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THE ROLE OF SATELLITE COMMUNICATIONS IN DISASTER MANAGEMENT

SUPPORTING ORGANIZATIONS

Access Partnership

— Since 1999, Access Partnership research focuses on policy and its effects on technology and people. Through close relationship with many governments around the world, and providing expertise in predicting the effects of future regulations, the company has helped countries and the private sector manage the outcomes of policy trends.

AlphaBeta

— AlphaBeta is a strategic economics consultancy, founded in 2015 by pragmatic economists. One of their thematic focus is sustainability where they help corporations, investors, governments, and NGOs identify risks. They have previously supported WEF in the development of the BiodiverCities 2030 report, which further supported their work with the Tropical Forest Alliance in identifying commodity-driven deforestation.

CANLA – Climate Action Network

— CANLA is a regional network of non-governmental organizations committed to fighting the harmful effects of climate change in Latin America. CANLA seeks to carry out public advocacy to urgently combat the impacts of climate change from a science-based approach. The organization is committed to climate justice and prioritizing Human Rights as part of their advocacy efforts. Through their work, CAN empowers a wide range of civil society organizations.

INDEPENDENT REVIEWERS*

GSOA/ESOA – EMEA Satellite Operators Association

— The pre-eminent platform for collaboration between satellite operators. The organization delivers a unified voice for the sector. GSOA provides thought-leadership and is a recognized representative body for traditional satellite operators at international, regional, and national bodies. The vision of GSOA/ESOA is to improve the state of global communications by bridging satellite technologies, education, health, social, gender and economic divides across diverse geographies and across mature and developing economies.

TSF – Télécoms Sans Frontières — Télécoms Sans Frontières (TSF) was founded in 1998 as the world's first NGO focusing on emergency-response technologies. TSF is a member of the United Nations Emergency Telecommunications Cluster (UNETC), a partner of the Office for the Coordination of Humanitarian Affairs (UNOCHA) and the Association of Southeast Asian Nations (ASEAN), and a member of the US State Department's Advisory Committee on International Communications and Information Policy. They deploy rapid-response communications equipment during humanitarian crises.

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*GSOA/ESOA and TSP have peer-reviewed this Whitepaper. The opinions and positions in this paper are those of supporting organizations only, not those of GSOA/ESOA nor TSP.

EXECUTIVE SUMMARY

Telecommunications regulatory frameworks can be developed to improve disaster management worldwide in the face of increasing hazards caused by climate change. The use of satellite-enabled technology allows for the enhancement of relief services, which save lives and reduce cost during emergencies, particularly where cellular networks cannot reach.

This Whitepaper highlights the impact these technologies can have and provides a roadmap to ensuring they can be taken up quickly by all countries that face natural or man-made catastrophes. It brings to light the effects of a wider use of satellite connectivity and integrating a global connectivity revolution in emergency services, by identifying the infrastructure gap between high-income and low-income countries, while analyzing how policy guidelines from multilateral organizations need to be adapted. Considering the long-term human and economic consequences of maintaining inadequate National Emergency Telecommunications Plans (NETPs), the recommendations listed hereafter serve as guidance for governments, the private sector, regional organizations, and supranational entities to act upon to expedite the application of existing and fast-developing technological solutions to the safety of life.

AT A GLANCE

A GLOBAL CHALLENGE

- The number of disasters is increasing globally at an exponential rate, even under the most conservative forecast.
- Every region, including currently less affected jurisdictions, may face natural disasters, emergencies, and threats that require effective emergency communications plans.

ECONOMIC COST AND HUMAN LOSS

- Next-generation satellite-enabled connectivity can facilitate the digital revolution required to save millions of lives and reduce GDP expenditure significantly
- The economic burden in low-income countries is disproportionate – enabling further cooperation with the emerging satellite sector will help utilize operators' networks and scalability.

INFRASTRUCTURE ADEQUACY AND DEPLOYMENT

- Complementarity between multiple networks for disaster management will always be required, as no single deployment model is sufficient to cope with the number and nature of projected hazards and the geographical diversity of different areas.
- The landscape of each jurisdiction may define the best deployment alternatives for a given country. However, the need for complimentary satellite-enabled connectivity is a must for even highly connected telecommunications markets, who also have underserved areas.

POLICY AND REGULATORY FLEXIBILITY

- The role of policy and regulation is key to guarantee responses are both effective and timely. For this, defining the institutional roles that are applicable during disaster and emergency management is of paramount importance.
- Licencing and authorization frameworks need to seriously consider the human and economic importance of enabling complimentary satellite-enabled connectivity in future years.
- More agile regulatory guidelines for the fast deployment of highly needed emergency communications technology are required.

CONTENTS

INTRODUCTION

Support is not limited to the commercialization and sharing of equipment, satellite service providers have historically helped predict, map out and deliver live information to minimize damage and casualties during natural disasters and emergencies. The satellite industry's Environmental, Social and Governance (ESG) commitment has been built organically by the very nature of its service provision[1], yet the humanitarian collaboration has gone beyond what is expected from companies, particularly during rescue activities, often channelled through UN agencies[2] or NGOs such as Telecoms Sans Frontieres (TSF)[3] and national security forces.

Governments around the world are aware of the importance of reinforcing their emergency response plans by expanding on their national satellite communication uptake. However, studies of disasters in recent years[4] suggest that the magnitude and immediacy of disasters and emergencies will overwhelm existing National Emergency Telecommunications Plans (NETPs), and even the capacity of licensed terrestial service providers in some jurisdictions. National bodies have the capacity to guarantee this dynamism at least during emergency situations, and their basic instruments are NETPs, licensing and exemptions schemes, and private-public collaborations.

Multilateral organizations, and particularly the International Telecommunications Union (ITU), through its different arms, have guided Governments to promote regulatory measures that permit a better satellite communication offering during emergencies. National proactivity is now required to implement guidelines provided by such organisations to guarantee national resilience as the incidence of increasingly complex natural disasters grow across the globe (an approximate 37% increase as per our analysis). Although current policy options and alternatives are considered in this paper, the importance of a fast-changing and highly innovative satellite industry should be highlighted, with an emphasis on the role of the private sector in providing connectivity when needed.

Satellite service providers have historically helped predict, map out and deliver live information to minimize damage and casualties during natural disasters and emergencies

Preparedness, as a climate adaptation concept[5] , is intrinsically connected to ensuring communications systems remain operational during inevitably difficult situations such as natural disasters. The different levels at which connectivity preparedness operates are national system communications, rescue forces-to-user communication, and user-to-user communication. In order to combat the user knowledge limitations faced by our present satellite solutions and their application in emergency response, a revolution is needed, and satellite-enabled technology is at the core of it. Because many vulnerable jurisdictions to climate change are unable to bear the financial cost associated with rapid intake of satellite technology, and the cost in human losses is irreplaceable, collaborative efforts are urgently needed to secure a safer and well-prepared future for generations to come.

ENHANCING DISASTER RESPONSE COMMUNICATION GLOBALLY

THE CURRENT AND FUTURE ECONOMIC IMPACT OF NATURAL DISASTERS

The number of natural disasters taking place in all regions of the world has been steadily increasing over the years, from an annual average of 161 disasters in the early 1980s to an average of 394 by the late 2010s (Figure 1). Due to the complex climate considerations and factors to be accounted for, it is difficult to project the future frequencies of natural disasters in exact terms. However, it is clear there is consensus among studies that the upward trend in natural disaster occurrences will continue. Examples of studies drawing this conclusion include:

- The Intergovernmental Panel on Climate Change (IPCC)'s sixth report released in 2021 indicated that climate change will contribute to an increase in sea levels throughout the 21st century. Extreme sea level events that previously occurred once in 100 years could potentially happen every year by the end of the century.[6]

- The International Monetary Fund (IMF) has reported that most types of weather-related disasters will become more common by the end of the 21st century, across all income group countries. Also, the frequency of disasters caused by heat waves, tropical cyclones, and wildfires are expected to rise considerably in the future.[7]

