Improvement of the quality of the geodesic support for the reconstruction of the roads

V O Penkov ¹, O O Skoryk², O M Uzviieva³, V Yu Panchenko⁴ and Ye M Korostelov⁵, ⁶

¹Department of land administration and geoinformation systems, O.M. Beketov National University of Urban Economy, , st. Marshal Bazhanov, 17, 61002, Kharkiv, Ukraine
²Department of track and track facilities, Ukrainian State University of Railway Transport, Feierbakh sq., 7, 61050, Kharkiv, Ukraine
³Department of researches and design of means of communication, geodesy and land management, Ukrainian State University of Railway Transport, Feierbakh Square, 7, 61050, Kharkiv, Ukraine
⁴Department of management of daily activities, National Academy of National Guard of Ukraine, Scientific Zakhysnykiv Ukrainy sq., 3, 61001, Kharkiv, Ukraine
⁵Department of researches and design of means of communication, geodesy and land management, Ukrainian State University of Railway Transport, Feierbakh sq., 7, 61050, Kharkiv, Ukraine
⁶Corresponding author kostya_90_@ukr.net

Abstract. Further development of the roadway network in Ukraine will basically take place by modernization, which, in fact, conversion of the system «Road Conditions-Traffic Flow-Environment» from one state to another. Generally, it changes not only the spatial axle position of an existing road, but also the geometric and technological parameters of the road. Modern technological design and construction processes demand higher accuracy and reliability in determining the output spatial parameters measured with survey methods and techniques. Therefore, substantiated higher accuracies and improved survey techniques are tasks of primary importance. They must be solved on the basis of determination of rational error limits in survey works and their influence on the accuracy of building, transport operational and economical parameters of the project and actual engineering structures. The objective of the study is to demonstrate possibilities and efficiency in using various models of the system of ensuring the accuracy in survey works for roadway modernization and for solving other tasks on determination of geometric element parameters of complicated sections on existing roadways.

1. Introduction
A demand for working out survey methods is conditioned by sustainable development and improvement of technological processes in design, construction and modernization of objects of various purposes including road facilities. But some regulations on survey support in construction works are out-dated and require an immediate update [1, 2].
The problem of a substantiated update of requirements for accuracy, and improved methods for survey works is important and urgent. It can be solved on the basis of determination of rational error limits in survey works and their effects for accuracy of building, transport operational and economical parameters of the project and actual engineering structures.

While determining requirements for accuracy in survey works, the system of construction tolerances, i.e. admissible deviations in geometrical parameters, are used. They, in turn, are established on the basis of deviations in the output parameter of the system under survey analysis. The analysis of requirements for survey accuracy in road engineering demonstrates a strong tendency to consider a wider range of various factors. In order to provide an optimal quality level of survey works, there is a need for timely and substantiated update of standards on accuracy and methods and techniques to ensure this quality. These alterations are inevitable and conditioned by a sustainable quality standard growth in road engineering [1 - 3].

A special survey technology used in modernization of roadways in mining regions on territories which are under survey works is conditioned by two factors; they require to consider this technology as specific [1]. One factor is constructional, the other – mine technical or geodynamic. Besides, there is a need to consider one more factor – a level of logistical and economic support for engineering survey works.

2. The analysis of studies and publications

At present an accuracy level of up-to-date measuring instruments is considerably higher than the accuracy level required for road engineering and construction. But, in fact, the economic efficiency is substantial and decisive issue for engineering survey before modernization. The research conducted demonstrated that even with innovative equipment, land survey quality in terms of accuracy and informative value is limited by other factors of technological and organizational nature typical for road engineering. Thus, detail and accuracy in a topographical model determine and limit errors in generalization of profile and limited graphic accuracy [2].

A construction factor is determined by a specific character of design and engineering survey and construction works for roadways subject to modernization. Survey works in road engineering must provide an optimal completeness, accuracy and validity of support for the system “Roadway” at various production stages. The requirements for survey operation quality include also both internal factors (related to special features of roadways), and external factors (related to the environment).

Each stage of modernization requires specific information, in terms of volume and content, on locality, spatial position of the roadway and its elements. Survey operation works in roadway modernization include receiving, submitting and processing quantitative information within a system. The state analysis of a roadway in both construction and survey is made on the basis of geodetic information of various kinds. The targeted processing and user-friendly presentation of the information make it possible to design and implement situational and environmental patterns.

