in relation to ensuring the passage through the roundabout. The bases for assessing the passage of the vehicle with excessive load through a roundabout are long-term results of video analyses of monitoring the movement of transports on similar intersections and determination of the theoretical probability model of vehicle movement at selected junctions. On the basis of a virtual simulation of the vehicle movement at crossroads and using MonteCarlo simulation method vehicles' paths are analysed and the probability of exit of the vehicle outside the crossroad in given junctions is quantified.

1. Introduction

Industry and engineering have a long tradition in the Czech Republic. These sectors produce products with dimensions which can be considered nonstandard. For these products the issue of transport on chosen routes on the roads arises. Routes for excessive transport were previously protected by the Ministry of Transport in terms of dimensions and weight. After year 1992 the routes for oversized loads stopped being protected. Oversized loads consist not only of products, but they also include various construction machinery cranes, etc. that with their dimensions and weight exceed standard allowed maximum limits [1]. Annually the Ministry of Transport of the Czech Republic permits 15 up to 20 thousand of oversized transports, out of which 5,000 transports with respect to the dimensions of the load require extra space to ensure the passage.

More and more resources, both financial and also time are spent in order to ensure the passage of oversized loads. These funds are spent on ensuring technical adjustments to the spatial layout of roads for the passage of individual oversized loads. Such examples include especially building of roundabouts [2,3] with parameters unsuitable for this type of transport, narrowing roads and creating bumps on roads in towns and villages. We can also mention the sc. sewerage transportation in crossroads and junctions and also on fly-over crossings. The problems are also caused by the proximity of lighting, traffic signs and other immobile road elements. Currently, the condition of the road network for usage by oversized load in the Czech Republic is insufficient. Although there exists European directive for transporting excessive loads on the road issued on May 17th, 2006 [4], which recommends to Member States to build a pan-European network of corridors for transporting excessive loads.

2. Critical Points on Roads

Since there are no fixed main routes for transporting of oversized loads in the Czech Republic, they are chosen by the transporter or by the escort. Route selection is based on previous experience and on the assessment of the road condition. This choice depends on the type of cargo, its dimensions and weight. Final approval of the proposed route is granted by the competent authorities [5]. The choice of route itself, due to the passage on roads and bridges, might take several months. Thus, the critical points during the route are level and fly-over crossings of roads, bridges, toll gates, traffic signs, electrical and other lines, etc.

2.1. Traffic Signs

Traffic signs are the most common collision points on the route of oversized load [6, 7]. The signs are located close to the roads, which makes the passage of loads impossible. These signs are very often not possible to be dismantled and it makes the manipulation for ensuring the passage of the transport impossible. If it is possible to dismantle the signs, the problems with anchor bolts of these signs occur. Anchor bolts protrude into the road and it is necessary to cover these places. However, it is not always possible to use the mentioned solution. The problem is caused not only by vertical traffic signs but also by signs which are mounted on the booms over the road. These are mostly newly built or reconstructed pedestrian crossings. [7]

2.2. Immobile Elements on Roads

These elements are primarily lighting, handrails, immobile elements, decorative elements and vegetation. Lighting on roads causes similar problems as traffic signs. Removing of the lighting is very complicated and in most cases it is impossible to pass. Non-removable railings that prevent the passage of cargo and other immobile elements on the route also complicate transport. Not only because of time during the passage but also while selecting the route. In such cases the given part of the road or the intersection becomes impassable for the vehicle. [6, 7]

2.3. Bridge objects

Bridge objects belong among the most critical points on the route of oversized loads. It is because of their limited load capacity but also because of low height clearance. Bridge objects are designed to standardized models of heavy traffic load which do not cover the whole variability of oversized vehicles. For each passage of oversized vehicle on a bridge structure it is necessary to make an individual assessment of static load capacity of the bridge. The height clearance is also connected to the bridges. It is very often inadequate on frequent routes. Since there are not known major routes for excessive loads, it would be useful to ask transporters for any possible requirements which could be used during the designing of new bridges and reconstructing the current bridges. [6, 7]

