The National Climate Change Adaptation Strategy for the Transport Sector in Bulgaria – Review of Design Norms and Maintenance Standards

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Abstract: *The National Climate Change Adaptation Strategy (NCCAS) for the "Transport" sector until 2030 was developed in the period 2017 – 2019. After 4 years in the context of several overlapping crises, the recommendations contained in the main adaptation measures document have largely not been implemented even in the initial phase. Those recommending the review and updating of legislation regarding adaptation to climate change were not subject to optimization. The article analyzes the problem of lagging behind in Bulgaria in relation to supplementing the standards and presents ideas for methodological approaches through which adaptation measures can be implemented in the design and maintenance of the road infrastructure.*
Keywords*: NATIONAL CLIMATE CHANGE ADAPTATION STRATEGY, DESIGN AND MAINTENANCE STANDARDS, CLIMATE ADAPTATION, REGULATION, METHODOLOGICAL APPROACHES, OUTSTANDING MEASURES*

1. Introduction

In recent decades, faced with global warming and rapid climate change, European Union countries have focused on preventing their catastrophic consequences and reversing their adverse direction. This is not a task that can be accomplished in a short period, as it requires restructuring and changes in many areas while rising levels of carbon emissions and the greenhouse effect are driving the planet towards ever higher temperatures and their adverse consequences. Therefore, adaptation of key sectors of the economy to the new challenging conditions is necessary. Bulgaria, as a member of the EU, is also working in this direction by planning and implementing the required measures. The transport sector, with its vital role in economic stability, also faces the need for urgent adaptation to changing conditions.

In this context, it is essential to clarify what constitutes adaptation in the context of climate change. It is understood as the process, actions, or measures that societies and systems adopt to deal with the realities of climate change. The aim is to reduce their vulnerability and increase the ability of systems to withstand the impact of climate change. It can be reactive (in response to manifested changes) or proactive (anticipatory, in anticipation of changes).

At the beginning of 2019, with a clear awareness of these challenges, with the help of experts from the World Bank, Bulgaria developed a "National Climate Change Adaptation Strategy and Action Plan" [1]. The strategy aims to properly direct future efforts by covering an analysis of the impact of climate change on critical sectors of the economy (agriculture, forestry, biodiversity, ecosystems, water, energy, transport, urban environment, health, tourism, and risk management disasters). It offers recommendations for overcoming barriers to adaptation, which must be implemented in the 11-year period from October 2019 (the document was adopted by decision No. 621 of the Council of Ministers of Bulgaria) until the end of 2030. However, four years after its adoption, we face the reality of delays and lack of active implementation of the proposed measures in many sectors, including transport.

The article aims to analyze and evaluate the degree of implementation of the National Climate Change Adaptation Strategy (NCCAS) for the Transport sector until 2030 in design norms and maintenance standards.

The main tasks of the article include:

- Analysis of the current situation regarding the implementation of the NCCAS for the "Transport" sector until 2030, in the context of several overlapping crises and the lack of progress concerning the update of the regulatory framework for adaptation to climate change;
- Analysis of the effects of climate change on transport infrastructure;
- Suggestions for methodological approaches that can support the integration of adaptation measures in the design and maintenance of road infrastructure.

2. NCCAS status five years after admission

The complex world situation in recent years has pushed into the distant future the need for a new approach to forming transport infrastructure objects, which would implement and apply the principles of sustainable development in Bulgaria, especially in the transport sector. The superimposition of the three large groups of crisis events in a short period led to severe shocks in the transport construction sector (especially in road construction). Practically, the series of crashes started at the beginning of 2020 with COVID-19, continued in 2021 and until now. Instability arising from political and economic reasons further significantly damaged and devalued the positive image and funding regarding the transport infrastructure. After February 2022, the financial shocks from the situation in Ukraine further reduced the opportunities for modern sector development. All this automatically led to a focus on the implementation of projects "piecemeal" and practically completely froze the possibility of working on the recommendations that the document on climate change adaptation (CCA) [2] set after October 2019. This halts the activities that should ensure the adaptability and resilience of the Transport sector.

The delay to date requires catching up on all elements of sustainable transport infrastructure modeling at an accelerated pace to expect commitments to be met (even in part) by the 2030 deadline.

A significant drawback for Bulgaria's transport sector at the moment is the fact that between 2019 and 2023, the report on adaptation to climate change [2] is the only document assessing and recommending actions to be taken to adequately respond, prevent, and react during the operation of the transport infrastructure concerning expected future extreme climatic events of national status.

