Challenges to the analysis of available data on crisis events and their effects on transport infrastructure under climate change

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Abstract: *The article focuses on issues related to the assessment and interpretation of existing data on crisis events in the context of transport infrastructure. In the face of global climate change, analyzing these data becomes increasingly complex and requires in-depth consideration. The main challenges the paper addresses include the lack of comprehensive and up-to-date data, limited opportunities to analyze causal relationships between climate events and their impact on transport infrastructure, and shortcomings in existing analysis methodologies. The authors call for the development of new, more efficient methods of data collection and analysis that can serve as a basis for future strategic decisions.*

Keywords*: CLIMATE CHANGE, TRANSPORT INFRASTRUCTURE, CRISIS EVENTS, CAUSAL RELATIONS, STRATEGIC DECISIONS, ADAPTATION MEASURES*

1. Introduction

In the conditions of global climate change, the sustainability and adaptability of transport infrastructure is becoming increasingly relevant and requires in-depth analysis. Climatic events such as heavy rains, storms, floods, and temperature anomalies can have a significant impact on the operation and reliability of transport systems. However, existing data on these crisis events are often insufficient or limited, making their analysis difficult and sometimes inadequate.

Transport infrastructure is vital to the day-to-day functioning of society and the economy, providing connectivity and access to critical resources and services. At the same time, it is exposed to various climatic risks that can affect its functionality, safety, and efficiency. The consequences of climate change, such as the increasing frequency and intensity of extreme weather events, lead to an increase in the exposure of transport infrastructure to risks. Accordingly, analyzing the impact of climate change on transport infrastructure and developing adaptation strategies becomes essential.

The purpose of this paper is to explore the critical challenges associated with the assessment and interpretation of available data on crisis events and their impact on transport infrastructure in Bulgaria. In particular, we address the problems stemming from the lack of comprehensive and up-to-date data, the limited ability to establish causal relationships between climate events and their impacts, and the shortcomings of existing analysis methodologies. At this stage, it is imperative to develop new, more efficient methods of data collection and analysis that can serve as a basis for future strategic decisions in transport infrastructure and climate resilience. These new methods may include the use of modern technologies such as the Internet of Things (IoT), geographic information systems (GIS), and artificial intelligence (AI) to improve data collection and real-time analysis.

The article calls for the urgent need to develop new, more efficient methods of data collection and analysis that can serve as a basis for future strategic decisions in transport infrastructure and climate resilience.

The problem of climate adaptation of transport infrastructure is technical but also institutional and organizational. Although technological innovations can offer new avenues for data collection and analysis, successful adaptation also requires coordinated efforts between the various institutions and agencies responsible for managing and maintaining transport infrastructure. Establishing inter-institutional partnerships and collaborative platforms can improve understanding and response to climate risks while stimulating the sharing of knowledge and resources.

Furthermore, educational and research institutions can play a key role in developing new methodologies and tools for climate risk assessment and transport infrastructure adaptation. Research and training of specialists in the field of climate resilience and transport infrastructure can contribute to the development of innovative solutions and sustainable practices. In the long term, introducing educational programs aimed at climate adaptation of transport infrastructure can prepare future professionals for the challenges associated with global climate change.

In conclusion, to achieve a successful adaptation of transport infrastructure to climate change, a comprehensive approach is needed that includes technological innovation, institutional and organizational cooperation, as well as investment in education and research. Creating solid partnerships between the public and private sectors, academia, and civil society can accelerate progress towards a more sustainable and adaptive transport sector in the face of ongoing climate change.

2. Analysis of available data on crisis events and their effects on transport infrastructure

According to the "UN Framework Convention on Climate Change" [1], "adaptation" to climate change can be defined as "the adaptation of a natural or human system in response to climate risks."

To prevent the consequences of climate change, the Member States of the European Union have prepared packages of strategic documents. The Bulgarian package for "National Climate Change Adaptation Strategy and Action Plan (2019 - 2030)" was approved in October 2019. The main document for the Transport sector is Annex No. 7 of [2-4].