2.4. Tollgates, power lines and other lines

Height clearance of these objects often limits the passage of loads on individual roads and the assistance of other subjects is often required. The wires of power lines, overhead lines or cables make the transport difficult. In these cases it is necessary to ensure the assistance of experts. The cables are lifted during transport. Sometimes it is necessary to switch off the electricity. [6, 7]

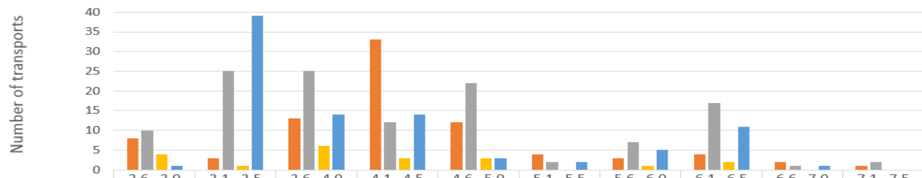
2.5. Intersections
At crossroads and junctions on level crossings the passage of excessive load is very difficult due to often unsatisfactory corner radius of intersections. The excessive transport is usually not taken into consideration during designing or reconstructing roundabouts [8]. Problematic parameters are mainly radius on entrance / exit, geometrical arrangement, the size of the roundabout, or complication with a raised central island and dividing islands [9].

3. Statistical Data for Determination of a Vehicle for Oversized Load and Verification of Passage Through Critical Points
For the verification of the critical points along the route of the oversized load first it is necessary to determine what types of cargos are located on the route. Further, it is also necessary to find out the parameters of trailers which carry the cargo. For this purpose the long-term author's database was used, from it the main route (road of 1st class) was selected. This database contains processed statistics of transports based on the transport time, type of cargo, weight, length, width, height of all set, the beginning and end of the route, a detailed schedule of the route and the number of days of transport.

For the verification of critical points on the chosen route there were used four cargo categories that use this route. A more detailed division into categories is shown in author's doctoral thesis [6]. For the purposes of the article the following categories were chosen:

- Long and heavy transports (generators, transformers, ...).
- Structures (frame structures, bridge structures, steel, wood, or concrete structures, ...).
- Machinery (construction equipment, cranes, ...).
- Mixed category (silos, technological equipment, boats, pools ...).

Individual transports were analysed and divided into a specified range of widths. Figure 1 shows observed values in the specified range according to individual types of transport.

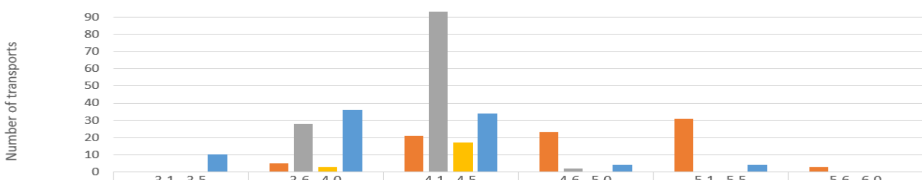


	2.6 - 3.0	3.1 - 3.5	3.6 - 4.0	4.1 - 4.5	4.6 - 5.0	5.1 - 5.5	5.6 - 6.0	6.1 - 6.5	6.6 - 7.0	7.1 - 7.5
Long and heavy transport	8	3	13	33	12	4	3	4	2	1
Structure	10	25	25	12	22	2	7	17	1	2
Machinery	4	1	6	3	3	0	1	2	0	0
Mixed category	1	39	14	14	3	2	5	11	1	0

Width [m]

Figure 1. Number of transports in a range of widths on observed route.

Another observed parameter for verifying the passage through critical points on the route was transport height. Figure 2 shows the resulting observed values within the specified range according to individual types of transport. Transports which were represented the most have between 4.1 to 4.5 meters.



