Optimization of the Layout of Motorway Overpasses on the Example of the A4 Motorway Section Jazwiny – Gora Motyczna

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Abstract. The developed, innovative method of estimating the impact of motorway on agricultural land allows determination of all the losses associated with the directions of this impact. The basis for the determination of losses is the analysis of variability in land use and the quality classes and location of access roads to the land along the axis of the planned motorway. The approved measure of the multidirectional impact of the motorway on agricultural land is a change in the value of land, which is determined with taking into account the differences of their suitability for agricultural production. The developed method of determining the impact of motorway on agricultural land was presented on the example of A4 motorway section between Jaźwiny and Góra Motyczna. The existing section of motorway was assessed and then for the same section, the calculations were made again, but with an alternative location of the motorway overpasses (flyovers). In the case of the existing section, the construction of one kilometer of the section of motorway under consideration will result in a reduction in the value of agricultural land of 2119 cereal units. Acquisition of land for the construction of the motorway and its negative impact cover about 78% of the total reduction in value of agricultural land. The remaining 22% of the land value reduction is related to the increase in transport and the deterioration of the plots layout. On the other hand, in the case of the section with alternative arrangement of overpasses, the value of agricultural land is reduced of 2088 cereal units. Acquisition of land under construction and under motorway's toxic impact will be equal 79%, while the combined effect of transport growth and deterioration of the layout makes 21%.

1. Introduction

The method of estimating the motorway's impact on arable land presented in this elaboration is simplified. The main advantage of this method is the possibility of preliminary assessment of the motorway's impact during the motorway route design stage [2]. For the proper analysis, it is necessary

to determine the variability of soils quality along the route of the investment, location of roads and motorway overpasses, areas of agricultural land to which access will be associated with crossing the motorway lane, parameters of plots layouts divided by the motorway, and the presence of green protective belts. Thanks to these data, it is possible to estimate the change caused by the construction of the motorway of these land features, which have a direct impact on the production usefulness of these areas, and then they are used to determine the total impact of motorway construction on the agricultural land.

By means of the simplified method of motorway impact assessment, it is possible to determine its impact taking into account all the major directions of the motorway's impact on agricultural land, which are as follows:

- the loss of land taken over by the road belt,
- the reduction of the production capacity of land located near the motorway
- the deterioration of the layout of farms crossed by the motorway.

The measure of the motorway's impact is the value that takes into account only the production usefulness of agricultural land [8]. Therefore, this value is only a measure of the valorization of the agricultural usefulness of land for agricultural production.

The biggest advantage of this method is that it has a simplified character, which greatly limits its labor intensity. This allows the method to be used to analyze many possible variants of the motorway route still at the stage of its initial design, which makes it possible to choose the best version. The entire calculation process was automated using a program written in Visual Basic, which uses Microsoft Excel spreadsheets for calculations, thanks to which this method can be widely used.

2. Characteristics of the test section of the A4 motorway

A section of the motorway A4 between the villages of Jaźwin and Góra Motyczna with the length of 10.506 km was used to conduct the analysis for the purposes of this article. This section runs through the following villages: Jaźwiny, Róża, Borowa, Wola Wielka and Góra Motyczna, located in the Dębica District, Podkarpackie Voivodship Figure 1.

Properly routed motorway, should run along the borders of the village and in possibly the greatest distance from larger clusters of buildings. Such a course of the motorway makes it possible to limit to a large extent the growth of the agricultural transport caused by cutting off the land from habitats. The above requirements are largely met for the analyzed area. The investment bypasses the main settlement centers of the village within a considerable distance and avoids the larger belts of compact buildings. The studied section of the designed A4 motorway crosses 44 roads, 5 of which have been equipped with overpasses. The motorway overpasses are distant from each other by an average of 2101 meters. This distance is one of the initial parameters used to assess the impact of the motorway on increase of the agricultural transport.

