natural and technical systems, railway,
exogenous processes, sandy deserts, sand drifts

Makhamadjan MIRAKHMEDOV
Tashkent Institute of Railway Transport Engineers
Adylkhodjaev str. 1, Tashkent, Uzbekistan
Corresponding author. E-mail: mirakhmedovm@mail.ru

ORGANIZATION ACTIVITIES FOR PROTECTION OF THE RAILWAY FROM EXOGENOUS PROCESSES

Summary. The paper focuses on the reduction of negative effects on the railway exogenous processes (sand bars, landslides, etc.). Proposed to introduce a system of design, construction and operation of natural and technical objects set of organizational and technical measures, consisting of techniques: the choice of method, to map the distribution of exogenous events, the development of a program of measures for the protection and the optimization of the work program, assess the quality and effectiveness. Methodological elements are developed by the author of the complex method of risk assessment exogenous expression and scale of priorities of road elements of the defense.

ОРГАНИЗАЦИОННЫЕ МЕРОПРИЯТИЯ ДЛЯ ЗАЩИТЫ ЖЕЛЕЗНЫХ ДОРОГ ОТ ЭКЗОГЕННЫХ ПРОЦЕССОВ

Аннотация. Статья посвящена вопросам снижения негативного воздействия на железнодорожный путь экзогенных процессов (песчаные заносы, оползни, обвалы и др.). Для этого предлагается ввести в систему проектирования, строительства и эксплуатации природно-технических объектов комплекс организационно-технологических мероприятий, реализуемых в следующей логической последовательности: составление карты распространения экзогенного явления; выбор способов защиты; разработка программы реализации защитных мероприятий, ее оптимизация; оценка качества и результативности работ. Методологическими элементами комплекса являются разработанные автором методики оценки опасности экзогенного проявления и приоритетов элементов дороги на защиту.

Natural and technical systems (NTS), for example, railways, roads, pipelines are under constant threat of negative impact on them exogenous processes (physical and geological phenomena) [1-4]. Common to exogenous processes is weathering, which has various manifestations. In the sandy desert it is a deflation - moving and sorting of sand by the wind [5-11]. Sandy flow encountering obstacles in its path under certain conditions, seek to destroy them, which leads to blowing of roadbed of railways and roads [12]. Obstacles in turn change the flow parameters of sandy flow and primarily its speed. Reduced speed below a certain limit results in the deposition of sand stream [13], which leads to drifts of NTS. In the mountains weathering leads to the formation of the monolith of boulders, stones, sand and smaller sized entities, which under certain conditions are set in motion in the direction with less than the strength of their holding, resistance, which leads to manifestations in the form of rockfalls, landslides, mudslides [14, 15]. As a result of all these manifestations of exogenous processes disrupted the normal functioning of the NTS [12-15]. Obviously, reducing the negative impact of these manifestations is one of the urgent tasks of ensuring security of land transportation. Therefore, it is required to perform specific construction activities.

Fig. 1. Problems of sand drifts
Рис. 1. Проблемы песчаных заносов

Implementation of these measures has an integrated feature, primarily works on construction of reliable protection [16, 17]. Reliability of protection provided by the choice of technological solutions appropriate to local conditions [18-20]. However, the quality of protective structures - this is only part of measures to reduce the negative impact of exogenous effect on transport facilities. Besides technological content it is also important organizational activities. Thus, reducing the negative impact of exogenous displays on transport facility - a complex of organizational and technological measures.

With this aim a comprehensive system of engineering preparation of works for protection of NTS from EP (EP PW NTS EP) [21] was developed including the following sub-systems: study of the new and replenishment of the technological solutions park; protection design through identification of the construction-technological characteristics of conditions (CTCE) and modes (CTCM) PW EP; organizational-technological preparation of works to protect NTS from EP.

Replenishment of the technological solutions park is undertaken in two stages. At the first stage, by using the express method a study is taken to identify technological feasibility of the mode, protection with the required characteristics. The positive outputs ensure sustainability of the protection to the specific load.