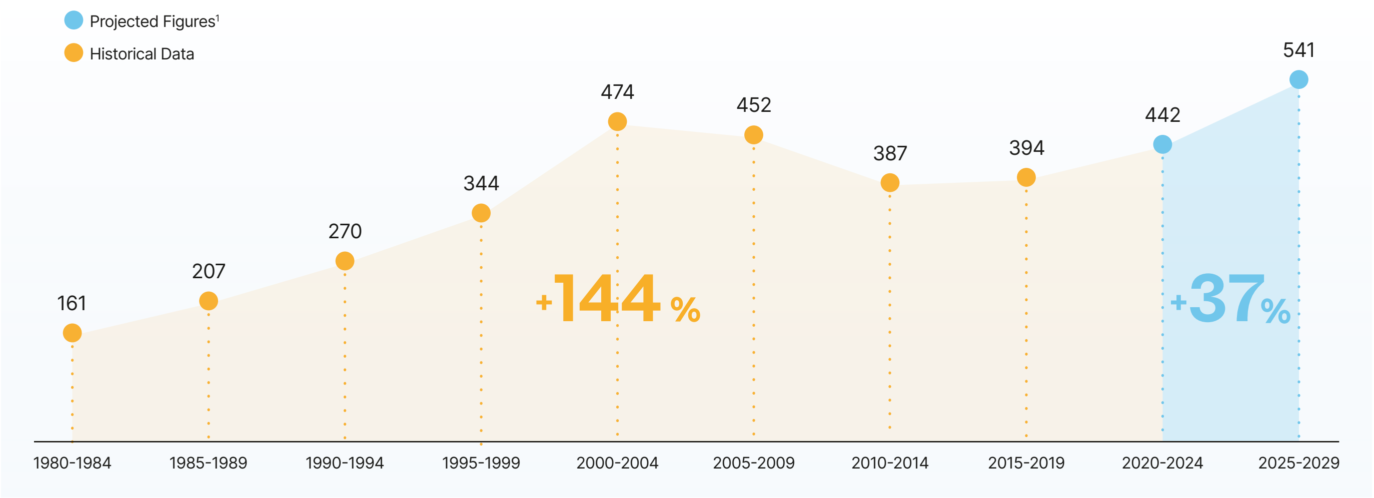
- The World Bank has reported that the number of drought days could increase by more than 20 percent in most of the world by 2080, with the risks of coastal floods increasing rapidly given the rising sea levels.[8]

- Vision of Humanity noted that the number of climate-related disasters globally has increased by ten times between 1960 to 2019.[9] It expects this trend to continue due to changes in climate conditions such as rising global temperatures.

- The World Meteorological Organization (WMO) states that climate change will lead to more extreme weather events, increasing their frequency and severity in many parts of the world.[10] Weather, climate, and water hazards currently already account for 50 percent of all disasters between 1970 to 2019.

Even with a conservative assumption that natural disaster occurrences continue to grow at the historical rate (which given the factors highlighted above, could be a significant underestimate), the annual number of natural disasters could increase by 37 percent by 2025-29 (Figure 1). A comparison of the estimated annual number of natural disasters across the different sources has also been made in the Appendix (Table 2) and reveals that the estimated number of occurrences aligns with available literature.

The number of recorded natural disasters has more than doubled between 1980-1984 and 2015-2019 - a trend likely to continue in the next decade



1. Projected based on the simple average of 5-year percentage changes in natural disaster frequencies over the past two decades, within each region.
Source: EM-DAT Universite catholique de Louvain (UCL) (2021), The Emergency Events Database. Available at: https://public.emdat.be

FIGURE 1: NUMBER OF NATURAL DISASTER EVENTS

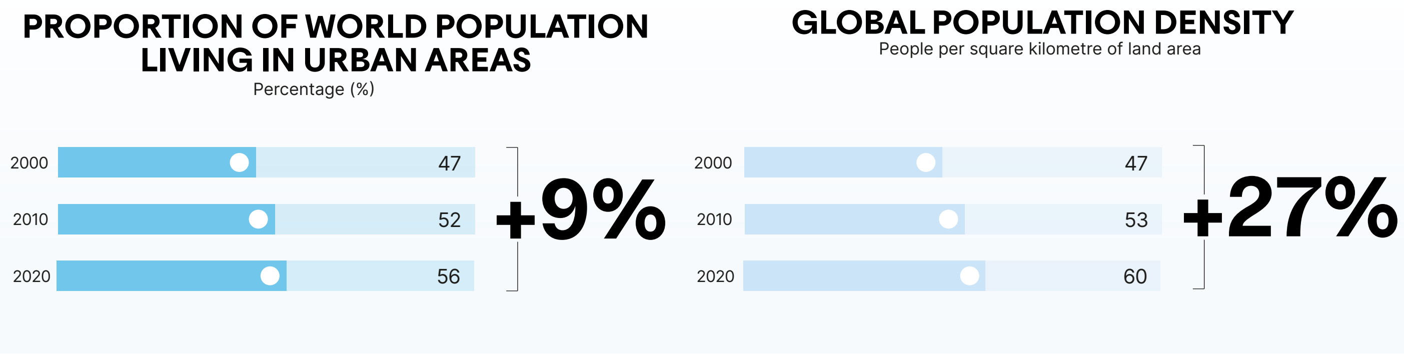
The economic impact of natural disasters is also expected to increase significantly. Consistent with the trend of the rising frequency of natural disasters, the average economic impact of natural disasters has increased by more than three times from an annual average of USD56 billion per annum between 1980 to 1984, to an annual average of USD199 billion between 2015-19 (Figure 2). In the United States (USA) alone, the average annual cost of natural disasters has grown by more than four times, from USD17.8 billion during the 1980s period to USD81.1 billion during the 2010s period.[11] These trends also correspond with estimates from the insurance and reinsurance industry. For example, data from Munich Re, a global reinsurance company, estimates that global disasters, exacerbated by climate change, produced a total of USD210 billion worth of losses in 2020 – 26.5 percent higher than its figure in 2019, which was worth USD166 billion.[12]

Much like the forecasts of natural disasters, there is a consensus that the total annual cost of natural disasters is expected to increase over the next decade, driven by three key global trends:

- **Climate change will intensify the impact (not just the frequency) of natural disasters.** The IPCC estimates that climate change will intensify for cities (as urban areas are usually warmer), with heat-related events, along with flooding from heavy precipitation and sea level rise, expecting to be amplified.[13] Rising quantities of evaporated sea water in the atmosphere will also lead to increasing intensity of storms and hurricanes, leading to severe flooding.[14] Due to these trends, the Cambridge Climate Change Business Risk Index estimates that climate change will add around 20 percent of the global cost of extreme weather events (considered to include storms, floods, and heatwaves) by 2040.[15]

- **The impact will be concentrated and increase among low- and middle-income countries, which are relatively less prepared to adapt.** As agriculture underpins the livelihoods of over 2.5 billion people who are mostly in developing countries, natural disasters disproportionately threaten the economic and food security stability of agricultural countries. In addition to the rising costs of climate change, the lack of financial resources available to developing countries to support their efforts to adapt to extreme weather events would lead to substantial costs building up over time. Natural disasters currently cost the agricultural sectors of these economies more than USD108 billion in damaged crop and livestock production. If the level of finance were to remain low, the United Nations Environment Programme (UNEP) estimates that climate change adaptation and natural disaster damages would cost developing countries between USD280 to USD500 billion per year by 2050, a figure four to five times higher than previous estimates.[16]
- **Urbanisation increases countries' exposure to climate-related disasters.** As the world population continues to grow, a higher population density and urbanisation level increases the vulnerability of these areas of human populations. This is evidenced by the rise in the proportion of the world's population living in urban areas from 47 percent to 56 percent, and a rise in global population density from 47 to 60 people per square kilometre between 2010 and 2020 (Exhibit 2). The rapid expansion of the built environment – a 66 percent increase in the urban land area in the first 12 years of the century – has significantly impacted the surrounding ecosystems, weakening traditional defences against natural disasters (e.g., mangrove destruction).[17] In addition, a large share of the population is now concentrated in areas with higher exposure to natural disasters. For example, roughly 40 percent of the world's population is located with 100 kilometres of the coast.[18] By 2050, population growth and rapid urbanization trends alone could put 1.3 billion people and USD158 trillion of insured assets at risk to river and coastal floods. Floods and tsunamis threaten cities and populations in coastal areas, while urban areas with rapid population growth are likely to be vulnerable to natural disasters due to larger populations living in high-risk areas.[19]

There is a trend of rapid urbanisation across the world, as seen by the rising share of urban populations and increasing population densities