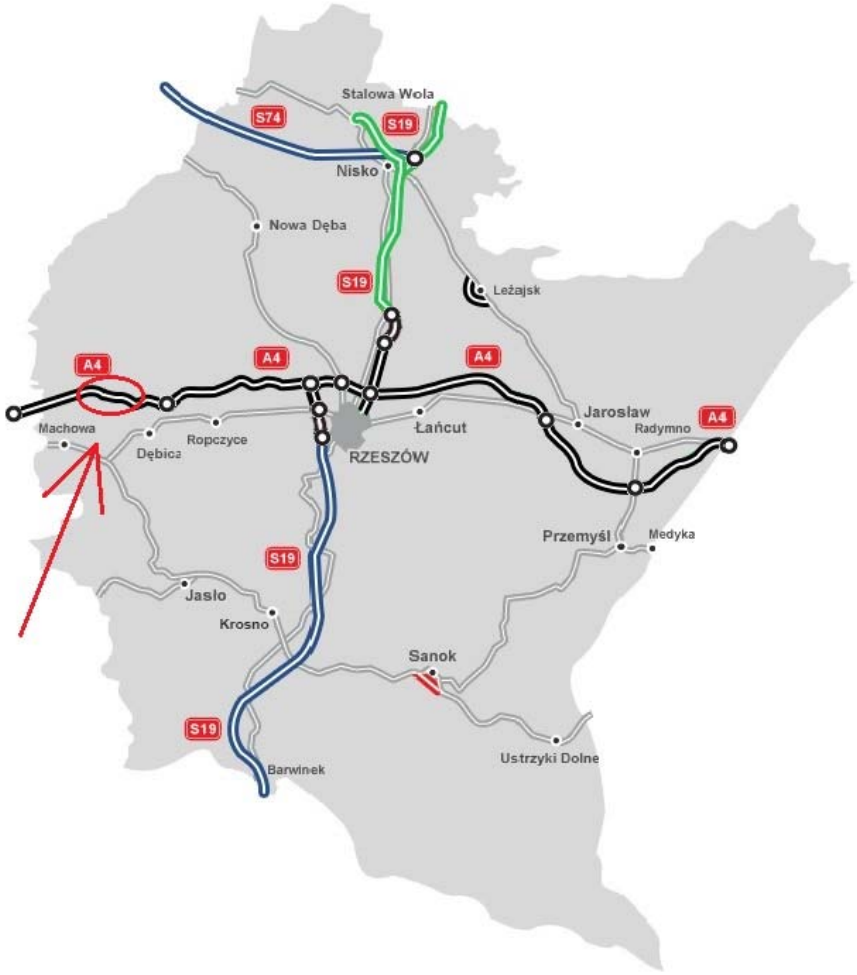

Figure 1. Location of the analyzed A4 motorway section (http://www.gddkia.gov.pl)

In the alternative version of the same motorway section, 5 overpasses were also designed, however, for other roads. The average distance between them is identical as in the case of existing overpasses in the initial version of the motorway and it is equal 2101 meters.

While analyzing the impact of the tested motorway section on agricultural land, it was assumed, that the width of the motorway lane is close to the maximum and is equal 70 meters. The adoption of such an assumption makes it possible to estimate the relatively high costs of the purchase of a wide motorway lane Figure 2.

In the case of the tested section there are no protective green belts, which are usually about 30 meters on each side of the motorway.

3. Reduction of the value of agricultural land as a result of the motorway construction

Tables 1 and 2 below show the reduction in the value of agricultural land in connection with the construction of the examined section of the motorway, divided into four considered directions of its impact on the section under study. The obtained values reflect changes in the unit value of land, as well as the corresponding land surfaces under a given direction, due to the motorway's impact.