At the second stage the construction-technological characteristics of the mode (CTCM) are studied, standards are developed, particularly, labor and material-technical resource costs.

The width of the protection placement is identified during the designing depending on the retention of the annual exogenous deposits. With this aim the cumulative ability of the applied mode is to be identified. NTS or PC NTS protection map is a basis for the development of the monitoring-technological programs (MTP).

MTP PW EP (fig. 2) can be started upon availability of the PC NTS design.

The map of the works to protect NTS from EP is a plan with the outlines of the NTS and the operating zones detailed by the sectors, used materials, as well as the drawings of the protection facilities, scope of work with the identification of the drift extent. These data are the basis of the monitoring-technological program for the works on NTS protection form EP. The scope of work within MTP NTS EP is provided in groups. The following is used as a grouping tool:

- classification of the EP negative impacts on NTS (NTS EP CNI). For instance, in case of sand drifts this means the qualitative condition of the NTS depending on the railways condition. Sand drifts are the function of the numerous factors (speed, direction, frequency of the wind, material and height of the fill (depth of the hollow), nearby plants, materials and many others). It is pretty difficult to quantify the extent of the sand drifts. Hence the classification is given in regards to the visual assessment of the space between the rails, which can be done during the inspection of the railways (table 1);

- NTS elements priority scale for protection from EP (NTS EPPS). In case of the railways the expert method identifies 5 elements scale, depending on the NTS elements in ensuring operational security (table 2). MTP PNTS EP program is an initial sequence of protection facilities designed on MM NTS EP map.

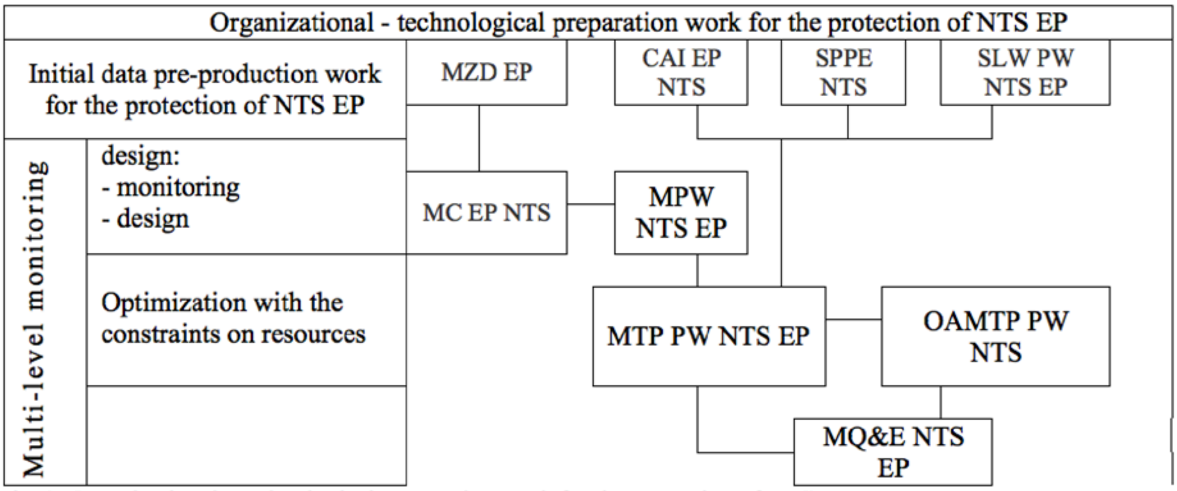


Fig. 2. Organizational - technological preparation work for the protection of NTS EP
Рис. 2. Организационно-технологическая подготовка работ по защите природно-технических систем (ПТС) от экзогенных процессов (ЭП)

EP DM - exogenous processes district map [6],
NTS EP CNI - classification of the EP negative impacts on NTS,
NTS EPPS - NTS elements protection priority scale,
LISN NTS P EP - labor inputs and salary norms for MTS protection from EP [7],
MM NTS EP - monitoring map for NTS from EP,
PWM NTS EP - protection works map for NTS from EP [1],
MTP PNTS EP - monitoring-technological program to protect NTS from EP,
OAMTP PNTS EP - optimization of the annual monitoring-technological program to protect NTS from EP,
QEM P NTS EP - monitoring the quality and effectiveness of protection NTS from EP [4].