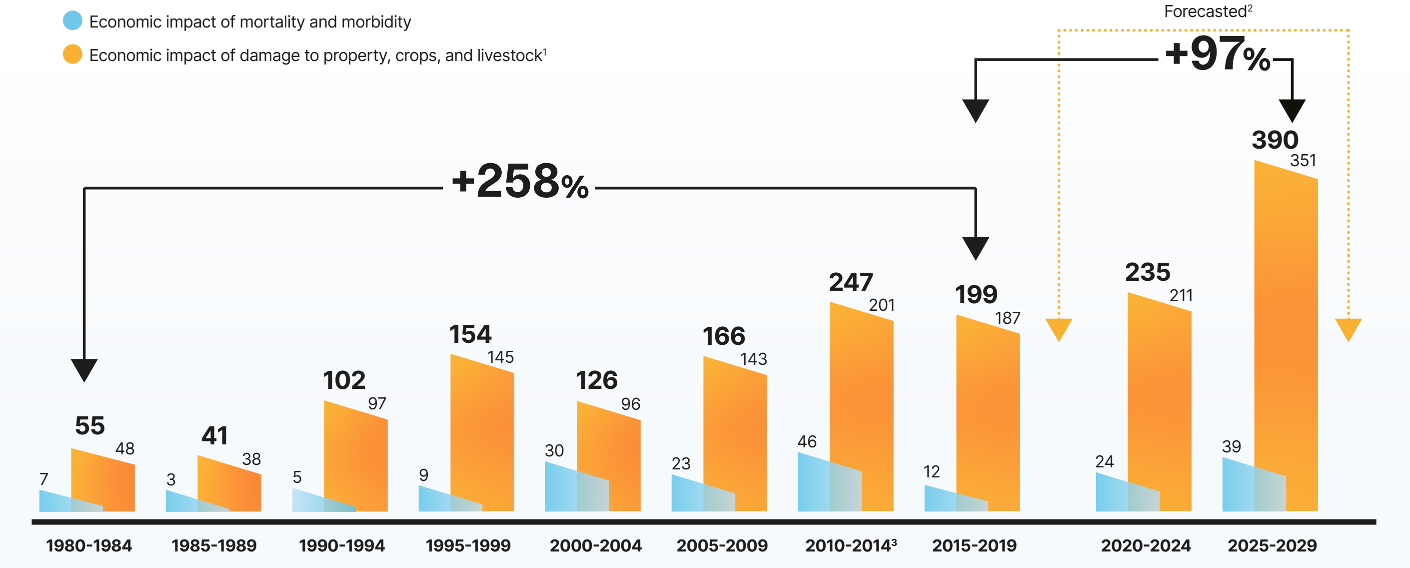


Sources include: World Bank (2020), "Urban population (% of total population)." Available at: https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS ; World Bank (2020), "Population density (people per sq. km of land area)," Available at: https://data.worldbank.org/indicator/EN.POP.DNST

FIGURE 2: INCREASING TREND OF URBANISATION

Again, assuming a conservative supposition that the cost of natural disasters continues to grow at the same rate as historically, the average annual economic impact of natural disasters will grow by 97 percent from USD199 billion in 2015-19 to reach USD390 billion in 2025-29 (Figure 3). A comparison of the estimated annual economic impact of natural disasters across the different sources has also been made in the Appendix (Table 3) and reveals that the estimated economic impact aligns with available literature.

There is a general rising trend in the economic impact of natural disasters, particularly driven by extreme weather.



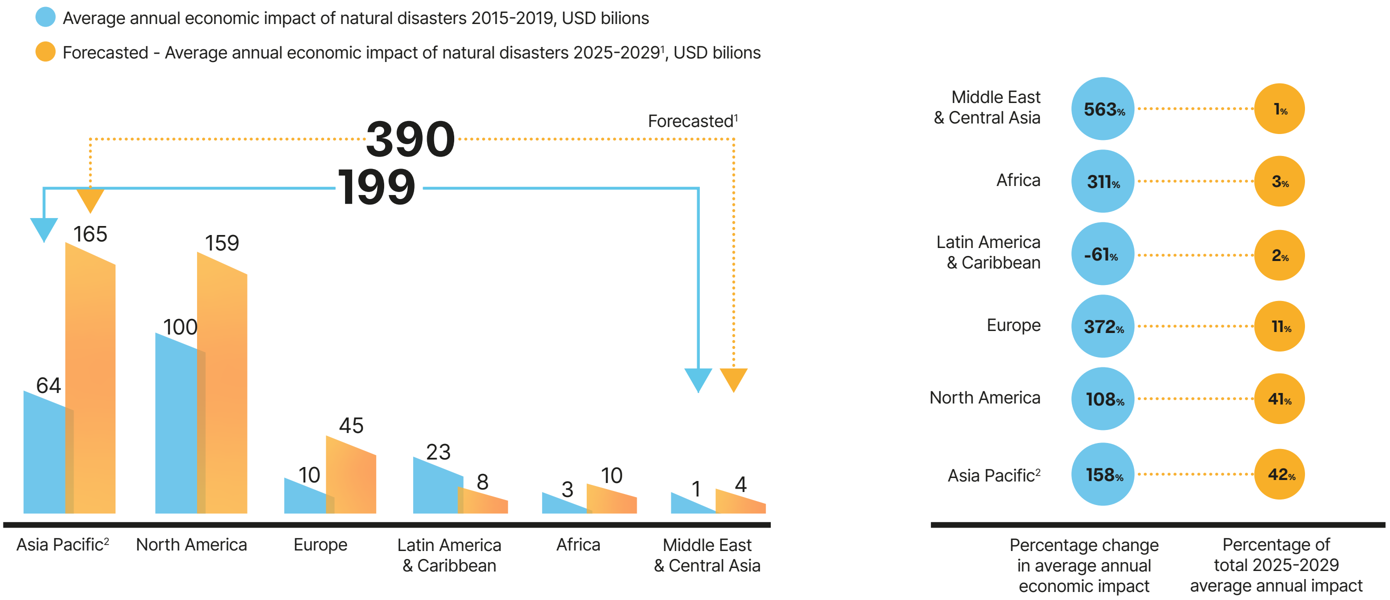
1. Damages includes the value of all damages and economic losses directly or indirectly related to the disaster.
2. Projected based on the simple average of 5-year percentage changes in natural disaster frequencies over the past two decades, within each region.
3. The most prominent natural disaster in 2011 was the Tohoku earthquake and tsunami in Japan where an earthquake of magnitude 9.1 Mw out of the 10-point Richter scale struck near the coast of Japan, shutting down and damaging three nuclear reactors. The resultant damage within Japan alone led to a cost of USD220 billion, the most expensive natural disaster in global history. Source: National Centers for Environmental Information (2017), "On This Day: 2011 Tohoku Earthquake and Tsunami."
Available at: https://www.ncei.noaa.gov/news/day-2011-japanearthquake-and-tsunami
Source: EM-DAT Universit catholique de Louvain (UCL) (2021), The Emergency Events Database. Available at: https://public.emdat.be/

FIGURE 3: ECONOMIC IMPACT OF NATURAL DISASTERS

The economic impact of natural disasters varies significantly across regions. Breaking down by regions, Asia Pacific is expected to incur the greatest economic damage at USD165 billion from 2025-29, or 42 percent of the total (Figure 4). This is unsurprising given that the region accounts for more than two-thirds of Global GDP at risk from increased heat and humidity by 2050, as it contributes to the largest number of people who are exposed to lethal heatwaves.[20] North America's expected damage is also predicted to be high at USD159 billion (just behind Asia Pacific). In terms of rate of increase in expected economic impact, the growth rate varies across regions considerably as well, due to differing levels of risk from natural disasters and base effects. For example, the average annual economic impact within Europe is expected to grow by 372 percent between 2015-19 and 2025-29, having grown from a smaller base figure of around USD10 billion per yeart to USD45 billion.[21]

The Middle East and Central Asia region is projected to grow at the fastest rate of 563 percent per annum between 2015-19 and 2025-29. With the urban population already accounting for between 65 to 72 percent of the total population in the Middle East and Central Asia region, natural disasters threaten to make considerable impacts in the Middle East and Central Asia.[22] In 2016, the World Bank declared the Middle East region alone as a highly vulnerable area, with countries such as UAE and Qatar being threatened due to their low-lying coastal areas.[23] The Latin America and Caribbean region have a negative percentage change (61 percent) due to an outlier event within the area: an exceptionally high level of economic impact from a natural disaster occurred in 2017 due to Hurricane Maria, which resulted in damages up to USD94 billion, the worst in over 80 years[24] - this resulted in the continuing projections from 2020 onwards to be much lower for the region.

The change in economic impact of natural disasters by the next decade is also highly differentiated across regions



1. Projected based on the simple average of 5-year percentage changes in natural disaster economic impact over the past two decades.
2. For this analysis, the Asia Pacific region excludes the Central Asian countries of Kyrgyzstan, Kazakhstan, Tajikistan, Uzbekistan, and Turkmenistan.