	3.1 - 3.5	3.6 - 4.0	4.1 - 4.5	4.6 - 5.0	5.1 - 5.5	5.6 - 6.0
Long and heavy transport	0	5	21	23	31	3
Structure	0	28	93	2	0	0
Machinery	0	3	17	0	0	0
Mixed category	10	36	34	4	4	0

Width [m]

Figure 2. Number of transports in a range of heights on observed route.

A diagram of clearance gauges was suggested on the basis of the processed statistical data. For the calculated clearance gauge similar requirements are valid as for the clearance gauge in chapter 6.1.2. of CSN 73 6201 Design of Bridges [10].

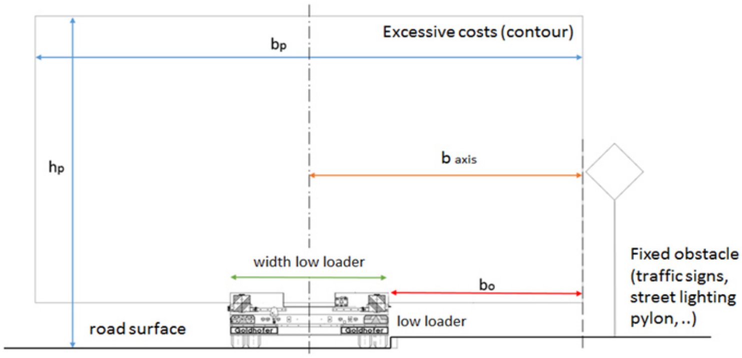


Figure 3. Diagram of clearance gauge including distance from solid obstacles [6,7].

The width of clearance gauge b_p for the passage of oversized loads is shown in Table 1. For individual types of cargo recommended distances are determined. The b_o was calculated as:

$$b_o = b_{asix} - \left(\frac{x}{2}\right) \tag{1}$$

Table 1 shows a type of transport and for each type the width of used trailer is determined. The width of the trailers was determined for each type of cargo on the basis of types of trailer used in the Czech Republic. The recommended values of b_o were determined on the basis of the calculation. The recommended height h_p is determined for each type of transport. The height h_p of clearance gauge is basis to a free height of the underpass which is listed in section 6.3.2. of CSN 73 6201 Design of Bridges [10].

Table 1. The distance from solid objects and the height area.

Type	The minimum width of used trailers [m]	Recommended b_o [m]	Recommended height h_p [m]
Long and heavy transport	3.00	2.30	6.00
Structures	2.55	2.50	5.00
Machinery	2.75	1,90	4.50
Mixed category	2.55	2.25	5.50
Resulting value	3.00	2.30	6.00

4. Modelling of the Vehicle and its GPS Verification

Based on the analysis and information about parameters, types of vehicles and cargo, it is possible to create the design of the vehicle for verifying trajectories of passages of oversized transports with usage of software AutoTURN. It was necessary to verify such a created model with the help of GPS technology which was installed on the set transporting excessive load (tractor, trailer).

4.1. Modelling of the Vehicle

Two vehicles were created for the verification of the critical points of the route. The first vehicle was created as a test model. On this model the procedure of modelling the car in program AutoTURN was tested. Subsequently vehicle verified with the real vehicle was created.

Figure 4 shows windows of the AutoTURN program that are used for modelling a new vehicle type (set that was tested by GPS technology). Technical parameters were inserted into the program from the manufacturer's data sheets. Other parameters for entering, which were not included in manufacturer's data sheets, were measured additionally. For testing the behaviour of created models of vehicles in AutoTURN program video analysis and data mapping from the transports on roads were used [6, 7].