Table 1

Classification of the drifts on the railways

Category	Upper railway condition depending on the sand drifts
I	The space between the rails is drifted by the sand, over 50 per cent of the cross-ties and rails height is covered by sand
II	In the space between the rails the rail bottom is covered by the sand, cross-ties in the middle part are dusted
III	The space between the rails is slightly dusted, the sand is not observed visually

Table 2

Railways elements protection priority scale

Priority	Characteristics of the upper railway construction element
1	Main line on the curved sections
2	Switches on the main line
3	Main lines on the straight sections
4	Switches on the other lines
5	Small artificial constructions
6	Stationery lines except the main line

The annual work program for the protection of NTS sand drifts, which presents the composition of the work after optimization can significantly reduce the total period of the works. For optimization MTP PNTS EP developed a method based on dynamic programming. As a limitation, the amount of annual funding supports work to protect NTS from EP.

The optimized PW program is the basis for the follow up scientific support to PW production, particularly for identification of the required materials (for instance, binding ones) and technical resources (machines and devices).

The important component of the PW scientific support is the product quality monitoring. The monitoring methodology provides the aggregated criterion of the PW quality, which is the *accuracy of the technological parameters* (1) [2].

$$T_M = \frac{m-\overline{M}}{\sigma^2}+R, \tag{1}$$

where: m - normative permissible variation; σ_M - standard deviation of the errors of the aggregated indices of the technological process quality; R - smoothness of the surface coverage with the bidding substance, Assessed visually (R=1 – the smoothness is achieved; R=0 – gaps are available).

Given that the quality is a set of the product characteristics which stipulate the usability, depending on its purpose, to satisfy specific needs and based on the precondition that the quality criteria are to be identified easily, and their quality is limited for more convenient application, the quality assessment methodology is developed as a complex of interrelated parameters characterizing all WCS stages (fig. 3). In this regard the *aggregated quality* criteria are identified.

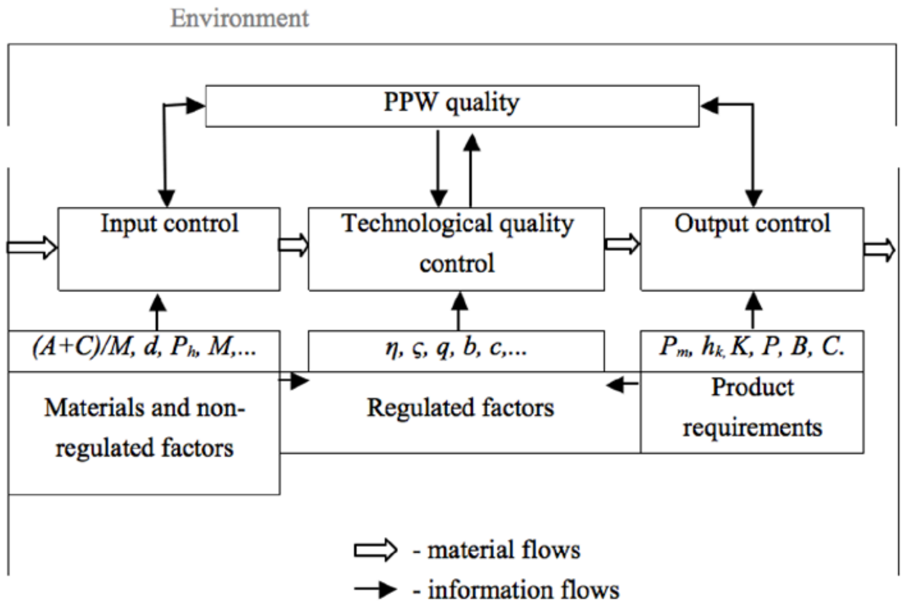


Fig. 3. Model quality control work to consolidate the sand (WCS) quality control model
Рис. 3. Модель контроля качества пескозакрепительных работ (ПЗР)