Source: EM-DAT Universit catholique de Louvain (UCL) (2021), The Emergency Events Database. Available at: https://public.emdat.be/

FIGURE 4: REGIONAL ECONOMIC IMPACT OF NATURAL DISASTERS

THE STATE OF CURRENT DISASTER RESPONSE COMMUNICATION SYSTEMS

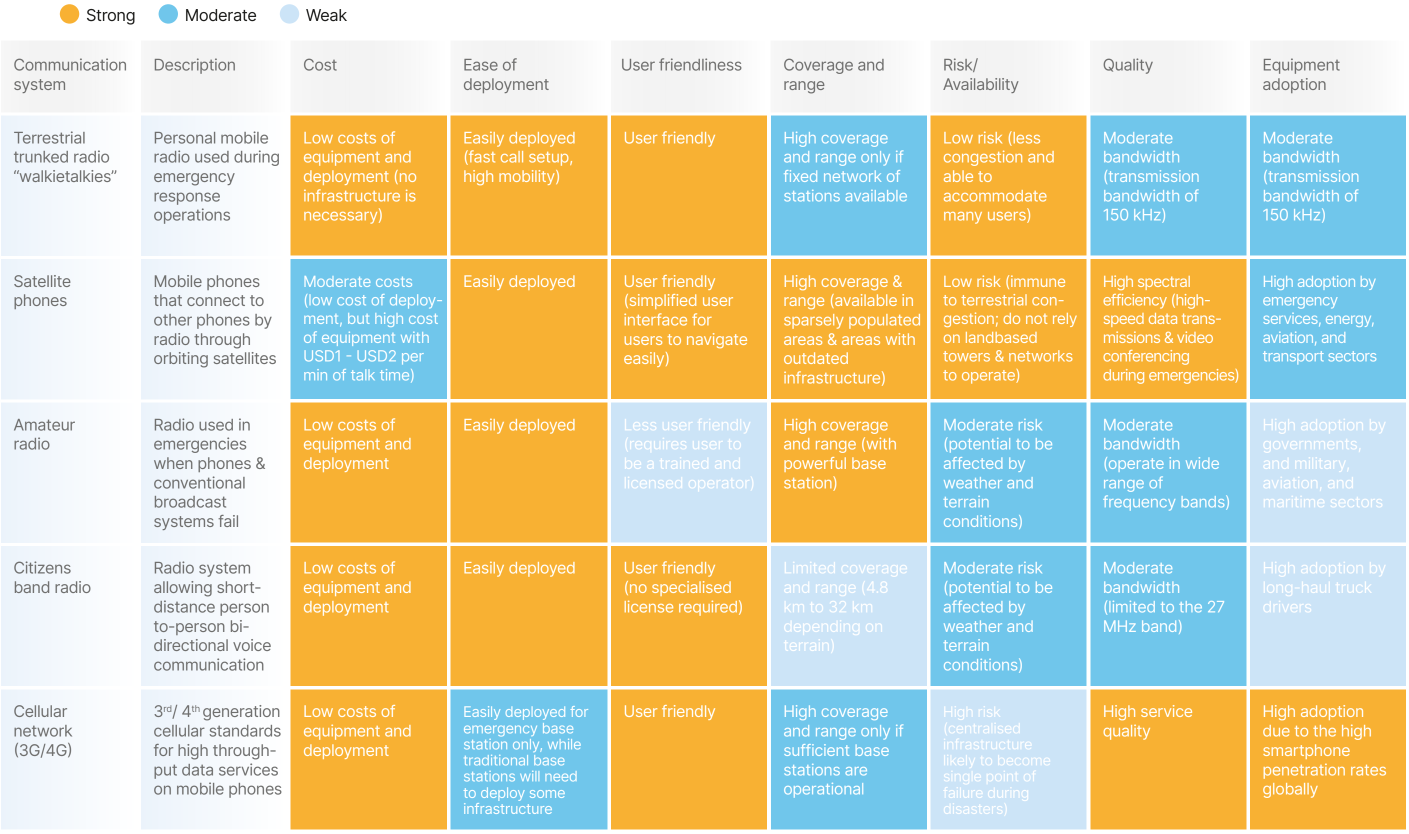
This section assesses the typical disaster response communication systems adopted by governments and citizens during natural disasters. These communication systems include:

- **i.** terrestrial trunked radio “walkie-talkies”;
- **ii.** satellite phones; BGANS, VSATs and access points;
- **iii.** amateur radio;
- **iv.** citizens band radio; and
- **v.** cellular networks.

The communication systems are assessed based on seven key attributes that are crucial in ensuring successful communication during natural disasters. These include the equipment costs and cost of deployment, ease of deployment, user-friendliness, coverage and range, risk and availability during natural disasters, quality in terms of bandwidth and spectral efficiency, as well as the equipment adoption rate. Further details on how each communication system is rated against these attributes can be found in the Appendix. We do not include Wi-Fi and other license-exempt technologies in this list, but we note that these technologies play a central and ubiquitous role in emergency response. For example, Wi-Fi serves as the means for responders ranging from TSF to government agencies to distribute connectivity to end users when these organizations use satellite, terrestrial wireless, or wired access technologies. We do not discuss Wi-Fi here in detail because, as license-exempt technologies, the policy and regulatory issues explored in this paper do not apply directly, but governments should nonetheless include Wi-Fi and other license-exempt technologies in their NTPEs and ensure that they designate adequate frequency resources to these technologies.

Satellite phones score better across more areas but are hindered by the high cost of adoption.
Out of all the current communication systems analysed, satellite phones appear to score strongly across five out of the seven attributes – the best compared to other systems (Figure 5). Satellite phones have high spectral efficiency and a wide coverage that allow communication links to be established even in sparsely populated areas and areas with outdated or damaged infrastructure. They are also easily deployed, user-friendly, and face low network disruption risk as they do not rely on land-based towers and networks to operate. However, despite being one of the best disaster response communication systems available today, there are some limitations of satellite phones, including their relatively high costs and slow deployment in several jurisdictions globally.

Satellite phones appear to score strongly across 5 out of the 7 attributes -the most compared to other systems



● Strong ● Moderate ● Weak

Communication system	Description	Cost	Ease of deployment	User friendliness	Coverage and range	Risk/ Availability	Quality	Equipment adoption
Terrestrial trunked radio “walkietalkies”	Personal mobile radio used during emergency response operations	Low costs of equipment and deployment (no infrastructure is necessary)	Easily deployed (fast call setup, high mobility)	User friendly	High coverage and range only if fixed network of stations available	Low risk (less congestion and able to accommodate many users)	Moderate bandwidth (transmission bandwidth of 150 kHz)	Moderate bandwidth (transmission bandwidth of 150 kHz)
Satellite phones	Mobile phones that connect to other phones by radio through orbiting satellites	Moderate costs (low cost of deployment, but high cost of equipment with USD1 - USD2 per min of talk time)	Easily deployed	User friendly (simplified user interface for users to navigate easily)	High coverage & range (available in sparsely populated areas & areas with outdated infrastructure)	Low risk (immune to terrestrial congestion; do not rely on landbased towers & networks to operate)	High spectral efficiency (high-speed data transmissions & video conferencing during emergencies)	High adoption by emergency services, energy, aviation, and transport sectors
Amateur radio	Radio used in emergencies when phones & conventional broadcast systems fail	Low costs of equipment and deployment	Easily deployed	Less user friendly (requires user to be a trained and licensed operator)	High coverage and range (with powerful base station)	Moderate risk (potential to be affected by weather and terrain conditions)	Moderate bandwidth (operate in wide range of frequency bands)	High adoption by governments, and military, aviation, and maritime sectors
Citizens band radio	Radio system allowing short-distance person to-person bi-directional voice communication	Low costs of equipment and deployment	Easily deployed	User friendly (no specialised license required)	Limited coverage and range (4.8 km to 32 km depending on terrain)	Moderate risk (potential to be affected by weather and terrain conditions)	Moderate bandwidth (limited to the 27 MHz band)	High adoption by long-haul truck drivers
Cellular network (3G/4G)	3rd/ 4th generation cellular standards for high throughput data services on mobile phones	Low costs of equipment and deployment	Easily deployed for emergency base station only, while traditional base stations will need to deploy some infrastructure	User friendly	High coverage and range only if sufficient base stations are operational	High risk (centralised infrastructure likely to become single point of failure during disasters)	High service quality	High adoption due to the high smartphone penetration rates globally

FIGURE 5: ASSESSMENT OF CURRENT COMMUNICATION SYSTEMS

Source: Literature review; AlphaBeta analysis

The ultimate objective of a communication system is to maximise connectivity options and minimize emergency response times during disasters. Emergency response time is key in reducing the human and infrastructure impacts of natural disasters, as it reduces preventable life losses, lessens the number of people affected by the disasters, and decreases property damage costs. Emergency response time is defined as the time between notification of an occurrence and the arrival of assistance at the scene. The availability of communications systems is directly related to the ability to respond quickly to an emergency. They are imperative to ensure efficient and accurate information flows during an emergency, especially during complex, continuously evolving events such as natural disasters. Many studies have been conducted over the past decade to understand the impact of reducing emergency response times on health and economic outcomes during natural disasters. A reduction in response times during natural disasters has a significant impact on mortality, morbidity, and property damage costs.