According to "Climate change adaptation - assessment of the transport sector" [2], in the medium and long term, the most critical risks for the Bulgarian transport system that can be expected as a result of the predicted climate changes are:

- Extreme heat: the forecasts are for a continued increase in temperatures and the duration of the situations that occurred;
- Blizzards and snowfall: long-term forecasts for the annual amount of snowfall predict a decrease (the latter is visible for the period 2020-2022), but in the short and medium term, the events that occur as a result of snowstorms will make it difficult for all modes of transport in certain areas;
- Landslides: Precipitation factors are the primary enablers of landslides and rockslides, such as due to the expected increase in the frequency of extreme rainfall events;
- Flooding: increased frequency and impact of flooding under all climate change scenarios.

In drafting the project [2-4], the main points that need to be worked on to obtain results in the specified period were determined. The more important of these, which have not been effectively defended to date and form the basis of the analysis in this publication, are the dysfunctionality of the underlying policies and the insufficient

capacity to adapt. Regarding the institutional framework, the following problem points stand out:

- Short-term vision and information-level fragmentation of the leading direct climate change risks and vulnerabilities facing the transport sector.
- Local analyses and risk assessments, respectively, show the impossibility of a comprehensive evaluation of the vulnerability of the transport sector as indicated in [2] and corresponding to the summary in Fig. 1.
- Climate change adaptation activities for the transport sector. On this point, it was concluded that stakeholders prepare strategic documents within the one-way impact, namely from transport on the environment. Adverse impacts (the impact of changed climate conditions on transport infrastructure) are practically not amenable to long-term analysis and planning, and issues are limited to the ongoing management of problems arising from short-term impacts.
- The lack of quality data to analyze and enable the creation of long-term strategies by responsible institutions forms a global low adaptive capacity of the sector.

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.*

Regarding the possibilities for building adaptive capacity, [2] points out several omissions in providing the basic options for adaptations that are still relevant today:

- Adaptation capacity – insufficient available information in terms of volume and quality with which to create management systems;
- Adaptation activities - most activities are aimed at crises and lack long-term effectiveness due to a lack of a systematic approach.

To justify a framework to parameterize these two indicators, it is necessary to expand the discussed national database with an additional resource. It should include elements of investment design (project preparation, design standards), operation and maintenance, emergency response, institutional capacity building, and data collection.

It is important to note that data collection is essential and accompanies all other aspects as a basis for their implementation. Given the backlog in implementing the recommendations, it is imperative to start a discussion and proposals for the collection and use of databases (climatic and transport infrastructure conditions) to accumulate a basis for concretization within the medium-term plan (5-7 years) opportunities for adaptation. Without improving data collection practices that are open enough to be used to process and complement climate model algorithms and interactions, the sector's climate event analysis and prevention methodology will not be justified. Accordingly, it is stated that vulnerability risk assessment for this sub-sector through a working model will not be possible until the 2030 deadline.

In [5], it is noted that work should begin on the application of adaptation parameters, and this should follow a principled algorithm to create a system that takes into account current and projected climate changes and links them to transport infrastructure, reducing its sensitivity to them, respectively, to improve its durability and serviceability, safety and continuity of movement.

In [5], it is stated that the main difficulties in the overall adaptation of the transport infrastructure to climate risks are the lack of awareness of climate patterns (as a consequence of the interaction of different possible behavior of humanity and the planetary climate), combined with the scope of change of each climate norm in which the parameters of the transport object are set. For Bulgaria, the task is complicated by insufficient publicly available and up-to-date data on the impact source and the recipient.

This makes it difficult to implement projects that solve adaptation tasks in the transport sector. To create an environment for research, monitoring, visualization, and response, the basic sustainable principles in construction must be respected - for example, introducing conditions to apply the concept of "life cycle" for the field of transport construction by analogy with that of buildings. This will enable a methodical approach to work on the main areas such as design norms, data collection for all stages of the investment project, preparation at the design level, operation and maintenance, and actions in emergencies already recommended in [6]. In second place is the gradation of the significance of the events and the possibilities for building adaptive capacity. In this case, the main problem for Bulgaria is the lack of data (missing, incomplete, irregular, unavailable) about the climate, the climatic phenomena that have occurred, and, accordingly, their consequences concerning the current state of the transport infrastructure.

Significant neglect of database collection leads to a lack of statistical parameters. This complicates the research work regarding adaptation and makes inapplicable the most modern methods of modeling (neural networks, artificial intelligence, etc. [7]) of the processes and their use for predictive analysis in the medium and long term.

