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Influence of the intelligent transport systems reliability on the use of the road network

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ABSTRACT
The Intelligent Transport Systems used in the public transport can be described in a following manner: it is a collection of properly designed complex devices, which create island systems, followed by their integration that creates one, centrally managed traffic control system in the whole road, or city area. Authors will present here information regarding the usability of the above mentioned systems for the interested parties. Reliability is an important factor in such systems, as the ITS that consist of many complex objects must be characterized by low level of errors. The utility value of the ITS drops significantly in case of large damages intensity in devices that are part of the system. Deliberations presented here are based on experiences with installation and exploitation of the ITS at class A and S roads.

KEYWORDS: usability, reliability, ITS

1. Introduction

Currently, more and more often, the adjective "intelligent" is used in regard to different spheres of our life. In the sector of transport, as well as in its infrastructure, one can define an intelligent transport system, and many of its intelligent subsystems. Practically each bigger city implements traffic control centres, which create traffic system an intelligent one. They erupt in order to improve safety, and the process of traffic participants transportation , who are an important segment of the interested parties here.

Intelligent Transport System is a very broad term. However, it can be defined in the context of the intelligent transport system definition, provided in the Act (Act of 27 July 2012, amending the act regarding the public roads, art. 4, point 33) that states: systems using information and communication technologies in the road transport area, covering infrastructure, vehicles and their users, as well as the traffic, and mobility management, and to interfaces with other forms of transport. In regard to the article thesis, ITS used in traffic transport can be described in a following manner: it is a set of properly designed complex devices, which create island systems, followed by their integration that creates one, centrally administered traffic control system in the area of the whole road or city. Such island systems can be created by: the meteorological system, variable message sign, travel time prediction system, dynamic information system for commuters, toll collection system, pre-selective weigh in motion system, and many more. Road systems designed in such manner are part of a bigger system, which can be, e.g. intelligent city, or intelligent road. The ITS task is to first of all improve safety for the traffic participants by having an impact on the traffic dynamic and influencing their behaviour. Dynamic and reliable transfer of information about threats ahead, and the receiver of such information by the road user with a proper advance give time for an effective reaction thus allowing change in behaviour.

Poland negotiated for the years 2014-2020 82,5 m EUR, according to the Partnership Agreement funds are going to be invested in those areas that will benefit in Poland's development the most. Among them one can find: increase of the economy competitiveness, improvement of the states social and territorial cohesion and increase of the state's efficiency. The most of the gained funds Poland intends to allot to the investments connected with the road and railway infrastructure, and the ITS fit in those areas. Due to the important role that already existing ITS play, and number of their implementations in the following years will be only rising, their reliability and its influence on the utility value for the interested parties will be an important factor.

2. Current views on the road infrastructure usability and utility value

Value is the basic category when it comes to deliberation in axiology, it means everything that is valuable, desirable, what is a goal of human actions. Axiology, as a general value theory, takes interest in:

- an analysis of the nature of the value, so the issue of what is value, what is it's character,
- searching for the sources and mechanisms of creating values,
- the basics and criteria of evaluation,
- classifying and building their hierarchy,
- their ontological status, relations with other beings, the ways of meeting them and implementing.

In the more narrow meaning, axiology is a detailed theory of values that is a part of the individual scientific disciplines that take part in deliberation about the particular values. Parallel to deliberation about the values conducted by the philosophers, economy used a price category, and identified the value with it. Two clear stands could be noticed in the history of economic though: objective, and subjective values. To simplify the problem one can say that economists like Karol Marks or Adam Smith, who are the supporters of objective understanding of the value, will look for it in the costs that are generated to create a merchandise, and in case of the ITS, costs needed for the design, implementation and start-up. Objective theory representatives when assign the producer the right to set goods value according to the production cost, pay attention only to the intake side of the market. The attempt to connect the objective and subjective understanding of the value concept was done by A. Marshall, who formulated a synthetic theory of the value. He pointed out that the value and price influence both demand and intake on the market. A good has value, because it contains production cost taken by the manufacturer, as well as it is useful for the consumer.