AREA OF IMPACT	EVIDENCE (NON-EXHAUSTIVE)
MORTALITY	For every minute reduction in response time in the United States[25]: • 8 – 17 percent decrease in overall mortality rates in the population • 1 – 2 percent decrease in mortality rates due to cardiac and neurological emergencies For every 10 percent reduction in response time in the United Kingdom[26]: • Average decrease of 7 percent in mortality rates in the population
MORBIDITY (HEALTHCARE COSTS)	For every minute reduction in response time in the United States[27]: • 6.9 percent decrease in healthcare costs for patients with cardiac and neurological concerns • 5.5 percent decrease in healthcare costs for patients with severe trauma • 3.5 percent decrease in healthcare costs for patients with time-critical concerns (e.g., choking, severe anaphylaxis)
PROPERTY (DAMAGE COSTS)	For every minute reduction in response time for fires in New Zealand and the United States[28]: • USD2,700 – USD6,000 reduction in infrastructure damage costs

TABLE 1: IMPACT OF A REDUCTION IN RESPONSE TIMES ON MORTALITY, MORBIDITY, AND PROPERTY DAMAGE COSTS

Five attributes of disaster response communication systems have a moderate to strong impact on emergency response times. Figure 5 shows that "Risk / Availability" and "Coverage and range" have strong direct impacts on response times as it would be impossible for users to communicate when networks are disrupted or when communication systems are out of range. For example, during Cyclone Harold in 2020, in the Solomon Islands, Vanuatu, Fiji, and Tonga, locals affected by the disaster were able to access the community WiFi service and quickly deploy disaster relief assistance, even after local network coverage was wiped out. This was due to the reliable communications equipment provided by the International Telecommunication Union (ITU) and Kacific. In comparison, attributes such as "Ease of deployment", "User-friendliness" and "Quality" have moderate direct impacts on emergency response times (Figure 6).

While these attributes are crucial in facilitating efficient transfer of information, people affected by the disaster will still be able to communicate with each other, albeit with greater difficulty. An example is the 7.8 magnitude earthquake that struck Nepal in 2015. The ease of deployment and user-friendliness of the communication systems provided vital connectivity services following the disastrous earthquake and allowed humanitarian responders to respond to calls for help quickly. Therefore, policies and strategies to improve these aspects of communication systems will be critical for a more responsive system.

Satellite phones appear to score strongly across 5 out of the 7 attributes - the most compared to other systems

🟠 Strong direct impact 🔵 Strong direct impact

Attributes of communication system	Impact on response times	Case Studies
Ease of deployment	🟧	**Nepal Earthquake (2015):** emergency.lu provided crucial connectivity services (rapid deployment kits) following the disastrous 7.8 magnitude earthquake that damaged the country's telecommunications infrastructure • **Ease of deployment:** The kit is easily deployed and can be **set up in less than 30 minutes by trained staff members** • **User friendliness:** The satellite terminal has been **developed for outdoor use to allow fast and easy installation in adverse conditions** • **Quality:** The system offers **high performance two_way communications providing up to 8 Mbps bandwidth for data, video and voice transmission**
User-friendliness	🟧	
Quality	🟧	
Risk/Availability	🟦	**Cyclone Harold in the Solomon Islands, Vanuatu, Fiji. and Tonga (2020):** International Telecommunicatiom Union and Kacific have collaborated to provide equipment such as very SmallAperture Terminals (VSATs) during the disaster • This allowed locals **to readily access the Internet even after all the big networks went offline** due to the community WiFi service offered by the VSAT, facilitating information exchange and resulting in faster response times
Coverage and range	🟦	**Hurricane Maria Response in Dominica (2017):** To support disaster response efforts, satellite Internet connections were installed at Roseau stadium • **Communication links were built even in remote areas of the country,** helping to facilitate disaster coordination efforts and provide relief supplies people in need

Source: emergency.lu; Inmarsat; Kacific AlphaBeta analysis

FIGURE 6: KEY ATTRIBUTES OF DISASTER RESPONSE COMMUNICATION SYSTEMS

THE UPSIDE BENEFITS OF A MORE RESPONSIVE COMMUNICATION SYSTEM

A significant opportunity exists for pro-active innovation and uptake of current communication networks to increase their responsiveness. To appreciate the upside benefits of an available communication system, this section estimates how the economic and social cost of natural disasters could evolve under three hypothetical scenarios. The three scenarios are:

- **Business-as-usual.** In this scenario, it is assumed that countries make no significant change in how they make use of existing communication systems.[29] This scenario shows the estimated cost if different countries do not improve their current systems, with emergency response times therefore remaining as they are today.

- **Connectivity divergence.** Under this scenario, all countries make developments to their use of communication systems, but development is differentiated (or divergent) across different countries. Upper-middle and high-income countries make significant developments, assumed to lead to a 20 percent reduction in median emergency response times by enhancing their communication systems. Low and lower-middle income countries are assumed to experience a 10 percent reduction in median response times instead.

- **Connectivity revolution.** Under this scenario, all countries revolutionise their use of communication systems, with response times assumed to reduce by 20 percent in both upper-middle and high-income countries, as well as low and lower-middle income countries.

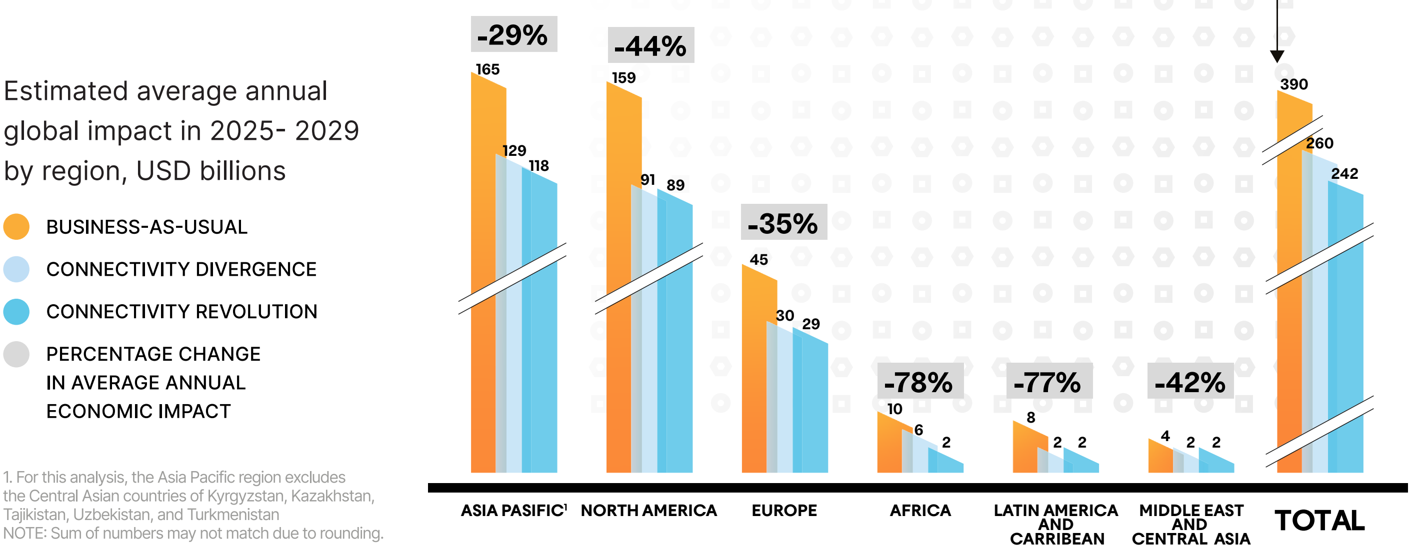
A "Connectivity revolution" will result in USD148 billion less economic impact, including significant reductions in preventable lives lost and people affected from natural disasters from 2025-29.

