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Increasing Impact of Climate Change-Induced Flash Floods on Railway Infrastructure in Türkiye

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Abstract:

It is obvious that an increase in extreme precipitation occurs, not only in some regions but around the globe. The fact that the world has experienced multiple record flooding events in recent years – including catastrophic flooding in Türkiye – is not a coincidence. Climate change is making record-breaking extreme precipitation more likely.

The latest assessment report published by the Intergovernmental Panel on Climate Change shows how this pattern will continue in the future as global temperatures continue to rise.

Climate change-induced flash floods have also become increasingly frequent in Türkiye, severely affecting the railway infrastructure since the last few years. Physical damages to railway tracks by heavy precipitation and flash floods are documented. However, the impact of these disasters on the railway infrastructure was beyond direct physical damages.

This paper aimed to explore the impact of climate change-induced extreme weather conditions such as flash floods on railway infrastructure in Türkiye using some cases. Three cases were used to analyze the cause and effect of flash floods damage on railway infrastructure

We find that damage to railway infrastructure and disruption of railway services were associated with missing modern monitoring services, under capacity of the railway culvert, and weakness of the railway infrastructure under extreme meteorological conditions, which triggered the disaster vulnerability.

The results show that under this current situation, climate change-induced heavy precipitation and flash floods might be significant potential threats to railway infrastructure in Türkiye.

Implementation of engineering works and strategic policies might reduce disaster risks. Therefore, policymakers and responsible state organizations should consider emerging risks and necessary measures to be taken under new meteorological and hydrological conditions.

Keywords: Railway infrastructure; Flash floods, Extreme weather, Railways safety, Climate change.

1. Introduction

Climate change has become a significant stimulating factor in many environmental disasters. Climate disasters refer to events that are either caused or worsened by climate change effects, including rising temperatures, changing rainfall patterns, sea level increments, and frequent violent weather [1],

Flooding of railway infrastructure can lead to significant adverse complications, including infrastructural damage and large-scale disruptions. These can lead to increased economic costs and decreased reliability(8).

Railway infrastructure is vulnerable to extreme weather events which lead to infrastructure failures and disruptions. Such events increase economic costs and decrease the reliability of railways as means of transporting goods and people. Flooding is one type of these extreme events, which can lead to infrastructure failures such as damage to railway slopes, embankments, electrical equipment, and railway tracks, as well as bridge failure due to scour (the removal of sediment) at bridge foundation, wash away the ballast and foundation material on the culverts due to the rapid movement of water (9).

The damage of flooding on railway infrastructure can result in several months of repair work and rerouting of trains, which is more prevalent in railway networks compared to road networks due to the complexity and less flexibility (10).

Heavy rains-associated flooding is one of the most prominent extreme weather-related concerns railroads face. Flood flows can weaken some rail bridges, wash away the ballast that stabilizes tracks, and damage sophisticated railroad signaling systems and electronic trackside equipment all of which threaten rail service .

Although flash floods can happen within a matter of minutes, railway administration should proactively monitor and prepare their networks for potential water-related risks every day

In Türkiye, we also faced some railways damage due to heavy rainfall-associated flooding for the last five years. In this study, these cases were used to investigate the causes of railway infrastructure damage. Three events were considered for this purpose, namely, the Çorlu flash flood in 2018, the Denizli flash flood in 2023, and the Ankara -Sivas railway line in 2023, which caused extensive damages to the railway infrastructure in the regions indicated on the railway lines map of Türkiye(Figure 1). Relevant data on the impacts were collected from diverse sources, such as technical papers, media coverage, Railway Organisation's official documents, and report.