Based on [6], we analyzed the significance of extreme climate events concerning the main parameters of transport (infrastructure

and traffic). The preliminary analysis of the actuality of the problem and the need for its step-by-step solution shows that there are levels of vulnerability in all elements of the transport infrastructure, with the road infrastructure being the most sensitive, which is summarized in Fig. 1. This was a prerequisite for the team to focus on checking the quality and quantity of the data that make up the available information base and its accessibility and visibility concerning the road infrastructure.

3. Sources of publicly available data on crisis events and their impact on transport infrastructure

The directions in which the search was directed were climate data, extreme events that occurred, and effects on the road network. For this purpose, within the framework of the project, sources with publicly available data were studied. Such are the National Statistical Institute (NSI) [8], Road Infrastructure Agency (RIA) [9], National Civil Protection Service (NCPS) [10], local sources at the district and municipal level, and information in the media. The latter is not an official source of data. Still, due to the high degree of missing data, fragmentation of the available data, or inconsistency in the registers of the mentioned national institutions, it was necessary to overlay all publicly available information.

Despite the efforts and complementary media-type elements, survey results are sparse, inconsistent, and difficult to track.

On the NSI website [8], statistics are available on climate crises for the period 2004–2021, and for the territory of the country for specific periods, the information is summarized in a form that is difficult to compare, from which to track and derive dependencies by area for types of climate risks and the territory of Bulgaria. As for the Republican Road Network (RRN), there are aggregated data for the entire country on the affected infrastructure by year for the period 2004–2008, and for each year, the data were provided by different respondents (RIA, NCPS, regional road administrations, etc.). In this case, it is impossible to determine the degree and significance of the impacts, but only the total number of those RRN objects that were the subject of direct budgetary costs for restoration.

A partial information base is maintained in the RIA, which refers to crisis events (according to data from the regional road administrations) by years after 2013 and separate announcements until 2022 for planned ongoing and/or major repairs on the state road network.

In this project, an attempt has been made to combine data from the RIA with information from NSI, NCPS (partial accident bulletin for the period 2009–2023), and the media on climate crises that are the cause of emergencies, traffic disruptions, and damage to the republican road network to derive a principle algorithm. Still, the quality of the databases is insufficient in quantitative and qualitative terms.

4. Results of the survey of available publicly available information

The conducted study confirmed the expectations that the possibilities of connecting climatic events with the current and subsequent state of the transport (for the needs of the road project) infrastructure could not be realized with the available publicly available information. Accordingly, a lack of adaptive capacity in these measures (database collection and organization) has been demonstrated, and the creation of a real-time verification program system with high predictive capacity cannot be ensured at the current stage of the project.

The data show that the climatic phenomena with priority in terms of the roadworthiness of the RRN and the continuity and safety of traffic are the following - heavy rains and the floods caused by them (Fig. 5), an increase in the geological risk of erosion (abrasion) in terms of precipitation factor, including combined with another occurrence component, snowfall from blizzards (except for the years 2020–2022, which had dry winters).

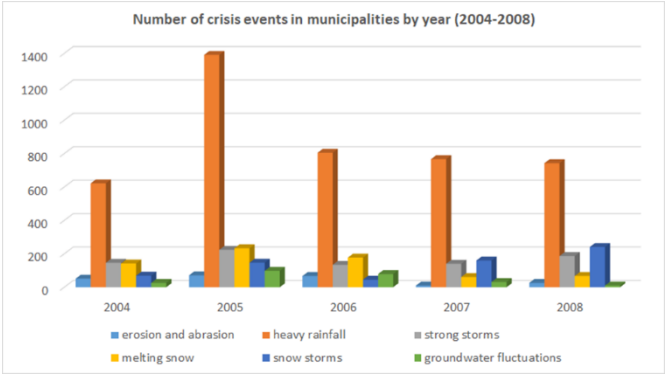

Fig. 2 *Number of crisis events in municipalities by year (2004 - 2008) by type. Data source – NSI [8]*