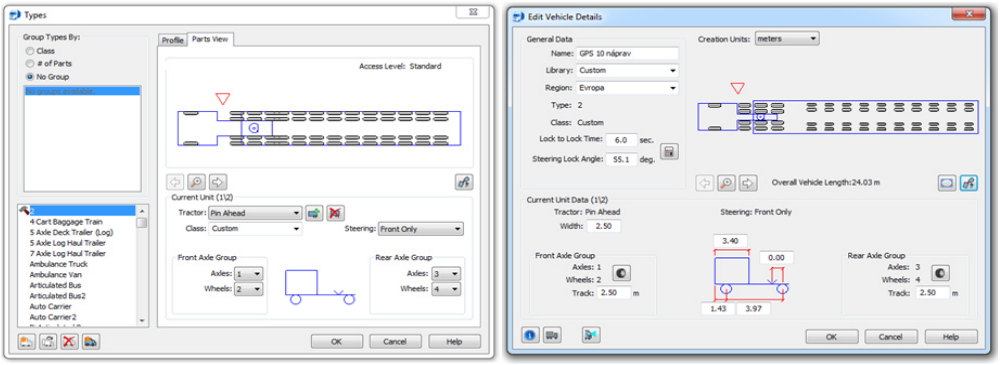


Figure 4. The windows for modelling a new vehicle type in AutoTURN program.

4.2. GPS Measurements and Model Verification

The verification of the created model was carried out on the vehicle with THP axes. GPS technology was installed on this vehicle. For the realization two sets of instruments Topcon HiperGD (GPS observation) and one set of Topcon HiperGGD (observation of GPS / GLONASS) were chosen. Each set consisted of GNSS devices, data recorder for controlling and saving measured data, and a mobile phone. The mobile phone was used for data connection to the source of corrections. TopSURV application was used for recording the measurements, it is a standard application for operation of Topcon. Due to the requirements for measurement accuracy the method of phase measurements with correction in in Real-Time Kinematic (RTK) was chosen.

The fixing the GNSS apparatus was done once to the cabin and twice to the trailer. Fixation and installation of GNSS apparatus is shown in Figures 5 and 6.

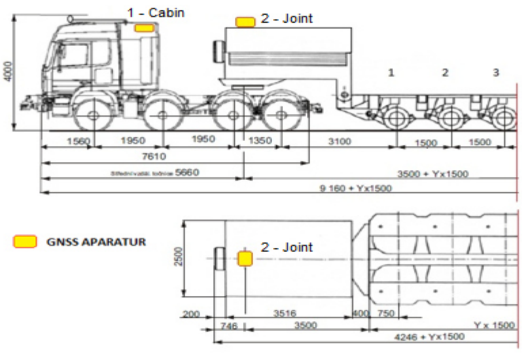


Figure 5. Part of the scheme of GNSS apparatus location on a vehicle transporting oversized loads.

Figure 6. Location of GNSS (2) equipment to trailer with tractor.

Data were processed in ArcGIS Desktop. On the basis of the technical documentation outlines of tractors were calculated from the measured data. Calculations were done by using a combination of formulas of analytical mathematics and analytical tools of ArcGIS Desktop (see Figure 7). For the calculation of the outlines the script for automation of evaluation of measured data was prepared. The result of the processing is – a class of 3D polygon objects (representing a ground plan of the tractor and the trailer) and a class of point objects (representing the outlines of significant edges in the ground plan of the tractor and the trailer).

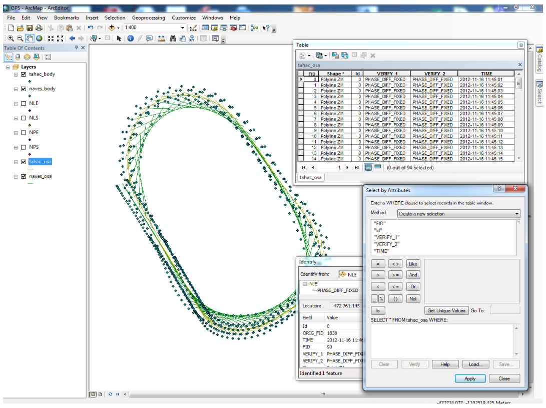


Figure 7. A preview of processing the measurement of GNSS apparatus in ArcGIS program.