Until now, the ongoing activities on the analysis of the expected extreme values of climate phenomena and those on the implementation of prevention recommendations do not provide a practical opportunity to achieve an adequate level of adaptation of the "Transport" sector for the five-year previous period.

For comparison, in the last five to seven years, countries such as the USA, England, Ireland, Brazil, and others [3, 4] have been looking for a projection of climate models when organizing the stages of the investment process in their transport infrastructure (from design, through maintenance to crisis prevention). In this way, socio-economic parameters are set for the saving of significant capital investments, which must be attributed to the maintenance of the functionality of the transport infrastructure (continuity of the transport service and a high level of road safety) in the medium and long term perspective.

3. Analysis of the effects of climate change on transport infrastructure

Climate change generates cumulative risk factors for transport infrastructure. In the long term, adapting the transport sector to climate change will affect the entire life cycle of transport modes. Following the signing of the Paris Agreement in 2016, the sector's commitments were stated through Part 7 in [1]. In accordance with it, an assessment of the Transport sector [2] was also prepared, where an initial scope and general guidelines were defined based on an analysis and a conclusion on the degree of risk.

The tracking of the processes during the operation of the transport infrastructure and their reference to the conclusions and recommendations in [1, 2, 5, 6] was summarized according to Fig. 1. It is a graphic representation of the significance of extreme climatic events concerning the main parameters of transport in Bulgaria (infrastructure and traffic) and the sensitivity of the sector to climatic risks.

Referring to the assessment of the Transport sector in [2] and scientific monitoring of the sensitivity of the transport infrastructure in our country [5, 6], the following more significant cases of climate risks caused by major climate events – high/low temperatures can be indicated, precipitation and storms, snowfalls and snowstorms, combinations between two and more factors.

4. Proposals for methodological approaches and solutions for integrating adaptation measures in the design and maintenance of road infrastructure

According to the conclusions in [2], to build adaptive capacity in the sector, it is necessary to work intensively in two large groups of tasks: 1) data collection and 2) formation of knowledge and capacity.

On the other hand, to fulfill the two groups of tasks, a package of adaptation measures should be developed [2], which refer to the following four groups of activities:

4.1 Guidelines for updating and supplementing design standards.

The norms for the design of the transport infrastructure were created with a high degree of conservatism, which makes them suitable from the point of view of set design parameters under standard operating conditions [7-9]. Documents that are not covered by national regulations, such as [10, 11], can be included under a condition. In addition, normative documents and standards are separate and independent documents that are not developed in a common system of rules. This hinders complex solutions related to the pressures of climate change.

The adaptation of the normative documents should be aimed at three essential elements of the normative base in Bulgaria:

- First, building institutional capacity, in which to create an available professional expert base of specialists to whom timely and regular updating of morally outdated documents can be assigned. Organizing this item should start immediately.

- Second, completing the newly created and available documentation with requirements arising from climate risks. These additions and extensions should cover extreme parameters of the operating conditions the potential for their modification, and be uniform as principles in the many accompanying regulations, including those related to operation and maintenance.

- Third, the unification and binding of normative and sub-normative documents covering the entire package of requirements for the design of transport infrastructure in terms of design parameters, which together are necessary for the volume of investment projects (from preliminary design studies to technical projects).

Climatic phenomenon	Vulnerability of transport infrastructure						Mitigation
	transport infrastructure			Attitude towards transport safety			Stages of prevention: ①- Level standards ②- Performance ③- Operational support
	Roads (streets)	Rail roads	Transport facilities, incl. airstrips	Car roads	Rail roads	Transport facilities	
High temperatures							① ② ③
Low temperatures							① ② ③
It's raining							① ② ③
Storms (wind, hail)							① ② ③
Snowfall							① ② ③
Droughts							① ② ③
Fogs							① ② ③
Snow storms							① ② ③
Sea level rise - excitement							① ② ③

Climatic phenomenon	Sustainability	Mitigation	Impact on the user and consequences
	Attitude towards maintenance and traffic management	Stages of prevention: ①- Level standards ②- Performance ③- Operational support	
High temperatures		① ② ③	TOTALLY NEGATIVE for traffic continuity and road safety
Low temperatures		① ② ③	
It's raining		① ② ③	
Storms (wind, hail)		① ② ③	
Snowfall		① ② ③	
Droughts		① ② ③	
Fogs		① ② ③	
Snow storms		① ② ③	
Sea level rise - excitement		① ② ③	

Fig. 1 *Vulnerability ranking of Bulgaria's transport infrastructure to the effects of climate change.* ***Legend:*** *highest sensitivity – red color / lowest sensitivity – green color*

4.2 Guidelines for optimization of project preparation procedures.

It is necessary to work on developing regulations, instructions, or guides for the consideration of climate change by types of transport within the scope of each investment project.