With improvements to communication systems, the average annual global impact from 2025-29, under the "Business-as-usual" scenario, could be reduced by 33 percent to reach USD260 billion under the "Connectivity divergence" scenario, and by 38 percent to reach USD242 billion under the "Connectivity revolution" scenario respectively (Exhibit 7). In addition to the economic costs, there is a potential reduction of 26 percent in preventable lives loss from 1.5 million worth of life years lost under the "Business-as-usual" scenario to 1.1 million life years lost under the "Connectivity revolution" scenario from 2025-29.

A connectivity revolution in disaster management could significantly reduce losses globally by up to USD148 billion in 2025-2029

PERCENTAGE CHANGE IN AVERAGE ANNUAL ECONOMIC IMPACT

USD 148 BILLION



1. For this analysis, the Asia Pacific region excludes the Central Asian countries of Kyrgyzstan, Kazakhstan, Tajikistan, Uzbekistan, and Turkmenistan
NOTE: Sum of numbers may not match due to rounding.

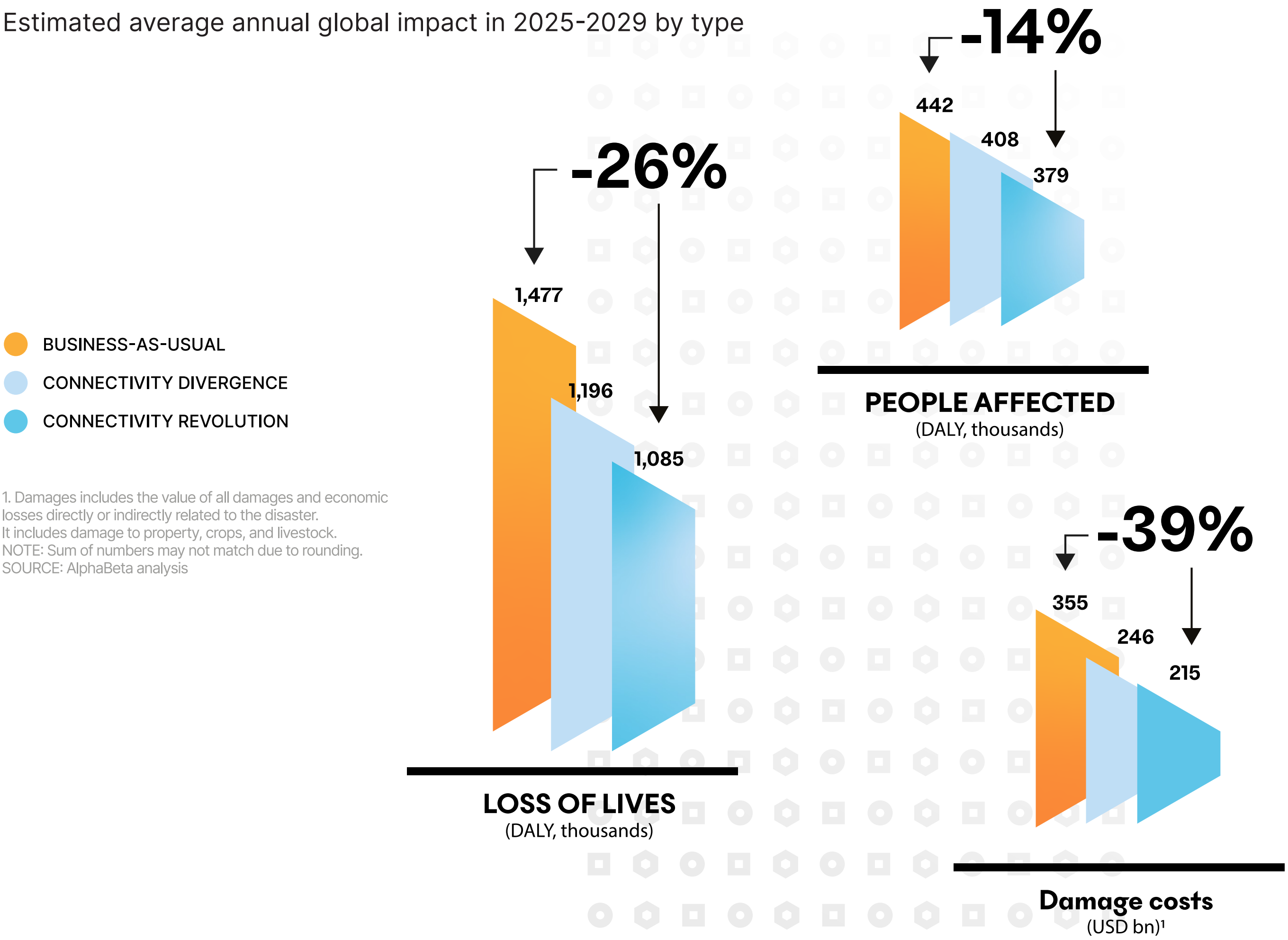
FIGURE 7: ECONOMIC IMPACT OF NATURAL DISASTERS BY REGION IN 2025-29

The North American region is estimated to be the largest beneficiary in terms of absolute change in economic impact, with a drop of around USD70 billion from USD159 billion to USD89 billion annually in the "Business-as-usual" and "Connectivity revolution" scenarios respectively. This is mainly due to the higher value of assets in the region and huge reductions in damages due to faster response times, particularly toward fire-related disasters, which contribute to significant amounts of damages. In the USA alone, climate change has led to the number of land acres burned owing to forest fires to rise by more than six times from around 1.5 million acres in 1980 to 10 million acres in 2020.[30]

The African and Latin American and Caribbean regions are also expected to reap a huge proportion of benefits, reducing their annual economic impact by 78 percent and 77 percent respectively. Similarly, to North America, this is mainly contributed by a huge decrease in damages by natural disasters. For example, in Africa, storms and floods contribute to 71 percent of reported cumulative economic losses within the period of 1970 to 2019.[31] As improved communication systems can prevent damages to critical infrastructure that mitigate these types of disasters – such as flood-control systems – both regions can experience a high level of reduction in economic impact.[32]

WITH BETTER CONNECTIVITY NETWORKS, DAMAGE COSTS FROM NATURAL DISASTERS CAN BE POTENTIALLY REDUCED BY 39%

Estimated average annual global impact in 2025-2029 by type



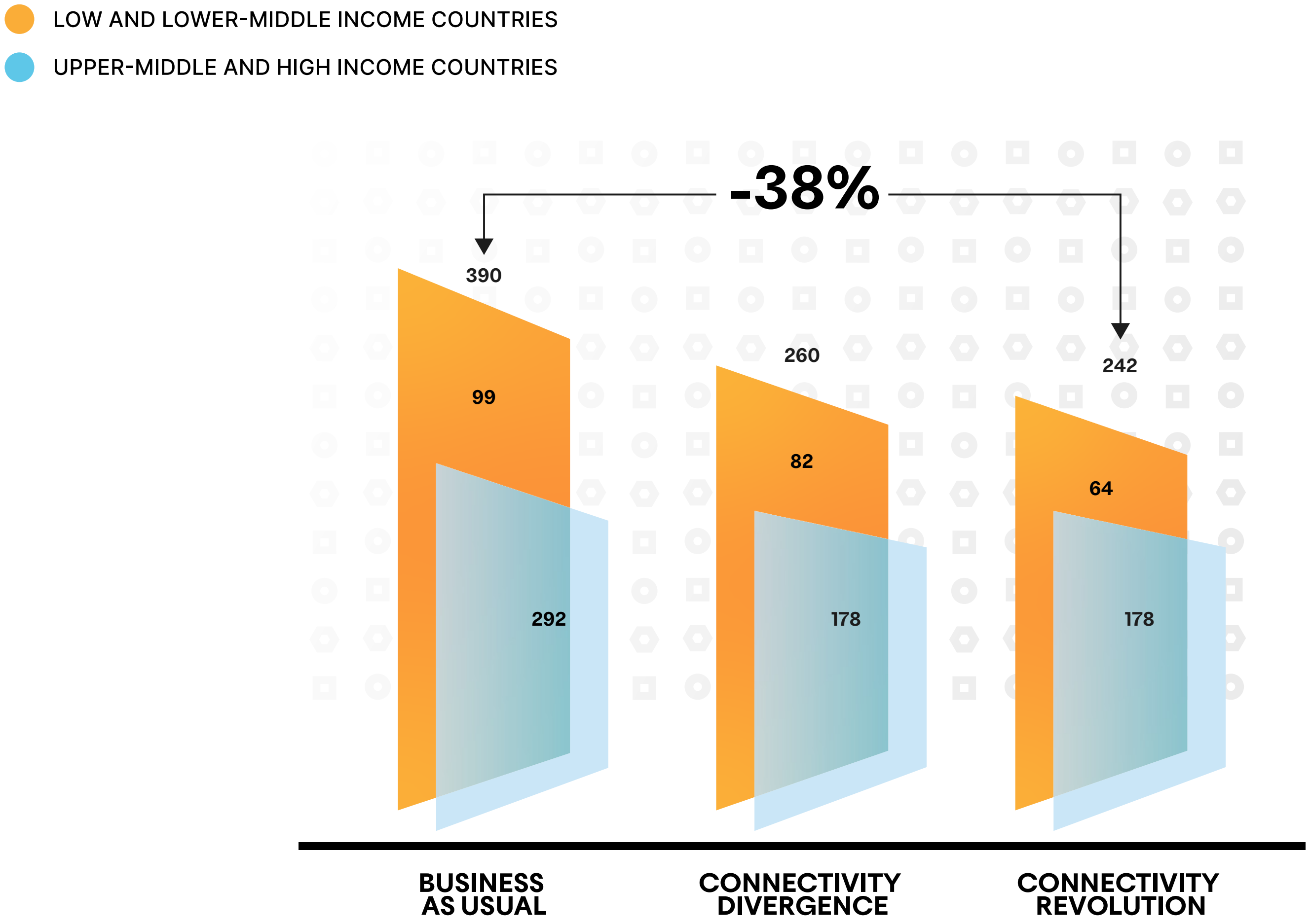
1. Damages includes the value of all damages and economic losses directly or indirectly related to the disaster.
It includes damage to property, crops, and livestock.
NOTE: Sum of numbers may not match due to rounding.
SOURCE: AlphaBeta analysis

