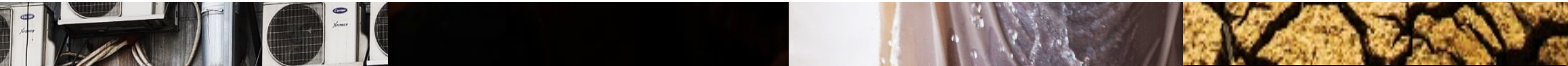
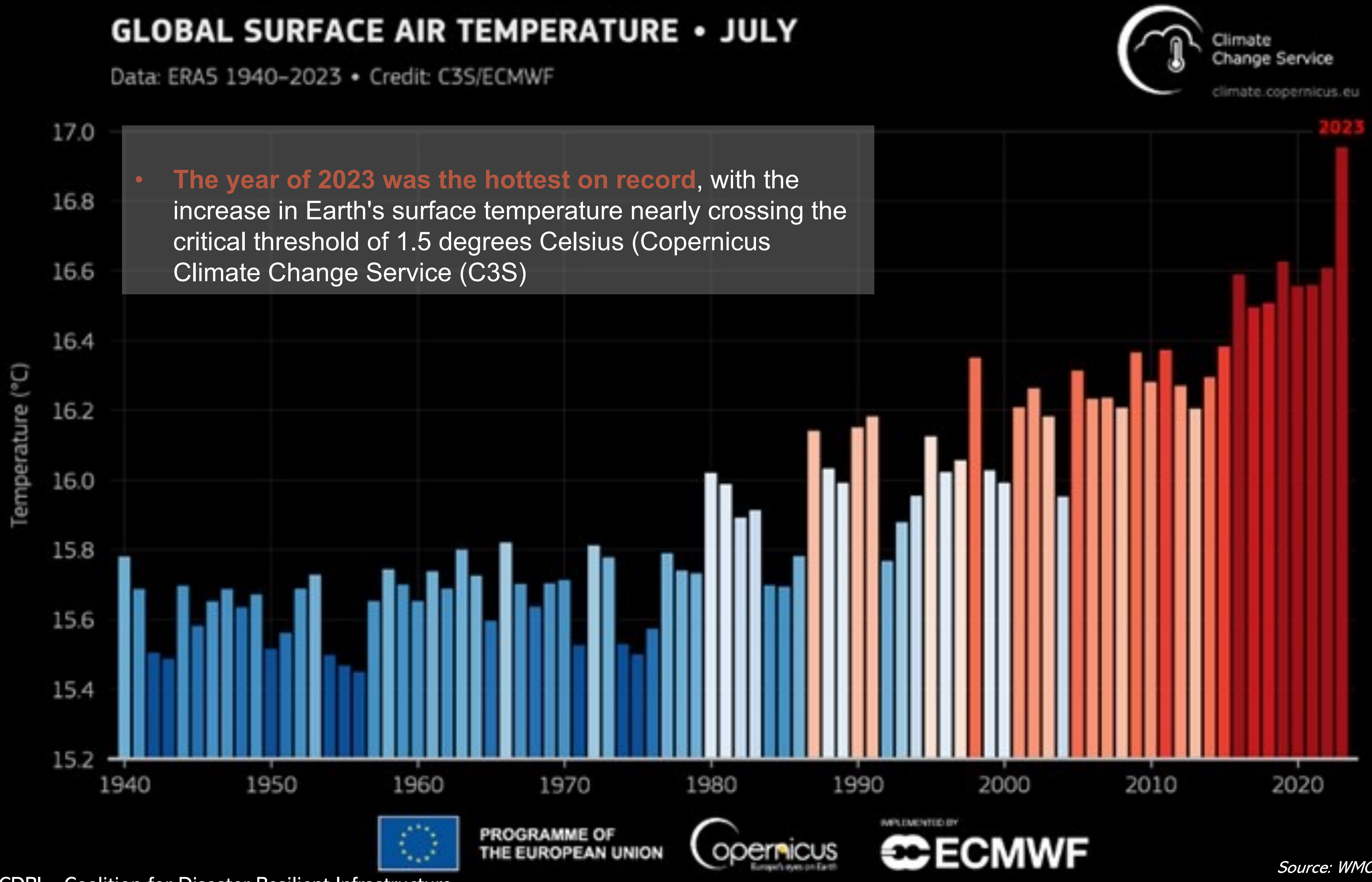

CDRI
Coalition for Disaster Resilient Infrastructure

# Risks to Critical Infrastructure due to Extreme Heat



- **The year of 2023 was the hottest on record**, with the increase in Earth's surface temperature nearly crossing the critical threshold of 1.5 degrees Celsius (Copernicus Climate Change Service (C3S)