Utility value involve inseparably with the goods category and is one of the basic features. The merchandise utility value is the entirety of the physical and chemical properties, thanks to which it can fulfil a certain demand. The utility value means that the merchandise, service, or the ITS is able to fulfil human needs. Utility value is examined in the context of its connection with the concept of quality, by which we can also understand reliability. Utility value is the goods ability to fulfil consumption needs, whereas the quality is treated as a degree in which the given utility value can fulfil a certain need. Therefore, quality and reliability are, somewhat, a gauge of the goods usefulness.

This article presents a safe and effective traffic transport system as such good. The article presents correlation between two types of values, the first is the investment's book value with the special emphasis on the proportion between investment costs of the construction and costs of equipping the road in intelligent devices. Reliability of the devices installed as a part of the ITS is an important factor of these costs, which influence further costs connected with their later exploitation and maintenance. The second type of value will be the utility value understood as an effect of goals implementation by the intelligent transport systems that are the utility value for the particular traffic participant . These goals can be: increasing the street network capacity, lowering the amount of time lost in the street network, increase of traffic safety (lowering the number of accidents), increase of the emergency services effectiveness, and the influence on the environment.

Investment in Chorzów can be seen as one of the examples reflecting the influence of the intelligent transport systems on the growth of utility value of the road infrastructure. Table 1 depicts the cost structure distribution connected with the implementation of the Intelligent Traffic Management on the Drogowa Trasa Średnicowa (the central highway) in Chorzów. The overall cost of investment completed by the Miejski Zarząd Ulic i Mostów in Chorzów (Municipal Board of Streets and Bridges in Chorzów) was 1.3 m PLN. the whole traffic management system consists of such island systems as: variable message signs, meteorological cover system, video surveillance system, section speed measurement system. Reports of the particular systems share of costs to the overall ITS worth was also presented in Table 1.

Table 1. Percentage share structure of the particular island system in the overall investment costs [own study]

Type of works	Percentage share of particular island systems in the overall system worth
Creating the fiber Optic network	28%
Creating the supply connections	16%
Delivery and installation of 4 high speed dome cameras for surveillance, and four automatic number plate recognition systems	12%
Delivery and installation of meteorological traffic system	3%
Delivery and installation of 3 variable message signs	12%
Delivery and mounting of supporting structures for the variable message signs and cameras	22%
Delivery and installation of the work stations with software for the system operator	5%
Project documentation	2%

Implemented system, through the variable message signs integration with the video surveillance, gives drivers information about the situation on the road, possible hold-ups caused by accidents, or other incidents on road. Such information given in a readable and understandable way, as well as with a proper advance will contribute to measurable economic and social benefits. Savings can be e.g. lower fuel consumption and saving time by avoiding the road block, which could lead to lowering the stress level among traffic participants, and consequently can lead to increase the safety on road. Software is a very important element of implemented system. Such software integrates all island systems and through a dedicated user interface, presented in Fig. 1, enables steering and control of the current road situation.

The value of the workload incurred to implement this task in regard to the goals realized by this system (the utility value) is disproportionately low. The central highway is a very important element of the Silesian communication system , where the daily traffic intensity exceeds 50 thousand vehicles. The three lane per direction road is treated by drivers as a highway, although the speed limit is 100 km/h. Small distances between the hubs, and existing exits to malls cause often manoeuvres of joining and leaving traffic generate many dangerous situations and result higher number of accidents. Each traffic incident, such as closing the tunnel located several kilometres ahead, construction works, or an accident causes traffic jams that last for kilometres not only on a highway, but also several kilometres from it. Changing weather conditions also result in an increase of collisions and accidents. Taking into consideration all the above information about the priority of this road in the Silesian agglomeration traffic system, a thesis can be formulated that the increase of the central highway utility value that was changed into intelligent road is qualitatively bigger, than the investment book value of the ITS would suggest. One of the easier methods of proving this thesis is calculating the factor on the basis of dividing the whole value of the investment by the daily traffic on the section covered by the system. Daily traffic is 50,000 vehicle, which gives about 18 m of vehicles per year. The whole investment cost was 1.3 m PLN, which gives 26 PLN per traffic participant per day, and less than 0,10 PLN per year. What may seem interesting is the reference of costs related to the ITS construction per one Chorzów citizen. System construction cost per one citizen was around 18 PLN (assuming 85% of financing from the European Union and 112 thousand of citizens).