Table 3

Work accuracy

#	Rating	Accuracy
1	Satisfactory	$2 \prec T_M \leq 2,5$
2	Good	$2,5 \prec T_M \leq 3,0$
3	Excellent	$T_м \geq 3,0$

In practice the following product characteristics conform with the rating marks:

Excellent – in case the work is done with specific accuracy and skill, all the quality criteria identified by the PPW design are met, the exploitation parameters are better the initially designed while the cost of work, labor and material were not increased. Smoothness is achieved, $R = 1$.

Good – in case the work is done in line with the design, $R = 1$.

Satisfactory **–** in case the work is done with minor departures from the design but does not worsen the exploitation quality of the fixed sand cover, $R = 1$, wand in case the planned costs are increased by up to 10%. The efficiency of the set of activities on which the theory of groups is based is estimated by the *efficiency criterion* and is undertaken upon completion of a specific period of time during the nearest object inspection.

The final stage of the WCS scientific support is the methodology of *efficiency assessment*. On the contrary to the quality assessment the efficiency is assessed upon completion of a certain period of time, for instance during the nearest object inspection. Only improvement of the railway condition, assessed by the reduction of the sand drift, results in lower risks of descent and/or condition of the upper railway construction. Based on the group theory [3] the railway WCS efficiency is estimated as the following (2)

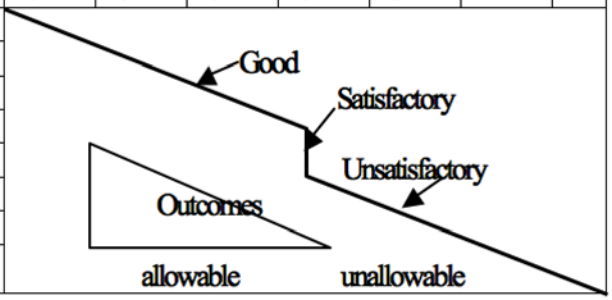
$$\alpha = \frac{\sum_{i=1}^{k} p_i \cdot n_i}{n \cdot k}, \text{ where } n_1 + n_2 + n_3 + \cdots + n_k = n \qquad (2)$$

Table 4

Assessment of the PPW efficiency

Assessment of the PPW efficiency

The year of assessment and marginal condition		Length by categories, km			Rates by categories			E_t	Efficiency $E_t \prec 0{,}33$ - good $E_t = 0{,}33 - 0{,}4$ - satisfactory $E_t \succ 0{,}4$ - unsatisfactory						
		l_{III}	l_{II}	l_I	$l_{it}/l_{iá}$										
$t_б$		300	300	300	III	II	I		0,11	0,22	0,33	0,44	0,56	0,67	
	1	-	-	-	-	-	-	0,0							
	2	300	-	-	-	-	1	0,11							
	3	-	300	-	-	1	-	0,22							
	4	-	-	300	1	-	-	0,33							
t_t	5	300	300	-	-	1	1	0,33							
	6	300	-	300	1	-	1	0,44							
	7	-	300	300	1	1	-	0,56							
	8	300	300	300	1	1	1	0,67							