2.Railways in Türkiye

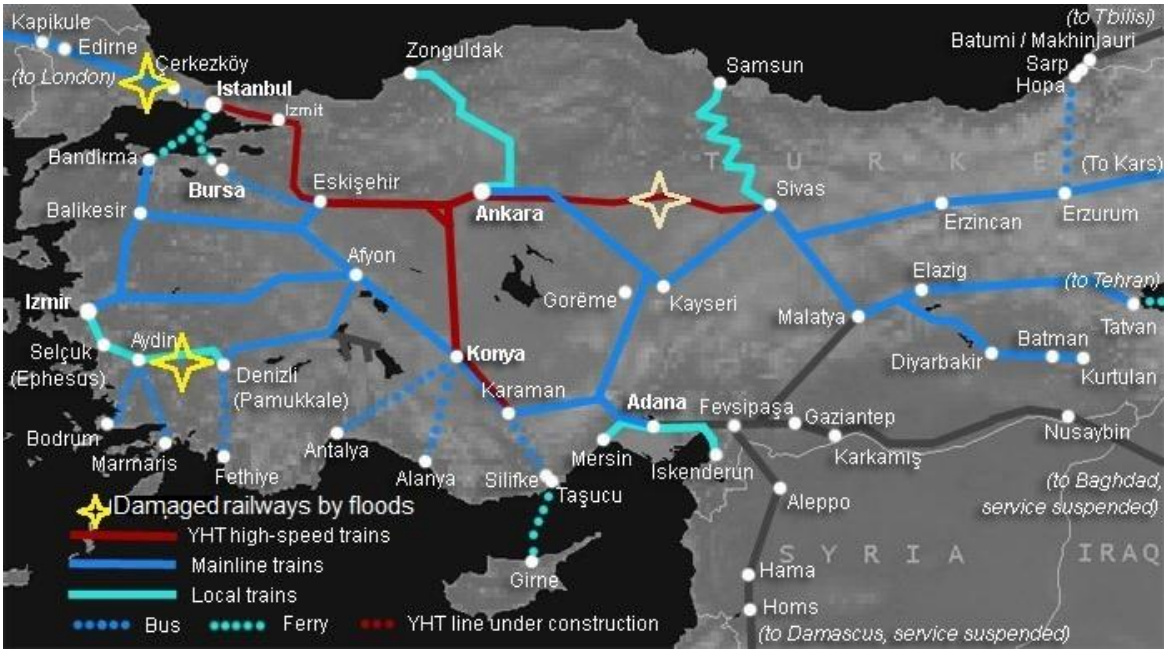

Figure 1. Railway lines map of Türkiye

The construction of the first railway lines within our present national borders was made in 1856. Approximately 13 000 km of lines, 4000 km in the Ottoman period, and 9000 km in the Republican period constitute Türkiye's national railway infrastructure network. In Türkiye, there is still 2032 km high-speed train line in operation(3).

The total length of railway lines in use in Turkey increased steadily between 2003 and 2021. In 2021, the usable rail network in Turkey was 13,022 kilometers long, the highest number of kilometers of railways recorded during the period given.

The superstructure part consisting of rail, sleeper, and ballast, which distributes the loads coming from the trains directly to the ground, is renewed every 10-15 years in practice(1). But bridges, culverts, and tunnels were built by calculating the meteorological and hydrological conditions of the period and have been used until today.

3. Heavy rains, flash floods, and railways safety

The extraordinary meteorological events that have occurred as a result of the climatic changes in recent years, could reduce the trust in the train journey, which is the safest type of travel all over the world.

Meteorologists and climatologists agree that there are significant changes in precipitation patterns. As a result of climatic variations, the frequency of local, short-term, and heavy rains has been increasing in recent years. These precipitations turn into flash floods in cities and cause loss of life and property.

These rains, which negatively affect land transportation in cities and outside the city, have also begun to endanger railway transportation.