Fig. 1. Example of the software that controls work of all island systems implemented in the central highway in Chorzów [own study]

Taking into consideration the two exemplary indexes, the cost of constructing the ITS attributed per capita and the construction cost per vehicle, one can say that these values are negligible in comparison to the road utility value growth for the traffic participants. One of important reference points while testing the utility value that comes from the ITS installation is comparing its book value to the book value connected with the road construction. The dependency described above is depicted at Fig. 2.

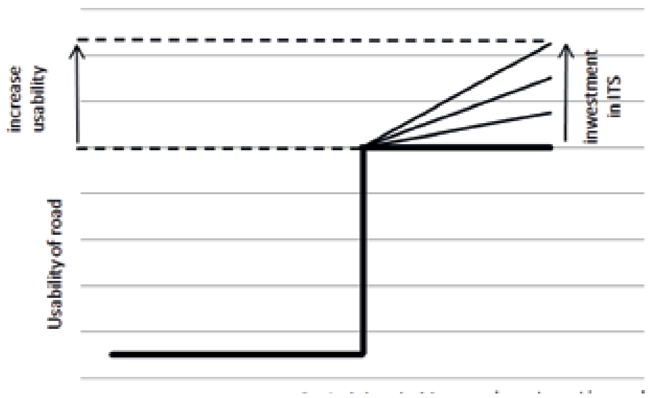

Fig. 2. Example of the investments connected with constructing a road infrastructure and equipping it in the intelligent traffic management system, along with their influence on the utility value [own study]

Fig. 2 shows the dependence of installed systems utility in relation to the construction costs of a new road section. Axis of ordinates contains road usability, whereas the abscissa axis represents cash outlay colligated with expansion of infrastructure. Figure shows that until reaching the point called expenditure threshold the road utility is zero. Such dependency happens when a completely new road section is being created, because until it is commissioned (expenditure threshold), utility for the traffic participants is zero. Utility has a zero value for the obvious fact of inability to use it, while expenditures on the construction rise. Only when it is opened the participant benefits from it, and that creates a rapid growth if usability. Next, if the road is equipped in an ITS, its utility value rises disproportionately to the expenditures connected to the system implementation. Such course of the chart results from the very low participation of the costs connected with the ITS investments in comparison to the benefits generated by such installations. Reliability is very important factor that should accompany the installed ITS.

3. Reliability of the intelligent transport systems and its influence on the utility value for the interested parties

Dynamic development of investments in the intelligent transport systems in the direct human surrounding, as well as increasing level of dependency on the broadly understood "intelligence" make the actions concerning increase of the of the ITS devices effectiveness more and more important. Each of the installed devices should work reliably, and possible damages should not imply after-effects that are dangerous for the traffic participant and the surroundings. Installed ITS and their proper functioning has with no doubt influence on our safety, and sometimes even life. The ITS reliability can be described as the probability of an incident which lies in the fact that the system used in certain conditions will maintain abilities to fulfil the given requirements in the given interval of use. Time reliability is also interpreted as the quality stretched in time - "reliable quality". However, quality is a superior value, because the high reliability does not guarantee a high level of quality. Definition of safety reliability in the context of the ITS is also worth mentioning. Safety reliability is a characteristic described as not occurring damages that create danger in safety or cause accidents, in which there can occur health deterioration, disability, or loss of life. Programmes about safety focus on methods of avoiding accidents, preventing people injuries inside and outside the vehicle, as well as product reliability and assurance that people and merchandise are safe.