*Source: WMO Website, 2023*

# Buildings

Melted rooftop of the Forbidden City Cultural Relics Museum in China amid a blistering heatwave in July 2022

- *Every one-degree increase in classroom temperature leads to 1% decrease in learning ability amongst students.**

*Source: Art World website, July 2022*
**Heat and Learning, Joshua Goodman, Michael Hurwitz, Jisung Park, and Jonathan Smith, NBER Working Paper No. 24639, May 2018, JEL No. I20,J24,Q5*

# Roads

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*Melted asphalt of road in New Delhi during the heatwave in May 2015*

- *In EU, the annual cost of heat and drought damage to the road sector from 1998 to 2010 was estimated to be 50 million Euros.*

*Source:: SBS News website, 2016*

# Railway

*Buckled railway tracks in UK during heatwaves in July 2022*

- *In the US, sun kinks (buckling of rail) caused over 2,100 train derailments in the last 40 years, equivalent to around 50 derailments per year.**

*Source:: Network Rail UK*

**https://www.scientificamerican.com/article/sun-kinks-in-railways-join-the-list-of-climate-change-s-toll/*

# Hydropower

*Lake Oroville in California in 2021, when the major West Coast reservoir sat at a dangerously low level.*
*The region faced severe drought driven by heatwaves*

- *A projected decrease of 20% in renewable water resources is expected for each 1°C rise in the global average temperature.**

*Source::AP News website 2021*

**Jiménez Cisneros, B.E., T. Oki, N.W. Arnell, G. Benito, J.G. Cogley, P. Döll, T. Jiang, and S.S. Mwakalila, 2014: Freshwater resources. In: Climate Change 2014: Impacts,Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 229-269*

# Buildings

- Creation of heat island in dense areas
- Productivity loss and health issues
- Reduced life of buildings due to deterioration of materials
- Increased energy demand and shortages in hospitals
- Loss of working hours in schools
- Increased demand leading to water shortage
- Impact on outdoor workers

# Transportation

- Softening, rutting and melting of bitumen/ asphalt
- Heat warping, curling, cracks in concrete roads
- Subgrade shrinkage
- Pier expansions and damages to bridges
- Buckling, warping and expansion of railway tracks
- Melting of runways
- Flight delays due to increased thrust required for takeoff

# Energy

- Increased peak loads due to cooling demands
- Reduced grid efficiency
- Grid failures
- Increased transmission and distribution losses
- Blackouts and brownouts
- Sagging of overhead lines and flashovers
- Decrease in lifetime of transformers

# Railway

Impact

### Type of impact

- Expansion ("sun kinks"), buckling, warping of tracks
- Damage to power supply lines - Reduced speed
- Temp. of 39 C or more can render intercity train tracks unsafe.
- Rail-track deformities; air temperature above 43°C (110°F) can lead to equipment failure
- Damage to rail infra. due to permafrost thawing

### Cost of Impact

- Cost arising from operations delays in US due to temp. increase can range from $103 to $138 billion by 2100 at a 3% discount rate
- 750 train services out of 2,400 had to be cancelled in Melbourne during 2009 heatwave.
- By 2050, repairs of thaw-damaged railroad sections in Alaska are expected to cost about $2 billion under current climate trajectory

Solutions

### Type of Adaptation

- Greater use of continuous welded rail lines
- Providing expansion joints between short lengthened tracks
- Mobile track gangs with water to cool tracks during hot weather
- Innovations in track management and potential changes in track materials (Solid concrete slabs, ballast less tracks)
- Painting rails white can reduce the temperature by 5°C to 10°C
- A pulley system keeps overhead wires tense and compensate for sag
- Replacement of timber sleepers with concrete sleepers
- Avoiding connection of signalling system to local domestic power supply

### Cost of Impact

- Laying tracks over solid concrete slabs is 4x expensive than normal
- Australian Rail Track Corporation (ARTC) through their $400 million project replaced 2.2 million wooden sleepers with concrete sleepers.
- This along with $100 million concrete re-sleepering project helped in reducing speed delays in summer due to buckling of rail.

# Railway



## Information available

### Alerts/Warnings

- RENFE, the Spanish rail operator, uses a tool for predicting weather events. During heatwave alerts above 38 °C, the Travel Management Centre provides recommendations for addressing air conditioning deficiencies and implementing preventive measures for closing doors
- Sensors fitted on overhead wires to collect weather data including temp. in HS2, the new highspeed railway in UK.
- Digital twin of HS2- A digital representation of the railway network - helps to simulate future scenarios and predict the impacts of high temp. and plan preventive action

### Data/Information

- Infrastructure condition assessments
- Asset management information
- Thermal expansion data (thermal expansion characteristics of materials)
- Real time track temp.
- Network Rail, UK has 'mini weather stations' and thousands of track-side probes to monitor local conditions along the railway.