The criterion identifies the ratio of the length of the section within the specific drift category in the year of estimation to the length of the section within the same category in the baseline year. The baseline is the year of the works implementation which efficiency is being estimated. For each extent of the sand drifts the following is true: $n_i = l_i = {l_i}/{l_б}$, where $i = III, II, I$ - is the drift extent. By replacing the effectiveness notion α with the efficiency criterion E_t for the terms of classification of the railways condition by three categories $k = n = 3$, given that the ratio is $p_1 \prec p_2 \prec p_3$ and, admitting that for the elementary case $p_1 = 1;\ p_2 = 2;\ p_3 = 3$, the formula (2) will be (3)

$$E_t = \frac{l_{III} + 2l_{II} + 3l_I}{nk} = \frac{\dfrac{l_{III\,t}}{l_{III\,б}} + 2\dfrac{l_{II\,t}}{l_{II\,б}} + 3\dfrac{l_{I\,t}}{l_{I\,б}}}{9}\,, \tag{3}$$

where: l_{III}, l_{II}, $l_I -$ dimensionless quantity reflecting the changes in the sand drift category in the year t, when the estimation is undertaken; l_{it}, $l_{iб}$ $-$ respectively the length of the sections by categories in the estimation year and the baseline year.

Generalization of the above leads to the following conclusions:

1. The complex organizational and technological system that allows to reduce the negative impact of the manifestations of exogenous processes on railways and roads, consisting of research, design and production subsystems and including a number of techniques used in the mutual communication at different stages of addressing the protection and safety conditions of construction and operation of natural technical systems of exogenous processes.
2. Study subsystem is intended to replenish the bank technology solutions. To this end, research is carried out in two stages. In the first phase rapid method detected the use of technological solutions for the detected values aggregated construction and technological characteristics, and then conducted a detailed study and identification of other construction and technological characteristics for use in the design.
3. Project subsystem consists of mapping techniques spread manifestations of exogenous processes on the basis of zoning maps and contingency plans drawn up in the area, a choice of ways to protect the identity construction and technological characteristics of the local conditions and technological solutions, calculation of parameters and design protection, determine the resources required.
4. Production subsystem includes the development of the annual work program and optimize them according to the degree of development and manifestation of exogenous process priority to the protection of natural and technical elements of the system in the context of limited resources, quality of work and evaluation of the effectiveness of work performed to reduce the expression of the exogenous processes.

References

1. Khalaf, F.I. & Al-Ajmi, D. Aeolian processes and sand encroachment problems in Kuwait. *Kuwait Institute for Scientific Research/Geomorphology.* 1993. Vol. 6. No. 3. P. 111-134.
2. Al-Awadhi, J.M. Mapping land degradation hazard in Kuwait: Using Delphi and AHP methods. *Kuwait Journal of Science and Engineering.* 2008. Vol. 35. No. 1. P. 71-91.
3. Hidalgo, C.H. & De Assis, A.P. A rainfall threshold for the occurrence of landslides in manmade slopes in residual soils in the northwest of Colombia. *Advances in Unsaturated Soils - Proceedings of the 1st Pan-American Conference on Unsaturated Soils. PanAmUNSAT.* 2013. P. 579-584.
4. Vranken, L. & Van Turnhout, P. & Van Den Eeckhaut, M. & Vandekerckhove, L. & Poesen, J. Economic valuation of landslide damage in hilly regions: A case study from Flanders, Belgium. *Science of the Total Environment*. 2013. Vol. 447. P. 323-336.
5. Fryberger, S. & Ahlbrandt, T. & Andrews, S. Origin, sedimentary features, and significance of low-angle eolian “sand sheet” deposits, Great Sand Dunes National Monument and vicinity, Colorado. *Journal of Sedimentary Research.* 1979. Vol. 49. No. 3. P. 733-46.
6. McKee, E.D. An introduction to the study of global sand seas. In: McKee, E.D. *(Ed.) A Study of Global Sand Seas*. U.S. Government Printing Office. 1979.