General rules for designing, conducting and accepting land survey works, needed in construction, modernization, refurbishment of construction objects of any purpose are given in [4], but all current normative documents regulating geodetic accuracy have certain features [1]. At present the geodetic accuracy is frequently achieved not by the accuracy of instruments applied (it can be rather high), but by special characteristics of state and form of the object under measurement, especially under modernization. The main drawback of current normative documents regulating the geodetic accuracy is establishing norms for geometry accuracy of the structure only through experience and data on geometry of the structure [1]. It requires the use of special methods of measurements and determination of their rational accuracy.

3. The basic part

One of the quality conditions in modernization is the maximum use of an existing roadway. While establishing the geodetic accuracy, it is reasonable, first of all, to consider requirements for accuracy
for sections of irregular configurations. And the fiducial value was a deviation of the roadway axle for the modified roadway from that of the existing one in the middle of complicated sections. Update of the roadway included a repeated marking of a roadway section into geometric elements, the numerical values being measured on the existing roadway.

Parameters of the geometric elements of existing roadways differed from parameters of design roadways due to various reasons. Therefore, roadway update was complicated because of a need to determine the actual parameters of geometric elements of the existing roadway. In order to determine elements of a new marking it was necessary to know parameters of geometric elements with the accuracy which provided the marking accuracy accepted in new construction rules [5].

Substantiated requirements for accuracy of parameters for complicated sections indicated the accuracy of needed additional measurements and set the appropriate ways to solve the problem in a given conditions with reasonable consideration of requirements for geometry generation. The accuracy of these measurements was determined on the base of the principle of equal effects and the coefficient of minor impact.

The condition of the maximum possible use of an existing roadway requires not only the information generally used in designing a new roadway, but also more detail information about the existing one. In Ukraine roadway modernization is characterized by relatively short sections (10-12 km at the average) under modernization with corresponding scopes of work. It considerably limits a possibility to effectively apply air survey and other technologies requiring highly productive methods and costly instruments (e.g. laser scanners). The existing roadways presumably run through habitable territories with developed infrastructure. Therefore, each considerable alteration in the roadway, which can break the economic activity on the adjacent territory has to be thoroughly studied and substantiated, thus, it can require individual approaches in terms of work organization.

Frequently, surveying works for modernization run without the initial design and executive documentation, therefore refurbishment and determination of the actual position and the values of geometric parameters of the roadway are conducted on the basis of in-situ measurements. And quality, volume and content of survey information have to be adequate for reliable description of the existing roadway; it must be used in estimation of the qualitative state and acceptance of optimal and consistent design solutions. Special features of the right-of-way, such as development, high and dense vegetation, productive farmlands, and also alterations of links in the geodesic networks (elimination, loss of visibility, appearance of new ones) decrease the efficiency, complicate or eliminate the possibility to use traditional measuring methods and techniques. Another important feature of survey works in modernization is a need to provide safety under intensive traffic; it requires lower number of workers and shorter periods of their work on the site [6].

According to the conditions, surveying works for modernization can be made by various technological diagrams but in any case performance and quality criteria are completeness, accuracy and validity of information, terms and cost of the works [4, 7]. As far as all criteria are interconnected, special studies are needed for determination of their optimal values.

Thus, under modernization, there is a combination of special features and requirements which differ it from new construction and require solutions to additional problems.
- substantiation of requirements for accuracy and volume of survey works;
- development and improvement of working methods;
- substantiation and determination of rational conditions for application of various instruments and technological surveying diagrams in terms of economic efficiency and actual recourses for material and technical support [8-10];
- maintenance of a needed level of working safety.

Substantiated update of accuracy and improved methods of survey works must be based on determination of rational impact of survey error limits on the accuracy of building, transport operational and economic parameters of the project and the actual engineering structure.
In order to establish optimal requirements for surveying accuracy in all life cycles of the roadway, the authors suggest alterations in requirements for surveying accuracy through changes in accuracy standards for geometric parameters on the basis of the system approach. It implies consideration of actual intersystem and inter-element links within the system «Driver-Car-Roadway-Environment» in the optimal volume for modernization.

The following factors were taken into account depending on a construction stage: requirements for technical and economic assessment; accuracy of determination of geometric parameters in design calculations, influence of alterations on the traffic speed and accuracy of determination of costs and volumes earthworks; a need for complete use of the existing roadway.

The concept aimed at revision of requirements for survey accuracy and techniques is the basis of accuracy monitoring for rational operation of the survey information system in construction.

The authors developed several models of the system of ensuring the survey accuracy to consider special features of various stages of roadway technologies in modernization. The general strategy for substantiation of admissible error limits in geometric parameters: the total rational impact of alterations in geometric parameters on the total change of the output performance factor of a higher level must be rationally low in comparison with the total impact on similar error limits for non-geometric parameters. The error limits at which a target function reaches the maximum value at given resources were considered rational.