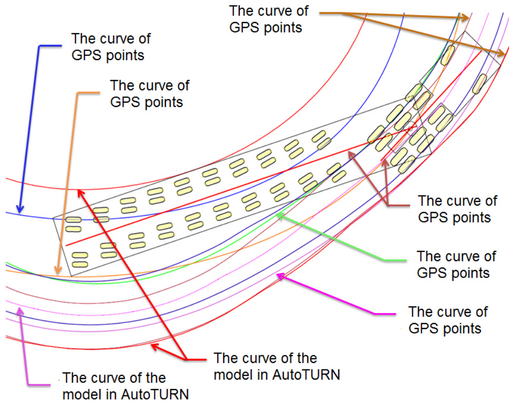


Figure 8. A comparison of the created model in AutoTURN program and GPS measurement.

The newly created vehicle in AutoTURN program was subsequently verified according to the processed and evaluated measurement with the usage of GPS technology. The curve created from the GPS points and the outline curve of the edges of the trailer of newly modelled vehicle in software AutoTURN were compared on the basis of the measurement. Based on the obtained data the conclusion is that the vehicle created in AutoTURN program corresponds to the “real” behavior of vehicle carrying excessive and oversized loads, which was used for the measurement (see Figure 8).

Based on this verified procedure a vehicle for verifying intersections on the route of oversized load was created. The processed statistics from chapter 3 were used for modelling of the vehicle in AutoTURN program.

5. Modelling of Passage of Vehicle and Analysis by the MonteCarlo Method

Based on the modelled vehicle in AutoTURN program a selected intersection on the route of excessive cargo was verified. This intersection is in city Litomyšl. The intersection is located on frequent routes of such cargos. This critical point of the route was deliberately chosen based on many measurements of the author, which were realized at this intersection [4, 7]. Nowadays the intersection is adapted for passage of excessive loads.

Figure 9 shows trailing curves from simulations of passages of the vehicle. For the analysis of the passage 100 realizations at the intersection were done. Figure shows 4 envelope curves of all simulated passages. These curves contain all simulations which were done.

- blue hatch – passage without the need of dismantling the traffic signs, the dividing islands were used for the passage
- grey hatch – passage with the need of crossing the road kerbs and use of unpaved road shoulders and greenery
- red hatch – passage which cannot be realized because of driving on the central island, road shoulder and dismantling the lighting
- purple hatch – passage which was recorded during monitoring of the transport – i.e. transport which was realized through this intersection – during the passage the traffic signs were dismantled, the passage was done across the road kerbs and unpaved road shoulders. Excessive load did not cross the central island of the intersection.

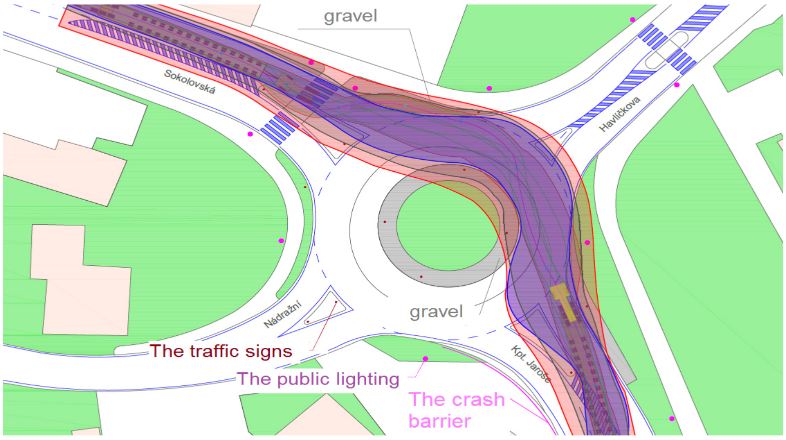


Figure 9. The resulting envelope curves from the simulation of passage through the roundabout in AutoTURN program.

Based on the simulation of movement of oversized vehicle through the intersection the probability of passage was analyzed. For these virtual simulations of the movement of the vehicle through the intersection the MonteCarlo simulation method was used. The trailing curves were analyzed and the probability of exit of the vehicle outside the outline of the intersection during individual passages was quantified. The critical points, such as the distance of the traffic signs, lighting, road kerbs, etc., at this intersection were taken into consideration in this analysis.