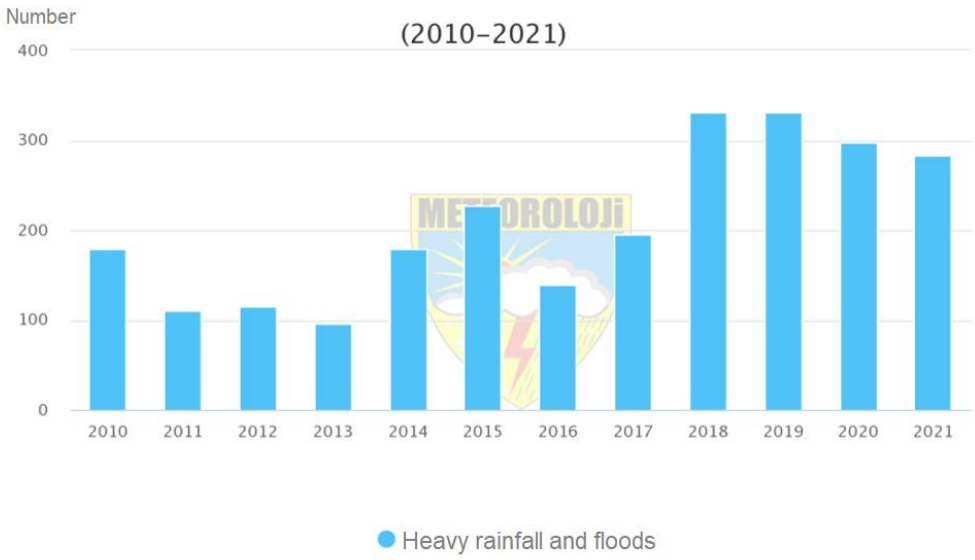

Figure 2.Total number of heavy rainfall and floods by months (2010-2021)(5).

3.1.Heavy rains and flash floods increase in June

According to the records of the General Directorate of Meteorology (MGM), heavy rainfall and flood disasters in Türkiye increased between 2010-2022. In this period, monthly heavy rainfall and flooding occurred mostly in June (Figure 2). According to MGM Report, more than 500 heavy rains and floods occurred in June.

In June of this year 2023, the flood disaster in cities such as Samsun, Sinop, Amasya, Çorum, Ordu, and Kastamonu caused loss of life and property. Most of the accidents that caused loss of life and damage on railways due to heavy rain and sudden floods also occurred in June and July.

The difference of the June areal precipitations compared to the long-term normal precipitation in Türkiye

Figure 3.The difference of the June areal precipitations compared to the long-term normal precipitation in Türkiye (5).

In June, it is known as a month in which rainfall is normally lower in Türkiye. The General Directorate of Meteorology (MGM) calculated the long-term normal precipitation in June between 1991-2020 as 33.6 mm.

However, for the last 9 years, June rainfall has been above normal precipitation value (Figure 3). This rainfall fell as very heavy rainfall caused flash floods in several cities.

Department of Climate and Agricultural Meteorology Department of the General Directorate of Meteorology report (5) shows that the number of heavy rainfall and floods has increased over the years (Figure 4).

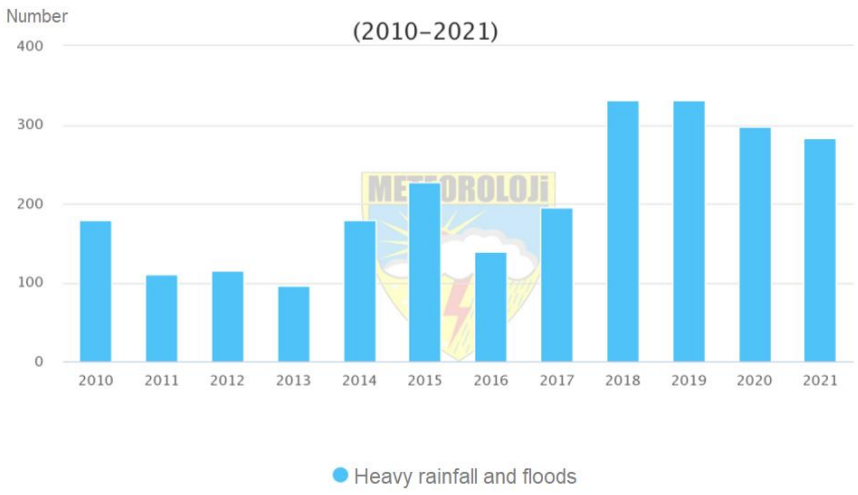

Figure 4. Total number of heavy rainfall and floods in Türkiye by years. (5)