With a higher level of roadway engineering and more complicated survey methods and techniques, optimal survey accuracy changes and, therefore, there appears a need to revise and update requirements for survey accuracy.

On the basis of the concept the authors designed models of the system of ensuring the accuracy within subsystems of substantiation of admissible deflections in geometric parameters, which were used for substantiation of the accuracy of geodesic works in the subsystem of accuracy of geodesic works. Different stages in roadway construction require different quality standards on the basis of the model «Driver-Car-Roadway-Environment». A change in the system level changes the role and value of geometric parameters from a system level to the element level. It is conditioned by the fact that new parameters are considered in the system, and their impact on the output factors of the system «Driver-Car-Roadway-Environment» corresponds to the impact of the system “Geometric Parameters” and exceeds it.

The use of proposed notions on the system state and corresponding to them the models «Driver-Car-Roadway-Environment» and deviations in geometric parameters will promote the input of the error limits of the geometric parameters according to the corrected requirements. Design of models and the structure «Driver-Car-Roadway-Environment» and its subsystems «Roadway», «Geometric Parameters» are conducted by multiple reviews of conditions, requirements and solutions, but each time at a new, higher quality, or organizational level. The models for the accuracy system proposed correspond to various quality states of the super-system «Driver-Car-Roadway-Environment», its subsystems and elements which consider structural features of modernized roadways, special building technologies, traffic conditions, a need to determine parameters of the existing roadway and its full use.

As an output parameter of the system «Driver-Car-Roadway-Environment» the authors took the total charges, values of admissible deviations of geometric parameters in the technical project, traffic speed, normative error limits from the State Constructive Norms accepted in Ukraine, which determine the accuracy of earthwork and roadway carpet generation. The highest accuracy is required for provision of an admissible displacement of the middle lines of curves relative to the existing road axle, after marking the curve by elements determined in the survey.

Surveying roadways at all stages, especially at final ones, for modernization is to be fulfilled with higher accuracy than that under new construction. The accuracy of certain survey measurements greatly depends on how shaping lines correspond to the design position, quality of generating the existing road and geometry of measurements.
4. Conclusions
In the models studied the survey accuracy for modernization was established on the basis of analysis
and generalized admissible deviations for certain geometric elements. The approach proposed makes it
possible to specify requirements for accuracy in the geometric elements complex and set the survey
accuracy with consideration of form and state of the structure, it can be used for solving practical and
research problems. The models of the system ensuring the accuracy can be applied for determination
and update of requirements for the survey accuracy in various technological survey diagrams and other
tasks on determination of geometric parameters of existing roadways.

5. References
[1] O V Adamenko 2014 The current state of normalization of the accuracy of geodetic works during
the construction of engineering structures. Engineering geodesy (Kiev: Scientific-technical.
collection 60 p. 6-11
[2] R A Demyanenko, M V Kovalev 2014 The analysis of the accuracy of geodetic marking works in
the construction of buildings and structures (Kiev: Scientific-technical. Collection) 52 p. 76-
84
[3] V A Penkov 2015 On the development of urban streets and roads research in man-made territories
(Kiev: Scientific-technical. collection) 58 p. 436-442
[4] System for ensuring the accuracy of geometric parameters in construction. Geodetic works in
construction (Kiev: Minregionstroy of Ukraine, 2010) p. 70
[5] A A Beliatynsyi, V A Penkov 1989 Features substantiating the accuracy of surveys in the
reconstruction of roads (Kiev: KGTBA) 32 p. 24-28
[6] O A Biliatynsyi, V P Starovoida 2003 Design of major repair and reconstruction of roads (Kyiv:
Higher Education) p. 343
[7] V O Penkov 2013 Features of ensuring the sustainable functioning of counterfeit streets and roads
(Kiev: Scientific-technical. collection) 9 p. 239
[8] V A Penkov 2014 Principles of ensuring the accuracy of geodetic works in the reconstruction of
highways (Kiev: Scientific-technical. collection) 53 p. 387-391
[9] V A Penkov 2015 Taking into account the parameters of the functioning of the system in
substantiation of the accuracy of geodetic works (Kiev: Scientific-technical. collection) 57.
p. 366-372
[10] V A Penkov 2016 Consideration of conditions of formation at substantiation of accuracy of
geodetic works (Kiev: Scientific-technical. collection) 62 p. 477 – 482