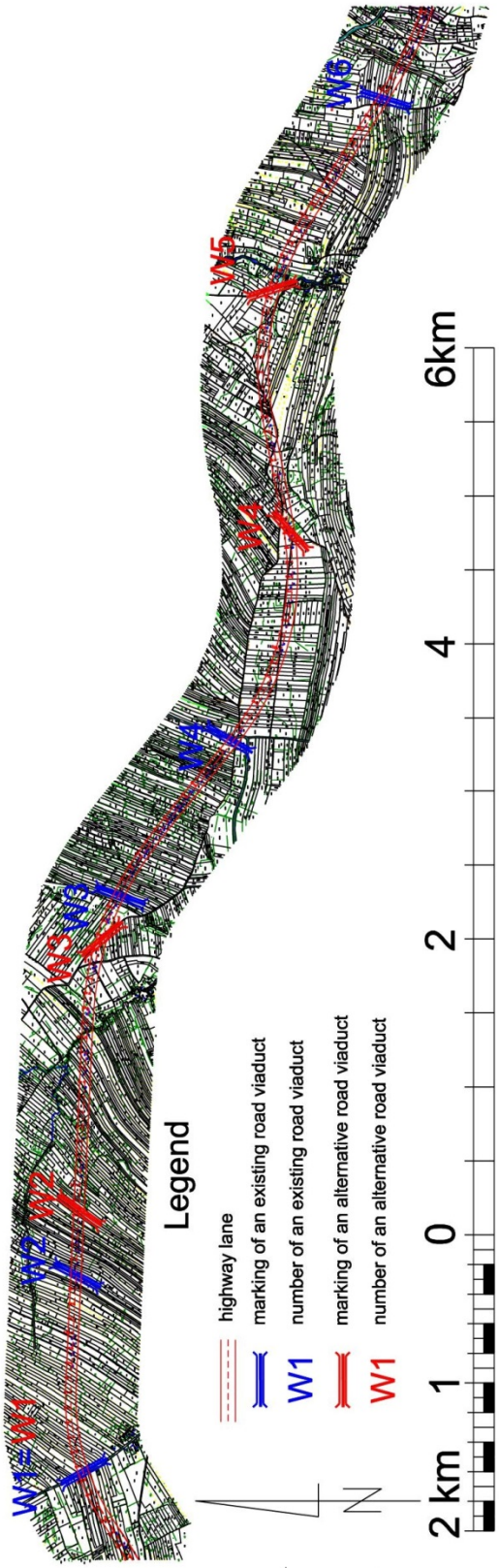

Figure 2. Location of the section together with viaducts on the registry map (own elaboration)

Table 1. The reduction in the value of land caused by the construction of the motorway for the existing section (own elaboration)

No	The reason for the decrease in the value of land	The value of one hectare of land [cereal unit/ha]		The area covered by the change [ha]	Reduction of income value				
		before the change	after the change		In the village [cereal unit]	Struct [%]	Per kilometer of motorway [cereal unit/ha]	Per kilometer of motorway section going through agricultural land [cereal unit/ha]	Struct [%]
1	The takeover of land for the construction motorway	119.43	-	68.08	8131.2	100.0	774.0	813.7	38.4
2	Deterioration in the quality of land located near the motorway	119.43	71.66	175.07	8363.5	102.9	796.1	836.9	39.5
3	The increase in distance of land from the farm due to changes in the communication system	119.43	103.06	108.26	1772.6	21.8	168.7	177.4	8.4
4	Deterioration of layout of parcels cut by the motorway lane	119.43	114.13	548.02	2904.5	35.7	276.5	290.7	13.7
Total		-	-	899.42	21171.8	260.4	2014.2	2118.7	100.0

For both cases studied, ie the existing section, and the section in the alternative version, for which different motorway overpases were designed, the value of the land taken over for the motorway construction is 813.7 cereal units / ha per kilometer of the motorway running through agricultural land. These lands are usually bought by the investor. On the basis of many carried out researches, it can be stated, that the purchase of land for the motorway construction covers only a small part of the losses, which are suffered by agricultural farms as a result of the motorway construction. However, it happens very often that the purchase price of land for motorways is 3 to 4 times higher than the average price of agricultural land [11]. In the analyzed versions, the acquisition of land for the motorway construction constitutes 38.4% of total loss of land value caused by construction of the existing motorway and 39.0% for the alternative version. A big influence on such a result has the fact that no protective green belts were made on the examined section.