Main interfaces of intelligent transport systems for traffic participants are Variable Message Signs (VMS). Therefore their quality and reliability should be at the top level, as these parameters reflect directly in safety. In 2013 Poland implemented into the legal system the European Parliament and Council directive 2010/40/UE from 7 July 2010 in regard to the intelligent transport systems framework in the traffic transport area and other kinds of transportation. The appointed provisions were published in the journal of Laws, 25 February 2013, pos. 260, and enclose four priority areas. The bill is the basic set of provisions allowing implementation of the Intelligent Transport Systems in Poland. However, in the set of formal rules there are still missing implementing rules, especially rules regulating principles of using variable message signs, which so far are one of the main medium of conveying important messages for the traffic participants. Lack of rules, unambiguously translates into quality of the tenders regarding the ITS implementation. Effects of a gap in our states regulations can be observed in Fig. 3.

Fig. 3. Examples of unreadable information on a variable message signs [own study]

Terms of reference (SIWZ) prepared by the officials do not contain enough formal-legal requirements in order to provide reliability and safety of the implemented systems. The second element influencing what is installed on road for the traffic participants is the criterion of choosing the tender offer by the lowest price. The two examples given above are the reason we can see on our roads "innovative" traffic management systems presented on Fig. 3. Savings gained from preferring on our market systems of low quality and reliability are only apparent. Necessary maintenance actions taken in order to "patch" the low quality systems are very time consuming, which results in high system exploitation costs. The book value of the ITS elements is so high (Table 1) that any savings on the materials completely unreasonable. Fig. 4 presents one of the examples of "apparent" savings on materials.

Fig. 4. Example of connecting GSM modem and other devices in a variable message sign to a power strip for domestic use [own study]

Arguments about the necessity of optimizing costs due to the choosing the lowest price offer even in this case seems unfounded , because of the symbolic worth of the extension cord in comparison to the value of the whole investment in the ITS. It is almost certain that installing replacements that are not suitable for industrial exploitation will result in impairing the whole ITS and cause meaningless lowering of the road usability (Fig. 5).

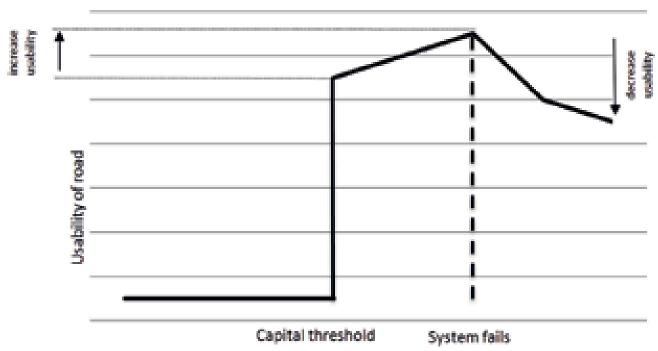

Fig. 5. Example of investments connected with the construction of the road infrastructure and equipping it in the intelligent traffic management system of low reliability and their influence on the utility value [own study]

Fig. 5 shows dependency connected with implementation of the low quality ITS. The initial utility value increase for a road equipped in such system is temporary. Point on the abscissa axis "system malfunction" represents the moment when the installed system malfunctions. This consequently leads to lowering the road utility value at least to the level of a road not equipped in such system. In extreme situations of system malfunctions, such as presented on Fig. 3, the road usability may drop even below the point reached when the road was opened, because the messages displayed by the devices mislead traffic participants. Psychological impact, associated with wasting the money, in most cases public, is also important in case of seeing the defective ITS by the users, as it clearly lowers the level of traffic safety.

4. Conclusion

Intelligent transport systems play more and more important role in our everyday life. In the age of continuous rush and searching for the most optimal solutions for increasing our movement, ITS seem to be perfect. These systems are to serve us by supplying us with relevant information. Through their installation the existing road infrastructure has a completely new character, and it's usability for traffic participants significantly increases. However, ITS must characterize themselves with high reliability , due to their role and the direct influence on safety. One should consider, how the behaviour of choosing the cheapest contractors and ITS elements, briefly described in this article, could be suppressed. Such savings directly and drastically lower the utility of whole intelligent traffic management systems, and indirectly lower the traffic safety of the upset users.

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