FIGURE 8: ECONOMIC IMPACT OF NATURAL DISASTERS BY COST TYPE IN 2025-29

Significant developments in communication systems also prevent loss of life. If all countries were to reduce their median response times by significantly, there would be an estimated 14 percent reduction in the number of people affected by natural disasters from 442,000 life years under the "Business-as-usual" scenario to 379,000 life years under the "Connectivity revolution" scenario from 2025-29, and an estimated 39 percent reduction in damage costs from USD351 billion under the "Business-as-usual" scenario to USD213 billion under the "Connectivity revolution" scenario (Figure 8). Additionally, cost savings from enhanced communication systems are estimated to be higher in upper-middle and high-income countries, with a 39 percent reduction in natural disaster costs (from USD292 billion to USD178 billion annually), compared to 35 percent in low and lower-middle income countries (from USD99 billion to USD64 billion annually) (Figure 9).

A connectivity revolution in disaster management could potentially reduce losses globally by up to 38% in 2025-2029

Estimated average annual global impact in 2025-2029 by country income groups[1], USD billions



1. Income groups are categorised according the World Bank's classification of countries. Low income countries' GNI per capita in current USD terms are less than USD1,046; lower-middle income contries are between USD1,046-4,095; upper-middle income countries are between USD4,096-12,695; and high income countries are greater than USD12,695.NOTE: Sum of numbers may not match due to rounding.
SOURCE: AlphaBeta analysis

FIGURE 9: ECONOMIC IMPACT OF NATURAL DISASTERS BY COUNTRY INCOME GROUP IN 2025-29

CLIMATE ADAPTATION: THE ROLE OF EMERGENCY COMMUNICATIONS

A. PARTNERING IN EMERGENCIES AND DISASTER MANAGEMENT

In the wake of the social and economic disruptions caused by climate change, engaging governments, intergovernmental organisations, civil society, private sector, and the technical community is key to ensure that governments have the resources and capabilities required to improve on-the-ground relief and recovery following major natural disasters. As recognized by the ITU and other organisations outside the United Nations System, Public-Private Partnerships (PPP) have a major role to play in assisting governments close the infrastructure gap while leveraging the power of ICTs within the context of disaster management and emergency preparedness.[33]

The below are a few noteworthy examples of initiatives jointly led by public and private entities that seek to manage climate change risks and/or create resiliency opportunities in the context of ICT infrastructure and services.[34]

- **Emergency Telecommunication Cluster (ETC):** The ETC is one of the 11 clusters designated by the Inter-Agency Standing Committee (IASC), an agency created by the United Nations General Assembly Resolution 46/182 in 1991. The IASC brings together the Heads of 18 UN and non-UN organizations to ensure coherence of preparedness and response efforts, formulate policy, and agree on priorities for strengthened humanitarian action. The ETC, which is headed by the World Food Programme (WFP), is a multinational network of humanitarian, government and private sector organizations that work together to provide communication services in humanitarian emergencies.[35]

- **Crisis Connectivity Charter:** The charter was developed to assist ETC humanitarian responders in their life-saving operations. This was developed with the intention to improve communication in cases of disaster management by setting out solutions that enable satellite-based communications more readily between affected communities and those involved in responding to disaster situations. According to the UN Office for Outer Space Affairs UN-SPIDER Knowledge Portal, the charter ensures satellite-based technology can be leveraged to provide life-saving connectivity to humanitarians and affected populations whenever a disaster strikes. The Crisis Connectivity Charter is composed of the satellite industry and the wider humanitarian community, such as members of the EMEA Satellite Operator's Association (ESOA) and the Global VSAT Forum (GVF), in coordination with the UN Office for the Coordination of Humanitarian Affairs (OCHA).[36] The Charter supports increased coordination by prioritizing access to bandwidth for humanitarian purposes during disaster responses and by allocating pre-positioned satellite equipment and transmission capacity in high-risk countries. It also provides training and capacity building for the humanitarian community around the world.

- **Disaster Connectivity Maps:** Disaster Connectivity Maps is a joint initiative of the International Telecommunication Union (ITU) and the Emergency Telecommunications Cluster (ETC), with the support of the GSMA Mobile for Humanitarian Innovation programme. The Disaster Connectivity Maps platform is hosted by the ITU. Disaster Connectivity Maps is a mapping platform to help first responders determine the status of telecommunications network infrastructure, coverage, and performance before and after a disaster. The information contained in Disaster Connectivity Maps (DCM) can be used to support decision-making by first responders about where telecommunication network services need to be restored.

B. SITUATIONAL ANALYSIS - GOOD PRACTICES FOR REGIONAL PRIORITIES

Every disaster affords the opportunity to examine what worked in terms of national emergency telecommunication plans and disaster management strategies, what did not work and where improvements can be achieved. Complete or partial breakdowns of communications systems challenge relief efforts and underscore the need for administrations and organisations to develop reliable and modernised disaster preparedness plans.

As satellite-based technologies are not as susceptible to disruption during natural disasters, satellite applications have been long recognized as an essential component of any country's disaster communications management strategy.[37] In 2006, two years after the tsunami that caused massive destruction in Southeast Asia, Yoshio Utsumi – Secretary General of the UN International Telecommunication Union (ITU) at the time - described how satellite phones "demonstrated the power of emergency telecommunications in saving lives and coordinating efforts during rescue operations"[38]. The article further mentions that that according to experts, had a satellite phones system operated in the Indian Ocean at the time of the 2004 tsunami, "it would have given hundreds of thousands of people several hours between the time the quake spawned the tsunami off the Indonesian island of Sumatra and its landfall in places like Sri Lanka and Thailand to flee to higher ground".

Many examples from past years highlight the ITU's mandate to aid in the context of disaster management and humanitarian response. The organization supported the Member States through the provision of satellite-based emergency telecommunications equipment when disasters struck and has been instrumental in leveraging its relationships with regulators to unblock situations where importation challenges have resulted in satellite equipment being delayed in customs. In 2015, after the tropical storm Erika decimated the eastern Caribbean Island of Dominica, the ITU deployed emergency telecommunication equipment, including satellite phones and broadband global area networks to support relief and coordination efforts. That same year, after lethal floods hit Kenya, the government requested assistance from the ITU. In response, the organisation deployed satellite-based emergency equipment for disaster recovery. Similarly, in response to Caribbean storms alone, TSF deployed emergency responders and satellite equipment in response to Hurricane Ivan in 2004,[39] Hurricane Jeanne in 2004,[40] Hurricane Gustav in 2008,[41] Hurricane Matthew in 2016,[42] Hurricane Maria in 2017,[43] and Hurricane Irma in 2017.[44]

More recent cases include the 2020 earthquake that hit the Vanuatu Islands (April 2020), the Hurricane Dorian that struck the Bahamas in 2019,[45] and the Cyclone Idai that hit south-eastern Africa the same year.[46] In all those instances, although at varying degrees of involvement and different timeframes, the ITU and NGOs like TSF activated satellite-based technology deployment plans to provide disaster relief, following the destruction of terrestrial infrastructure.