To implement an adaptation option, one must start with optimization in three directions:

- First, introducing the principles of sustainable development and defining the concept of "life cycle" for transport infrastructure. This will help organize planning activities at all stages of the investment process.

- The second is adopting an approach that, in addition to being a pollutant, to a large extent in the medium and long term, climate change will increase the vulnerability of the transport infrastructure. Therefore, this object must be treated as a victim entity of our national industry, which must be provided within the framework of the preparation of the projects.

- Third, the optimization of the procedures and parts of the projects should be done for scientifically determined relevant current climate models for forecasting and, if possible, seek to simulate the interaction between climate risks and the relevant objects of the base, possibly with the help of new computational technologies and artificial intelligence [12].

4.3 Guidelines for updating and supplementing standards and procedures for operation and maintenance

The documentation and the procedures it provides are shaped by several national standards for railway and road infrastructure [14-24]. Only a part of them are open access, and about roads, no national-level updates of their variants adopted at the end of the 20th century are known [20-24]. The minimum initial steps to catch up with the serious backlog in updating this type of documentation can be given in the following activities:

- Building institutional capacity to regulate renewal processes and increase the adaptability of maintenance procedures and standards during operation. Establishing connectivity between the nationally designated administrative structures that are responsible for the processes in this part. In this way, the framework for processing the documentation and activities will be set;

- Optimization of applied materials and methods with all the results obtained from research and innovation. Introducing a wide range of technological innovations and systematic condition monitoring to enable transport infrastructure to function effectively in the face of the dynamics of changing climate conditions. Entry of scientific research into the processes of practice. This element can be developed within the framework of "Education 4" to the Fourth Industrial Revolution.

4.4 Guidelines for increasing the effectiveness of emergency activities

This task requires a strategic framework that contains a criticality assessment and programs based on which to develop crisis management plans. Within these plans, the dynamics of climatic events must be considered, for example, floods, geological risks, fires, intense snowfalls, and others.

Increasing the effectiveness of risk prevention activities in connection with CCA requires planning to cover two large groups of tasks – 1) determining the level of service and 2) related to solving the crisis event that has occurred. Recommendations for improving the management of transport infrastructure processes can be summarized according to the stages of development of the emergency situation:

- **Warning phase**: the emphasis should be on a real-time information transmission model to expect the effectiveness of the early warning principle. This means the use of a nationally available (open access and free platform for institutions and organizations) information model by analogy with the European Union's Earth observation and monitoring program "Copernicus" [25, 26].

- **Phase of the occurring crisis**: here, the problems of mastering the occurring event for the transport infrastructure are practically of a global nature for the country's territory. This is due to the separation of responsibilities of the institutions that must secure the developing effects with potential consequences on the service and human health and life.

The study of the authors within the scientific project "Impact of climate changes on the transport infrastructure in Bulgaria - conceptual approach to assess the potential impact on achieving sustainability and safety of elements of the transport sector' showed that the lack of communication connectivity between institutions and their heterogeneous databases value the same event with significant differences in significance and degree of risk.

- **Phase of suppressing the residual effects and dealing with the consequences:** here, the institutional capacity must provide a unified database on the level of resources invested and the affected sub-directions in the Transport sector. This way, databases will be accumulated, especially regarding recurring crisis events linked to extreme climate events. This will not only refine the prevention measures by types of risks on a territorial basis but also provide a framework for the optimality of the response in the acute phase of the situation, again by types of climatic events.

5. Reasons for non-implementation of the recommendations of the National Climate Change Adaptation Strategy in Bulgaria

Within the framework of the study carried out about a general review of the design norms and standards for the maintenance of the transport infrastructure in connection with the implementation of the recommendations under the CCA [1, 2], a significant delay in the implementation of all the recommendations that were made in the documents of The 2019 National Climate Change Adaptation Strategy and Action Plan. Indeed, the program's launch coincided with a series of overlapping international and national crises. This should logically delay the procedural implementation of [1, 2], especially in the "Transport" sector, but in terms of adaptation measures, which refer to the design, operation, and maintenance of the transport infrastructure, there is practically no progress.