Table 2. The reduction of the land value caused by the motorway construction for alternative version of existing section (own elaboration)

No	The reason for the decrease in the value of land	The value of one hectare of land [cereal unit/ha		The area covered by the change [ha]	Reduction of income value				
		before the change	after the change		In the village [cereal unit]	Struct. [%]	Per kilometer of motorway [cereal unit/ha]	Per kilometer of motorway section going through agricultural land [cereal unit/ha]]	Struct [%]
1	The takeover of land for the construction motorway	119.43	-	68.08	8131.2	100.0	774.0	813.7	39.0
2	Deterioration in the quality of land located near the motorway	119.43	71.66	175.07	8363.5	102.9	796.1	836.9	40.1
3	The increase in distance of land from the farm due to changes in the communication system	119.43	99.27	72.70	1466.0	18.0	139.5	146.7	7.0
4	Deterioration of layout of parcels cut by the motorway lane	119.43	114.13	548.02	2904.5	35.7	276.5	290.7	13.9
Total		-	-	863.87	20865.3	256.6	1986.0	2088.0	100.0

The reduction of the quality of lands located near the motorway in both cases is equal 836.9 cereal units / ha per kilometer of the motorway what includes 39.5% of the total reduction in the value of agricultural land in the existing version and 40.1% for the concept with alternative overpasses. As in the case of land acquisition for the motorway construction this percentage is very much dependent on the existence of green protective belts. Lack of the protective belts causes an increase in the area of land subjected to the negative impact of the motorway. In the first case, the total impact of land acquisition for the motorway construction and its toxic impact on land located in the immediate vicinity on the examined section is about 78% of the total motorway impact on arable land. However, in the case of the version with an alternative arrangement of overpases, this percentage is slightly larger and represents about 79% of total losses.

Deterioration of the spatial structure of villages and farms is caused by the construction of the motorway including negative changes to the layout of the parcels and an increase in their distance from the settlements. In both cases it leads to the loss of value of agricultural land by 290.7 cereal units / ha per kilometer of the motorway (this is 13.7% of its total impact on this land for the existing motorway system and 13.9% in the alternative version).

The construction of the motorway greatly affects local transport. It cuts many roads and causes the land to be cut off from the settlements, what increases the length of access to land, and therefore, the cost of transport increases. Very often it happens that the existing access is not possible, and the new one takes place by a circular route. Most often, new access roads run along the motorway lane to the nearest overpass. In this case, the extension of the access to the land is about half the distance between roads with overpasses. [10]

In the case of a reduction in the value of agricultural land due to the increase in the distance caused by their being cut off from the settlements by the motorway belt, the values for the researched concepts differ. The reduction in the value of agricultural land caused by this direction of motorway impact is 177.4 cereal units / ha per kilometer of the motorway (this is 8.4% of the total losses related to the investment). However, in the alternative version, where the same number of overpasses was designed but on other roads the decrease in value is much smaller and amounts to 146.7 cereal units / ha per kilometer of the motorway representing 7.0% of total losses.

4. Conclusions

A simplified method of motorway impact assessment presented in this paper includes all the most important directions of the motorway's impact on agricultural land and it shows this impact in a measurable way and in comparable units. A very big advantage of the method used is a low labor consumption, this is due to the fact that many simplifications have been introduced in this method concerning assessment of the motorway's impact, which to a large extent limit the scope of obtaining the initial data necessary to analyze the course of the motorway axis. The automation of calculations has also a large impact using computer software [1].

A simplified method of motorway impact assessment can be used especially during the preliminary estimation of the motorway construction impact on agricultural land still being made while making decisions about the motorway's course and in the assessment of various considered variants of the course of the planned sections of the motorway [4].

The study of two versions of the motorway that have the same course, but different arrangement of motorway overpasses aims to illustrate the usefulness of this method when considering various possible variants of designing this investment and what influence on the decrease in the value of agricultural production has the location of the overpasses on the motorway. The reduction in the value of land caused by the construction of the motorway on the existing section is 2118.7 cereal units / ha per kilometer of the motorway section, while in the alternative version with the modified overpasses layout it is 2088.0 cereal units / ha per kilometer of the motorway section. This difference is caused by different values of the decrease in value associated with increase in the distance of land from the settlement due to changes in the transport system, which is more advantageous for an alternative motorway concept.

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