4. Problems caused by heavy rainfall and flash floods

4.1.Halkalı-Edirne Railway Line-Çorlu -8 July 2018

Investigations showed that the Çorlu Train Accident, in which 25 citizens lost their lives and 317 citizens were injured on 8 July 2018, occurred when the wagons derailed as a result of the washing away the ballast and foundation material under the railway on the culvert due to heavy precipitation flooding (3).

A *culvert* is a *structure* that allows water to flow under a roadway or *railway*, In the accident nearby Çorlu town, the railway culvert capacity was insufficient and this caused the flood. Flood discharge flowing over the railway infrastructure washed away the soil between the rail and the culvert (Figure 5,Figure 6).

Figure 5 . Çorlu Train Accident Area (3).

In the report prepared by the relevant Department of the Ministry of Transport on the train accident in Çorlu (3), it was mentioned that "*Since no train or personnel is working on the line that can see this heavy rain and the damage it has started to cause to the infrastructure, there has been no notice or warning to prevent the accident.*"

Figure 6. The ballast and foundation material on the culverts washed away by flowing water over the infrastructure

In the same report(3), it was also mentioned that "*it has been revealed that the procedures to be carried out on the road after the heavy rain, the principles of which are specified in the "*Director General of the *Turkish* State *Railways* (*TCDD) Line Maintenance Handbook and the general order No. 105, are not sufficient to prevent the accident in the local, unexpected, non-registered line sections. It is insufficient for the personnel responsible for controlling the railroad with conventional methods. It has become a necessity to monitor the bridges, culverts, and tunnels on the railway lines with advanced technologies "*

4.2. Aydın-İzmir Railway Line -4 June 2023

Figure 7. Damaged railway line after the flood

Some part of the Aydın -İzmir train line nearby Denizli City Goncalı district was flooded. Heavy rain turned into a flash flood in this part of the railway. During the flood, the soil under the tracks was washed away and the railway line collapsed. A possible train disaster was prevented by the citizens who noticed the situation and stopped the train. Investigation showed that the discharge capacity of the culvert on the train line was insufficient. Gökpınar Stream was flooded and this caused the flow over the railway washed the bedding materials away and the line to collapse (Figure 7,8).

Figure 8**.** During the flood, the soil under the tracks was washed away and the railway line collapsed.

4.3.Ankara-Sivas High-Speed Train Line -18 June 2023

Another aspect of rail vulnerability relies on reduced soil stability triggered by climate change impacts, such as heavy precipitation or temperature fluctuation

In Türkiye, there is still 2032 km high-speed train line in operation(3). In high-speed train operation, many safety measures are taken, including the guide train service before scheduled train service with passengers. On 18 06 2023, heavy rainfall affected the high-speed railway line infrastructure between Sivas and Yozgat.

Figure 9.Railway line and derailed guide train

The Guide Train, which set out to check the road safety on the Ankara-Sivas High-Speed Train line on 18.06.2023 before the first High-Speed Train (HST) expedition, was derailed due to the heavy rain emptying of the ballast under the rails and sleepers near Yozgat City(Figure 9). After the heavy rain experienced, the derailment of the guide train, which had set off for control, prevented a possible accident similar to the Çorlu accident.

5.General Evaluation

One of the most critical vulnerabilities in the railway transport system is the low flexibility of both infrastructure and operations in the event of disturbances

In Türkiye, increasing heavy rain associated with flooding in recent years necessitates studies on recalculating the culvert's discharge capacity and how to discharge flash floods safely through the railways culverts, and bridges. In this context, it is of great benefit to review the discharge capacities of all highway and railway culverts taking into account the new precipitation regime and current meteorological and hydrological conditions. In this context, the capacities of all culverts that are likely to have low discharge capacity as a result of new hydrological calculations should be safely increased. In addition to the culverts, there is also a need to review the bridges, and tunnels on the railway lines.