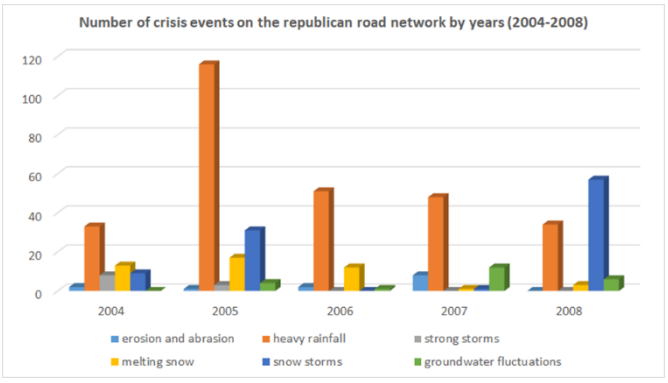

Fig. 3 *Number of crisis events by type for the republican road network of Bulgaria by year for 2004–2008. Data source – NSI [8]*

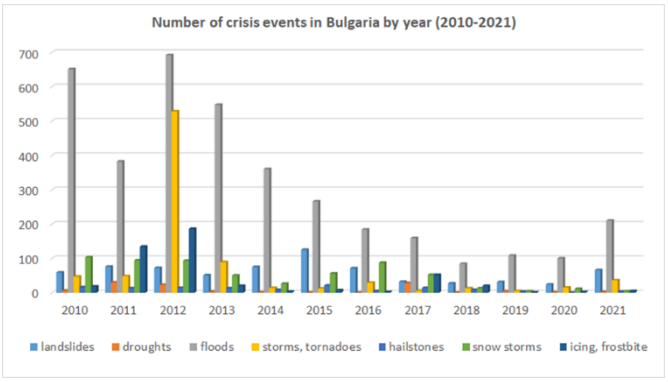

Fig. 4 *Number of crisis events by type in Bulgaria by year for 2010–2021. Data source – NSI [8]*

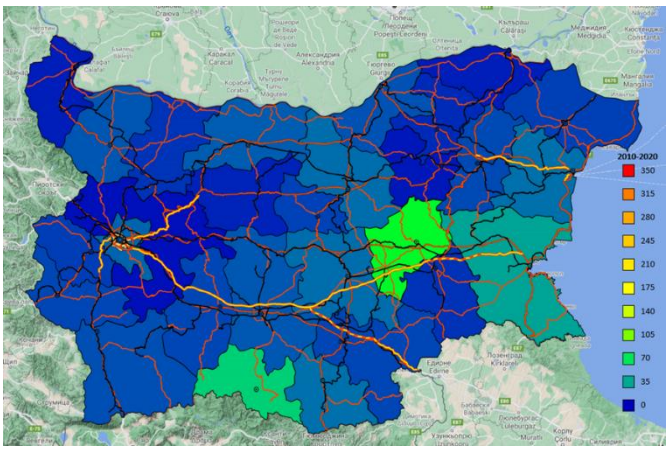

Fig. 5 *Map of the regions in Bulgaria with the average number of floods per year for 2010–2020. Data source – NSI [8]*

Nevertheless, the tracking of statistics made it possible to draw several more essential conclusions about the overall severity of the main climate crises in Bulgaria for 2004–2023. Figures 2, 3, and 4 show that most crisis phenomena in municipalities and RRN are caused by heavy rains, according to NSI statistics from 2004 to 2021. This often leads to floods (Fig. 5), landslides (Fig. 6), etc.

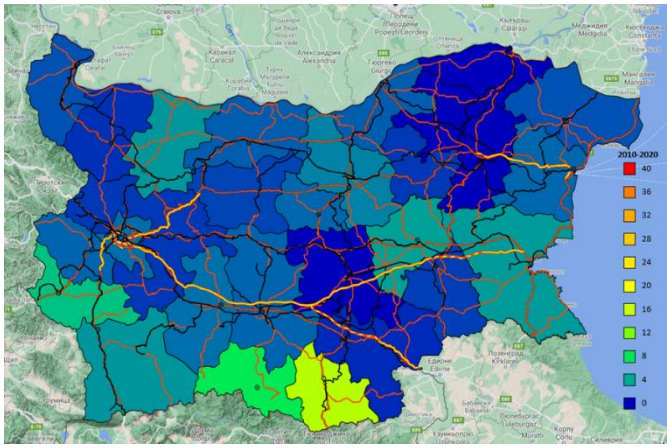

Fig. 6 *Map of regions in Bulgaria with the average number of landslides per year for 2010–2020. Data source – NSI [8]*