## Guidelines and SOPs

- Weather Resilience and Climate Change Adaptation Strategy 2017-2019 - Network Rail,UK
- Rail Adapt -Adapting the railway for the future - International Union of Railways (UIC )
- Tomorrow's Railway and Climate Change Adaptation: Executive Report, Rail Safety and Standards Board Limited,UK
- Rail Infrastructure Resilience: A Best-Practices Handbook, Elsevier
- Eurotunnel have an established a Heatwave plan requiring increased shift turnover of staff between indoor and outdoor positions, possible installation of water mist equipment in loading areas and the possibility of reducing the number of vehicles loaded onto each shuttle.
- Rail- Resilience Primer by The Resilience Shift

### Existing initiatives/programmes/partnerships

- International Union of Railways (UIC) - Projects: ARISCC project ( Adaptation of Railway Infrastructure to Climate Change) , UIC RailAdapt project.

### Gaps and Challenges

- Asset management systems to better operations and maintenance during heat waves
- Impact based warnings specific to railway assets
- Standards for railway infrastructure to reduce impact of higher temperature in cold weather countries

# Roads & Bridges

## Impact

### Type of Impact

**Roads**

- Softening, rutting and melting of bitumen/ asphalt, appearance of heat bumps
- Concrete roads: heat warping, temperature-related curling, transverse crack formation, "blow-ups" as moist base layer expand
- Subgrade shrinkage and loss of bearing capacity
- Thawing of permafrost causes subsidence of roads and rail beds, cave-in of bridge supports, pipelines, and runway foundations
- Damage to Intelligent Transport Systems

**Bridges**

- Thermal expansion of piers, cracking of metal structure
- Stress on bridge integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coats and sealants.

**Tunnels**

Operation and performance of ventilation systems will be impacted

### Cost of Impact

- Estimated total cost due to heat & drought on road sector in EU for the period 1998-2010 is 50 million Euros annually
- Maintenance and construction costs for roads and bridges are likely to increase as temperatures increase.
- Fixing pavement distress caused by a 2011 heat wave and drought cost the Texas DoT $26 million
- At current climate trends, the cost to replace thaw-damaged road sections in Alaska will be over $19 billion by 2050. By 2013
- Road-maintenance costs caused by thawing permafrost in one district itself had reached $11 million a year

# Roads & Bridges

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**Solutions**

## Type of Adaptation

- Cool Pavements - cool-colored coatings for asphalt concrete, use a clear binder that reveals highly reflective (light-colored) aggregate
- Shade with trees, building overhangs, Vegetation interlocking paving, highway landscaping
- Replace or reconstruct bridge deck expansion joints
- Development of new, heat-resistant paving materials
- Greater use of heat tolerant steel
- Concrete roads/rigid pavements: better accounting for coeff. of thermal expansion and drying shrinkage of concrete, shorter joint spacing to reduce warp stress, using thicker slabs and/or less rigid base material, installing flexible expansion joints between slabs

## Cost of Impact

- Cost of cool pavements varies depending on various factors. But it has multiple benefits like such as improved stormwater management and water quality
- Lighter-colored, more reflective roads can reduce temp. more than 1.4C. (*upto 5C diff. in temp. in LA*)
- Typical asphalt sealants cost about $4.40 per sq yd, while the cool pavement reflective sealants cost about $5 per sq yd (Phoenix city, USA)
- Benefit: cool pavement reduced heat wave impact by 41% in US cities

**Information available**

## Alerts/Warnings

- **Cool routes app in Melbourne** shows streets and spaces that are relatively cooler during time of heatwaves.
- Tool to predict swelling of bridge during heat wave in Netherlands
- **Heat Health Alerts in UK**- New Impact based EWS operational from June 2023 which will give warning on national critical infrastructure failures – such as generators and power outages or major roads and rail lines closed due to melting roads or overheating rail lines
- **Korea Meteorological Administration (KMA)** has an impact based warning system which provides risk levels impact information and response tips for various sectors including transport and power

## Data/Information

- Type of pavement material and its grade (upper bound temperature)
- Bridge Deck Temperature
- Road Traffic Data