Figure 10 shows histogram of evaluation of passage of excessive load through the roundabout. The horizontal axis indicates total width of circulatory roadway which can be used for the passage of the vehicle. Value 0 indicates a half of this width. The vertical axis represents the amount of passages. The blue dashed line indicates a boundary when it is necessary to dismantle the traffic signs and it is necessary to prepare for the passage through this intersection. The black dashed line indicates the necessity of crossing the road kerb (the necessity to underlay the kerbs). The red line indicates the boundary when the passage cannot be realized (there is no possibility to underlay the kerbs, the assistance of many subjects, dismantling the lighting, dismantling the traffic signs is needed).

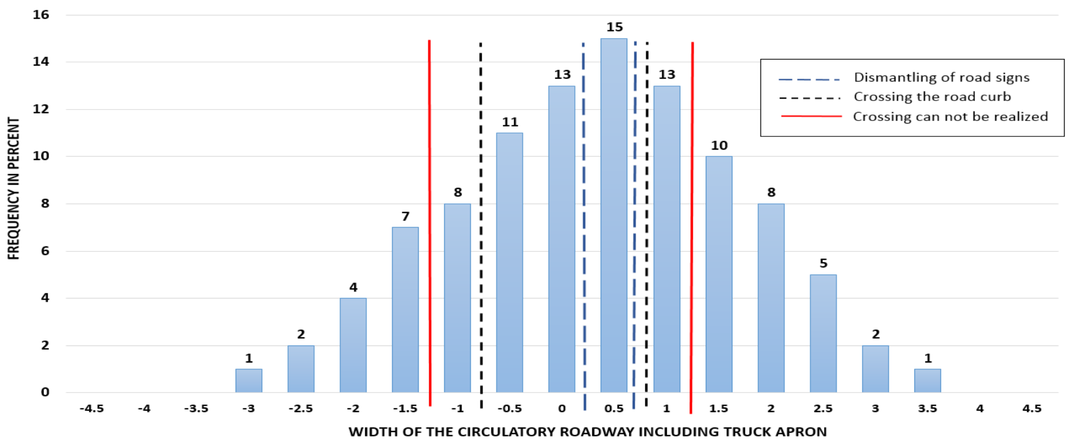


Figure 10. Evaluation of the probability of the passage of excessive load through the roundabout.

6. Conclusion

The article tries to draw attention to the issue of passage of excessive and oversized loads through critical points on the roads. For the purposes of the article one route of excessive cargo was chosen an example. The most common types of transport were evaluated with the help of created database.

Based on the measurements and processed video analyses a passage of vehicle through the selected roundabout was simulated by the usage of a newly created vehicle in AutoTURN program. On the basis of the simulation of vehicle movement through the roundabout the probable passage was analyzed.

From the evaluation of 100 virtual simulations of passage of oversized load through the roundabout arises that only 15 passages can be realized without any adjustments. Further 45 passages can be realized with some adjustments of the route during the passage. And 40 passages cannot be realized.

Based on long-term research and analysis of other critical sites and the results described in this article, indicate that road network in the Czech Republic is not designed for the passage of excessive and oversized load [7,11]. There are many critical points on the main roads of such transports [11, 12]. It causes not only long delays but also financial losses (construction adjustments, rent of other entities for realization of the transport). For these reasons the price of transport (product) increases and this causes reduction of competitiveness of Czech producers. That is why there should be developed main routes for transport of these excessive and oversized loads and there also should be some regulation which would determine suggested parameters of these routes. [6, 7]

Acknowledgements
This paper was supported by MORAVIA CONSULT Olomouc a.s.

The work was supported from sources for conceptual development of research, development and innovations for 2016 at the VSB-Technical University of Ostrava which were granted by the Ministry of Education, Youths and Sports of the Czech Republic.

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