Figures 5 and 6 present a visualization of the average annual number of floods and landslides in different regions of Bulgaria for the period 2010-2020, based on data from the National Statistical Institute in Bulgaria (NSI). According to the statistics shown, it can be seen that heavy rains are the main catalyst for floods and landslides in the country, and the consequences of these crisis phenomena significantly affect the transport infrastructure. The distribution of floods and landslides by region highlights regional differences in exposure to such risks. The analysis of this data is essential as it helps to identify vulnerable areas and allows for better planning and implementation of measures to prevent and address the effects of climate change. Furthermore, the analysis of this geographic data can serve to improve crisis management and infrastructure adaptation strategies, which are essential to maintain the functionality and safety of the country's transportation systems.

5. Conclusions

Within the scope of the study, it was established that the building of adaptive capacity according to the principles laid down in the climate change adaptation will require an enormous human and financial resource from related institutional units and the immediate launch of measures to implement the specified adaptive practices.

At this stage of the research, we found that, apart from the huge delay (from 2019 to the present), the primary problem is the lack of collected, archived, applicable, processed, and accessible databases relating to the status of the impact on the Transport sector. The second fundamental problem is that at the national level, a coordination model for creating appropriate archives has not been developed and, therefore, does not function. At the moment, every instance and/or institution responsible for certain sectoral policies and possibly required to keep an archive maintains some level of it, which is usually unavailable, incomplete, and out of sync with other transport-related agencies.

Therefore, the legal framework and regulations for its implementation must first be worked on to create a multidisciplinary data archive. Thus, given the level of technology development, all institutions will be able to count on having access to a dynamic platform where they can enter the information they are responsible for. It will be constantly updated, and with the help of a model for the AI to work with, it will be possible to connect events and facts that can be processed to correctly assess the risk and its consequences (from a short-term to a long-term perspective).

It is thus expected that in addition to point-in-time data (for climate events, traffic disruptions, accidents, and the need for repair and restoration of transport infrastructure, for accidents and others), these data will presuppose a relevant link between climate change and the occurrence of extreme climate an event that led to a crisis on the transport (road) infrastructure, traffic violations and damage to the transport infrastructure, respectively the subsequent recovery measures and, as a result, a realistic forecast model for the prevention of a subsequent similar situation.

The presented problems and recommendations emphasize the importance of creating an integrated data collection and processing system to support the prevention and management of crises in the Transport sector, especially in climate change. Developing a legal framework and guidelines for effectively implementing the principles of adaptation to climate change is key to building adaptive capacity and sustainability of the transport infrastructure. The establishment of a multidisciplinary data archive and the creation of a dynamic platform for the exchange of information between different institutional units will allow a faster and more accurate analysis of the risks and consequences of climate events. Also, it will support the development of precise forecasts and effective crisis prevention and response plans. Implementing these recommendations requires a concerted effort by all parties concerned, as well as a commitment to continuously update and optimize data collection and processing systems in line with the latest technological developments and climate change adaptation requirements.

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References

1. Framework convention of the United Nations for the amendment on the climate
2. Advisory Services on a National Climate Change Adaptation Strategy and Action Plan
3. Republic of Bulgaria National Climate Change Adaptation Strategy and Action Plan
4. National climate change adaptation planning and strategies
5. E. Ivanova, S. Matev, S. Ivanova. Impact of climate changes on transport infrastructure in Bulgaria. Annual of the University of Architecture, Civil Engineering and Geodesy – Sofia, Vol. 56 (2023), Issue 1, pp. 117-131.
6. Republic of Bulgaria, Consulting services by National Climate Change Adaptation Strategy and Action Plan, Appendix 7: Assessment on "Transport" sector, No on project: P160511, 2019.
7. S. Ivanova, E. Ivanova, M. Medarov. Guidelines for the application of artificial intelligence in the study of the influence of climate change on transport infrastructure. *Proceedings of International Scientific journal “Industry 4.0”*, Year VIII, Issue 3 / 2023, pp. 75-78.
8. National Statistical Institute (NSI), website: https://nsi.bg/bg
9. Road Infrastructure Agency (RIA), website: https://api.bg/bg/1642084331.html
10. National Civil Protection Service (NCPS), website: https://www.mvr.bg/