The change in the precipitation regime threatens the safe operation of railway lines. After heavy rains the soil under the tracks is washed away by flash floods and the railway line is collapsed. Then train accidents occur due to the absence of signs of line disturbance on the approach route, and the absence of any warning in the signaling and electrification systems.
Extreme weather events, such as heavy rain and associated flooding require both infrastructure and operational resilience should be developed in railways.

5.1.Advanced detection systems are required for the control and surveillance of the line.

It has been revealed that the operations to be carried out on the railroad after the excessive rainfall, the principles of which are specified in the Director General of the *Turkish* State *Railways* (TCDD) Line Maintenance Manual is insufficient for controlling the road with traditional methods. For this reason, it becomes a necessity to monitor the bridges, culverts, and tunnels on railway lines with advanced technologies.

Extreme meteorological conditions that cause problems revealed the need for closer coordination between the railway infrastructure operator TCDD and the General Directorate of Meteorology.

5.2.The railway infrastructure maintenance concept needs to be renewed

Routine control/maintenance is considered sufficient since many culverts still existing on the railway lines have not encountered a similar flood before. However, the damages on the lines due to the new precipitation regime reveal that these routine controls and maintenance are not sufficient.
For this reason, the infrastructure maintenance concept and other instructions and procedures of the railway infrastructure operator should be revised, taking into account the danger of "flooding" that occurs as a result of local, sudden heavy rains that we have started to experience more frequently in Türkiye.
Therefore new maintenance and operation concepts and traffic operation instructions need to be prepared with the opinions and support of expert institutions and organizations (Meteorology, State Hydraulic Works (DSI), etc.) (3).

6. Conclusions and Recommendations

Climate change poses significant challenges for railways in Türkiye. Extreme meteorological events, such as heavy rain and flash floods create a negative impact on railway infrastructure. Three case studies showed that railways are not vulnerable to the threat of climate change-induced flash floods. They can cause severe damage to railway infrastructure.

To mitigate the effects of climate-induced flash floods on railways we need to adopt various measures, particularly the use of advanced technologies for monitoring and predicting natural disasters, including satellite imaging, remote sensing, geographic information systems (GIS), and other advanced data analysis tools. By using these tools, the railways can be classified into areas with higher risk and potential risks and take preventative measures to mitigate the risks.

It is obvious that climate change could increase the frequency and severity of extreme weather. Therefore it is vital to check and recalculate the discharge capacity of railways culverts and bridges by using the most up-to-date hydrometeorological data and expertise.

In addition, setting new safety procedures, and investing in advanced monitoring systems and detection technology is also important. In some flooding-prone parts of the railways' network, high-water sensors or damage detectors can send notifications about track conditions to approaching trains, helping them determine whether to slow the train or perform an inspection before passing.

6.1.Priority recommendations

- Developing projects with modern detection systems and advanced monitoring technologies. that will make it possible to monitor the extraordinary conditions that will endanger railway traffic in engineering structures such as bridges, culverts, and tunnels on railway lines,

- Recalculating the flow rates of bridges and culverts considering new meteorological and hydrological conditions, and taking measures for places deemed insufficient,

- Railways organizations should establish a coordination structure with the Meteorological Institutions It should provide education and training courses on meteorology to the relevant personnel at a level that can interpret the incoming data,

- Preparing a new regulation or revising the existing legislation regarding the measures to be taken in such floods, which generally occur in summer, and the procedures to be carried out by maintenance, traffic, and train personnel,

- Elimination of organizational deficiencies that will ensure compliance with the inspection procedures specified in the Line Operation and Maintenance Manual,

- A "Guidebook for Enhancing Resilience of Rail Transport in Extreme Weather Events" should be prepared that splits responses to extreme weather events into long-term planning measures, actions to be taken immediately before the event, and recovery actions.