# Roads & Bridges

## Guidelines and SOPs

- California Extreme Heat Action Plan, 2022, TRACK C - GOAL 1, E3: Support communities seeking to invest in heat-resilient transportation infrastructure.
- Cool Roofs And Cool Pavements Toolkit (s)
- Climate Change and Extreme Weather Vulnerability Assessment Framework-guide and collection of resources for use in analyzing the impacts of CC and extreme weather on transportation infra. by Federal Highway Administration, US
- Climate Change, Extreme Weather Events, and the Highway System: Practitioner's Guide and Research Report National Cooperative Highway Research Program (NCHRP) Report, US
- A Methodology for Incorporating Climate Change Adaptation in Infrastructure Planning and Design: Bridges, USAID
- Application of solar heat-blocking pavement: an environmentally friendly pavement technology, Published in the PIARC magazine

## Existing initiatives/programmes/partnerships

- Cool Roadways Partnership (website)
- PIARC - Technical standards
- International Transport Forum

## Gaps and Challenges

- Lack of infrastructure-specific impact-based warning systems: Current impact-based warning systems lack the ability to consider factors such as the temperature of pavements, bridges, and material composition.
- Increasing heat thresholds of infra. for adaptation during heatwaves can lead to increased stress during cold weather in colder climates, requiring updated standards and guidelines.
- Limited guidance documents on extreme heat adaptation in transport infrastructure

# Aviation

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## Impact

### Type of impact

- Melting of runways
- Damage to navigation equipment and thermal expansion of airfield equipment (aprons, hangars)
- Aircrafts require more thrust, lighter takeoff weight and longer runways for takeoff leading to cargo restrictions, cruise altitude changes, flight delays, and cancellations.
- Problem is exacerbated at high-altitude airports.
- Impact on fuel handling and storage, due to maximum temperature restrictions
- Permafrost thawing may lead to ground instability causing damage both to aircraft movement areas (holes and buckling), and infrastructure integrity and stability

### Cost of Impact

- Reduction in payload (passengers or cargo)
  - ✓ Increased temp. and water vapor will cause summer cargo loss of approximately 17% and 9% for a single Boeing 747 at Denver and Phoenix airports by 2030
  - ✓ 50 flights were grounded in Phoenix, Arizona in July 2017 as temp. reached 48C
  - ✓ If no adaptation measures are taken, then 200-900 flight groundings by 2030 and 500-2200 by 2050 globally

## Solutions

### Type of Adaptation

- Lengthening of runways; innovative runway cooling methods.
- Improving aircraft technology
- Runway surface treatments
- Enhanced pavement design
- Cooling measures for aircraft
- Innovative designs of terminal buildings
- Reinforcement or elevation of runways and access roads, and relocation of facilities in permafrost thaw affected areas

### Cost of Impact

- Resurfacing done at Queensland's Emerald Airport runway using Stone Mastic Asphalt (SMA) which can withstand higher temp.
- SMA used at Emerald Airport cost 4% more up front but will provide an increase of around 4-6 years on the time-to-maintenance compared with dense graded asphalt.

# Aviation

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## Information available

### Alerts/Warnings

- Aerodrome Weather Warnings Service by Met office, UK - Warnings to aviation users, including airport operators, air traffic control units, and general aviation pilots
- Warnings by NOAA (refer : A Pilot's Guide to Aviation Weather Services)

### Data/Information

- Temperature Inversion (an increase in air temperature of 10C or more in the lowest 1000ft) (UK Met office)
- Permafrost depth and land subsidence at airport location

## Guidelines and SOPs

- Standard Operational Procedure for Aviation Meteorology (IMD)
- A Pilot's Guide to Aviation Weather Services (NOAA, US)
- Policy Brief: Airports' resilience and adaptation to changing climate, ICAO
- ICAO Airport Planning Manual (2018)
- ICAO Climate Adaptation Synthesis (2018)
- Climate Resilient Airports, ICAO Toolkit
- Standard Operational Procedure for Aviation Meteorology (IMD)
- A Pilot's Guide to Aviation Weather Services (NOAA, US)
- Policy Brief: Airports' resilience and adaptation to changing climate, ICAO
- ICAO Airport Planning Manual (2018)
- ICAO Climate Adaptation Synthesis (2018)
- Climate Resilient Airports, ICAO Toolkit
- ICAO Climate Risk Assessment, Adaptation and Resilience Report: (3 reports in this series) (2022)

1. Key steps in Aviation Organisation Climate Change Risk Assessment and Adaptation Planning
2. Key climate change vulnerabilities for aviation organisations
3. Menu of adaptation options

# CDRI Focus


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1. Share examples from Coalition partners on addressing risks to critical infrastructure from Extreme Heat
2. Identify data gaps and opportunities for Early Warning for Utility Providers
3. Develop SOPs and Guidelines in partnership with critical infrastructure providers and support capacity building activities
4. Facilitate research and innovation on new solutions
5. Organize communities of practice for continued dialogues

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# Thank you