7. Kasper-Zubillaga, J.J. & Zolezzi-Ruiz, H. Grain size, mineralogical and geochemical studies of coastal and inland dune sands from El Vizcauno Desert, Baja California Peninsula, Mexico. *Revista Mexicana de Ciencias Geologicas*. 2007. Vol. 24. No. 3. P. 423-438.
8. Yizhaq, H. & Isenberg, O. & Wenkart, R. & Tsoar, H. & Karnieli, A. Morphology and dynamics of aeolian mega-ripples in Nahal Kasuy, southern Israel. *Israel Journal of Earth Sciences*. 2008. Vol. 57. No. 3-4. P. 149-165.
9. Mesbahzadeh, T. & Ahmadi, H. Investigation of sand drift potential (Case study: Yazd - Ardakan plain). *Journal of Agricultural Science and Technology*. 2012. Vol. 14. No. 4. P. 919-928.
10. Ashkenazy, Y. & Yizhaq, H. & Tsoar, H. Sand dune mobility under climate change in the Kalahari and Australian deserts. *Climatic Change.* 2012. Vol. 112. No. 3-4. P. 901-923.
11. Mason, J.A. & Swinehart, J.B. & Lu H. & Miao, X. & Cha, P. & Zhou, Y. Limited change in dune mobility in response to a large decrease in wind power in semi-arid northern China since the 1970s. *Geomorphology*. 2008. Vol. 102. No. 3-4. P.351-363.
12. Cheng, J. & Jiang, F. & Xue, C. & Pang, Q. Computational method for maximum sediment discharge and sand-carrying wind load in the prevention and treatment of wind drift sand for railway in strong wind area. *China Railway Science*. 2012. No. 1. P. 1-5.
13. Han, Z. & Wang, T. & Sun, Q. & Dong, Z. & Wang, X. Sand harm in Taklimakan Desert highway and sand control. *Acta Geographica Sinica*. 2003. Vol. 58. No. 2. P. 201-208.
14. Stumpf, A. & Malet, J.P. & Kerle, N. & Niethammer, U. & Rothmund, S. Image-based mapping of surface fissures for the investigation of landslide dynamics. *Geomorphology*. 2013. Vol. 186. P. 12-27.
15. Negi, P.S. Ecological manifestation of slope instability, its application in identification of areas of potential hill slope movement in Indian Himalaya. *Ecological Indicators*. 2013. Vol. 25. P. 85-91.
16. Saad, A.A. A study of sand stabilization in eastern Saudi Arabia. *Engineering Geology*. 1994. Vol. 38. P. 65-79.
17. Freer, R.J. & Hewish, R.J.F. & Ghataora, G.S. & Niazi, Y. Stabilization of desert sand with cement kiln dust plus chemical additives in desert road construction. *Proceedings of the ICE - Transport.* 1999. Vol. 135. Issue 1. P. 29-36.
18. Mirakhmedov, M. & Muzafarova, M. Expansion of a scope of methods of protection of the railways from entering by sand. *Transport Problems*. 2013. Vol. 8. No. 2. P. 55-61.
19. Muzaffarova, M. & Mirakhmedov, M. Differences and commonalities impregnation of air-dry and the wet sand. *2 International Symposium of Young Researchers "Transport Problems"*. 24-25 June 2013. P. 573-576.
20. Мирахмедов, М. Строительно-технологическое районирование условий строительства и эксплуатации железных и автомобильных дорог. *Известия вузов. Технические науки*. 2002. No. 4. P. 73-78. [In Russian: Mirakhmedov, M. Building and Zoning technological conditions of construction and operation of railways and roads. *Proceedings of the universities. Engineering.* 2002]
21. Mirakhmedov, M. Organizations protect the railway from exogenous processes. *IV International conference scientific "Transport Problems"*. 26-28 June 2013. P. 355-360.
22. Balde, A.O. & Fofana, S.L. & Mirakhmedov, M. & Papkovskaya, O.B. & Sebeldin, A.M. Estimation d'un syst`eme non stationnaire fini. *Revue des Sciences de l'Universite de Conakry. Serie Math-Phys.* 2006. No. 5. P. 23-27.

Received 17.11.2012; accepted in revised form 09.04.2014