7.References

[1] G. Alimonti, L. Mariani, F. Prodi, and R. A. Ricci, "A critical assessment of extreme events trends in times of global warming," Eur Phys. J. Plus, vol. 137, no. 1, Article ID: 112, 2022. https://doi.org/10.1140/epjp/s13360-021-02243-9.

[2] S. Roy, P. Debnath, and S. Mitra, "Impact of climate disasters on railway infrastructure: A case study of Northeast India," Acadlore Trans. Geosci., vol. 2, no. 1, pp. 33-45, 2023. https://doi.org/10.56578/atg020104.

[3] 8 Temmuz 2018 Tarihindeki 12703 Numaralı Trenin Deray Kazasına İlişkin Kaza İnceleme Raporu
Demiryolu Kaza İnceleme Raporu Rapor No:1/DMY-5/2019 23 AĞUSTOS 2019. T.C. Ulaştırma ve Altyapı Bakanlığı Ulaşım Emniyeti İnceleme Merkezi Başkanlığı.
[4] Yıldız D.(2023) " Ani Seller Demiryolu Güvenliğimizi Tehdit Ediyor " Su Politikaları Derneği. Rapor No: 51. Ankara.21 Haziran 2023

[5] Türkiye Meteorolojik Afetler Değerlendirmesi (2010-2021) Raporu .T.C. Çevre, Şehircilik Ve İklim Değişikliği Bakanlığı Meteoroloji Genel Müdürlüğü. Ankara

[6] Rossetti A.M. (2003) "Potential Impacts of Climate Change on Railroads" available at https://trid.trb.org/view/663830

[7] S. Roy, P. Debnath, and S. Mitra, (2023) "Impact of climate disasters on railway infrastructure: A case study of Northeast India," Acadlore Trans. Geosci., vol. 2, no. 1, pp. 33-45, 2023. https://doi.org/10.56578/atg020104.

[8] Ochsnera M., Palmqvista W.C., Olssonc E.O.N., Hiseliusa W.L.(2022) The effects of flooding on railway infrastructure: A literature review.Transport Research Arena (TRA) Conference Available online at www.sciencedirect.com

[9] Dikanski, H., Hagen-Zanker, A., Imam, B., Avery, K., 2017. Climate change impacts on railway structures: bridge scour. Proceedings of the Institution of Civil Engineers - Engineering Sustainability 170.5, 237–248. https://doi.org/10.1680/jensu.15.00021

[10] Doll, C., Trinks, C., Sedlacek, N., Pelikan, V., Comes, T., Schultmann, F., 2014. Adapting rail and road networks to weather extremes: Case studies for southern Germany and Austria. Natural Hazards 72.1, 63–85. https://doi.org/10.1007/s11069-013-0969-3

[11] Armstrong, J., Preston, J., Hood, I., (2016). Adapting Railways to Provide Resilience and Sustainability. Engineering Sustainability

Biography

Dursun Yıldız (Msc.) is a hydropolitics specialist and Director of the Hydropolitics Academy Association located in Ankara-Turkey.He is a civil engineer and used to be Deputy Director at State Hydraulic Works in Turkey; completed a hydroinformatics post graduate course at the IHE in Delft, a Technical training program in USBR-USA, and a master's degree in Hydropolitics at the Hacettepe University-Turkey. He has over 5 years of teaching experience in some Turkish Universities and now works as head of his own Hydro Energy & Strategy consulting company located in Ankara. He has published several international articles and 15 books. He received the Most Succesful Researcher Award on International Water Issues from Turkish Agricultural Association in 2008 and from the Central Union of Irrigation Cooperatives in 2016. He received the Professional Services Award of Excellence from İstanbul Çekmeköy Rotary Club in 2021. He becomes a part-time lecturer at the IZTECH International Water Resources Department in In the 2020-2021 academic year

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