The main reasons for this are:

- **Lack of institutional capacity**

This refers to 1) starting procedures for awarding an expert-level request for renewal, optimization, and binding of the documentation with climatic risk factors, as well as the mutual binding of all legal, by-law normative documents in a common package; 2) launching procedures to create connectivity between agencies and institutions that are responsible for activities in emergencies; 3) synchronizing the received information between them to assess the actual extent of the invested resource for the response and elimination of the consequences.

- **Lack of collected, archived, appropriately processed, and accessible databases** relating to the state of impact on the "Transport" sector.

At the national level, a coordination model for creating common archives has not been developed and, therefore, does not function. Currently, every instance and/or institution that is responsible for given sub-sector policies and is possibly required to keep an archive maintains some level of it. Additionally, they are usually unavailable, incomplete, and inconsistent with information from other agencies relevant to the transport service and its carrier. Without data, it is not possible to obtain a statistical basis with which to supplement the regulations for design, maintenance, and operation.

- **Lack of models for the interaction between climatic elements and those of the transport infrastructure** and, accordingly, for the correct forecasting of risk factors such as degree of manifestation and significance. Without implementing climate models and methods for simulating the risk factors, it will not be possible to set parameters in the normative documents, which will be taken into account within the entire investment process and life cycle of the relevant linear facility.

The stated reasons seriously complicate the adaptation of the transport infrastructure to the changing climatic conditions in Bulgaria, which may have negative consequences on the sustainability and safety of the sector in the long term. It is essential to pay attention to these problems and to take concrete steps to overcome the identified obstacles to the successful implementation of the recommendations of the NCCAS.

To overcome the identified problems, a clear institutional framework is essential. It should include launching procedures for regularly updating and optimizing climate risk documentation, as well as creating an effective communication link between the various agencies and institutions responsible for emergency management. In addition, standard procedures for collecting, archiving, and analyzing data on climate impacts on transport infrastructure need to be developed and implemented. The creation of a centralized and accessible database can support the process of making informed decisions and updating the regulatory framework. In addition, the development and implementation of models for the interaction between climate conditions and transport infrastructure, as well as the prediction of risk factors, are essential for correctly

setting parameters in regulatory documents. This may include collaboration with academic institutions and modern technologies such as artificial intelligence to analyze and simulate different scenarios. With joint efforts and commitment from all interested parties, it is possible to overcome the identified obstacles and improve the adaptation of the transport infrastructure to the changing climatic conditions in Bulgaria.

6. Conclusion

The present study analyzes the reasons for the non-implementation of the recommendations of the National Strategy on CCA in Bulgaria and proposals for methodological approaches and solutions aimed at the integration of adaptation measures in the design and maintenance of road infrastructure in response to climate change as well as additional guidelines for adaptation of the transport sector to climate change in Bulgaria, focusing on updating operation and maintenance standards and procedures, as well as improving emergency response. Key points include:

- Updating and supplementing the existing design norms, with the aim of reflecting climate risks and unifying the various regulatory documents into a common system of rules.
- Development of guidelines for optimization of project preparation procedures, including introduction of sustainable development principles and consideration of transport infrastructure as a victim of climate change.
- The potential use of new technologies and artificial intelligence to simulate the interaction between climate risks and transport infrastructure in the design process.
- Renewal of standards and procedures: It is proposed to build institutional capacity to regulate the processes of updating documentation and increase the adaptability of maintenance procedures and standards. It is also recommended to optimize the materials and methods used, introduce technological innovations, and track the condition of the infrastructure over time.
- Increasing effectiveness in emergency situations: A strategic framework and crisis management programs are proposed that take into account the dynamics of climate events. Key aspects are the phases of warning, responding to the crises that have occurred, and extinguishing the residual effects. It is also recommended to build a unified database of resources and affected areas, as well as optimization of the response to different types of climate events.

The publication highlights the need for intensive work on data collection and knowledge and capacity building to improve the sector's adaptive capacity and respond effectively to climate change challenges, as well as the need for clear communication and coordination between different institutions, as well as the inclusion of scientific research in practical processes to improve the sustainability and safety of the transport infrastructure in the country.

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