This section focuses on five case studies that provide a better understanding of response strategies related to natural disasters, while identifying lessons and best practices from past responses to such events.

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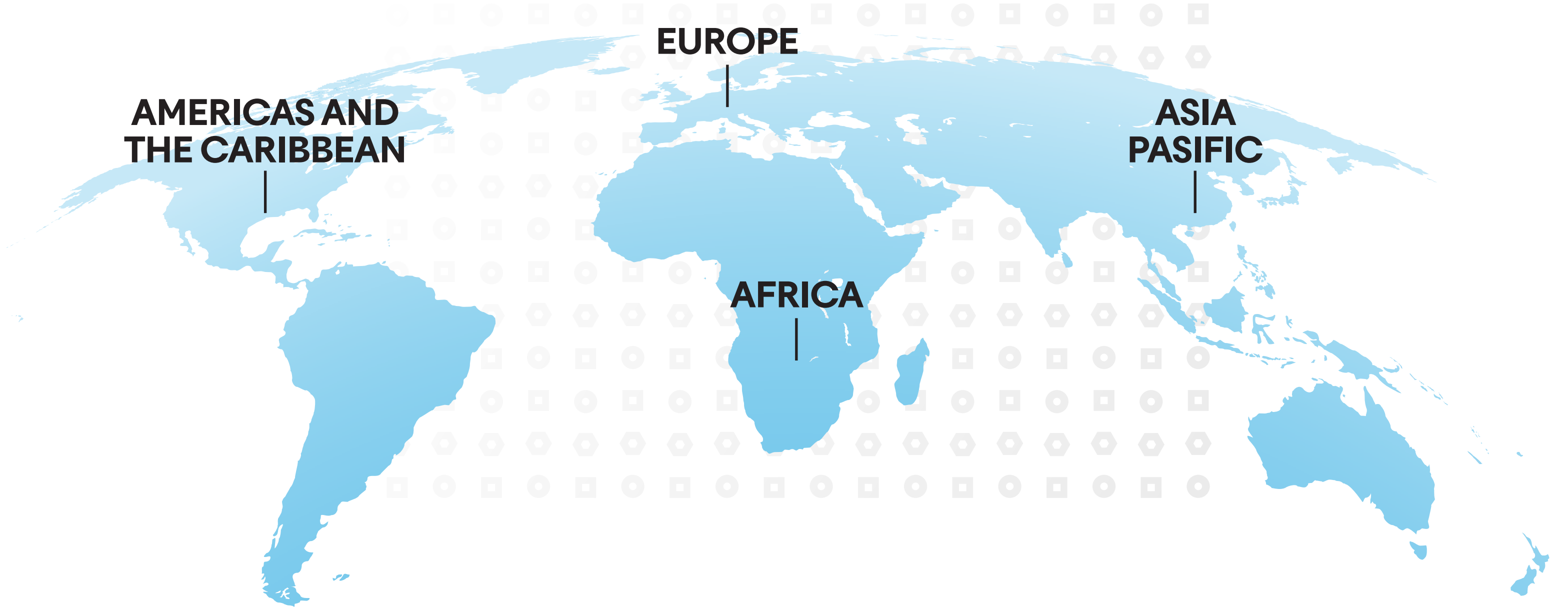
[37] International Telecommunications Union (2009), "Guidelines for Implementation of Satellite Telecommunications for Disaster Management in Developing Countries". Available at: https://www.itu.int/md/D06-RGQ22.2-C-0057/fr

[38]



AMERICAS AND THE CARIBBEAN

1. US - HURRICANE KATRINA (2005)

Context
The scale of hurricane Katrina's devastation in the U.S. was so intense that cellular communication service restoration happened much slower than usual.[47] As described by the ITU, "the storm left 80 percent of New Orleans submerged, tens of thousands of victims clinging to rooftops, and hundreds of thousands scattered to shelters around the country. Three weeks later, Hurricane Rita re-flooded much of the same area".[48]

Challenges Endured
According to a 2010 ITU report, "the twin storms downed telephone poles and wires and caused long-term power outages, which prevented service to the digital gear and cell-phone towers that formed the terrestrial network".[49] When the bridge that connected New Orleans across Lake Pontchartrain collapsed, so did the fibre-optic cables that transported calls and internet traffic to and from the city. The systems and devices that were most relied upon for day-to-day communications were rendered useless for weeks.[50] While the mobile networks were down, satellites remained on the job, providing reliable and redundant communications solutions.

As explained by the Satellite Industry Association (SIA), Hurricane Katrina's destruction of terrestrial communications facilities in the Gulf region was striking. As a result of almost three million customer telephone lines being knocked down, more than 1,000 cell sites out of service, approximately 100 broadcast stations having been destroyed, and with hundreds of thousands of cable customers having lost service, the ability of first responders and others to provide disaster relief and recovery efforts were severely impeded.

Employing Satellite-based Communication
On the other hand, "in the hours, days, and weeks following these disasters, satellite networks have provided critical communications capabilities to emergency personnel and a vital information link for all citizens". It was through mobile satellite telephony that the "Federal Emergency Management Agency (FEMA), The National Guard, the Red Cross, state and local first responders, utility workers, reporters, people in search of relatives, and even local phone companies" were communicating in the aftermath of Hurricane Katrina.

In the context of the independent panel reviewing the impact of Hurricane Katrina, the Satellite Industry Association (SIA) argued however that, "although the performance of satellite systems was impressive, their use has often been limited by a lack of preparation". SIA explained that if satellite systems had been more effectively integrated into the emergency communications network, many of the communications problems that occurred in Alabama, Louisiana, and Mississippi as a result of hurricane Katrina, but also as a result of manmade disasters such as 9/11, "would have been substantially mitigated".

- **Key Insights:** Due to their reliance on land, cellular, and radio-based communications, first responders could not communicate once the land-based infrastructure was damaged. The major lesson to be learned from Hurricane Katrina, in FCC's Chairman Martin's words: "we cannot rely solely on terrestrial communications".

2. HAITI EARTHQUAKE (2021)

Context

The southern part of Haiti was the victim of a devastating 7.2 magnitude earthquake, resulting in the injury of 12,763 and the death of 2,248 people, as well as a USD 187.3 million response cost. The earthquake exposed the country's already-existing susceptibilities. At the time of the disaster,Haiti was dealing with growing food shortages, rampant gang violence, and declining infrastructure – liabilities that have only worsened after the earthquake.[51]

Challenges Endured

Whilst the damage to ICT infrastructure was severe and is still being quantified,[52] affected areas were rendered inaccessible because of it – particularly the areas along the route from Port-au-Prince to Les Cayes. Data traffic and intermittent coverage by Mobile Network Operators were caused by both the earthquake's effect and the flow of rescuers to the impacted areas. Furthermore, heavy gang presence added to the access difficulty for response teams in contacting victims given the security threat. This also meant the limitation of access to sites where quality coverage may have been attained also restricted the installation of VHF repeaters for security communications.[53] Internet Service Provider (ISP) services were also damaged and, following the influx of humanitarians, were under strain in the initial days of the response.[54]

Employing Satellite-based Communication

The ETC provided the government with a response plan that encompassed recommended satellite communication efforts. As additional support, the ITU provided its Disaster Connectivity Map system, developed in conjunction with the ETC and Global System for Mobile Communications Association (GSMA), to map connectivity gaps in affected areas.[55]

Whilst this Disaster Connectivity Map system was effective in exposing areas that had lost connectivity, it also became evident that most affected areas lacked coverage prior to the earthquake. To this end, Télécoms Sans Frontières (TSF) and other international ICT responders such as Ericsson Response moved in to provide support in establishing VSAT connectivity.[56]

- **Key Insights:** The humanitarian response operations led by the ETC is a clear example of how private and public entities can partner up to support such efforts after the disaster strikes. The work, which involved the establishment of a radio network for security communications, was the result of an initiative jointly led by the WFP, UNDSS, emergency.lu and Ericsson Response.[57]

ASIA PACIFIC

3. THE PHILIPPINES - STORM AGATON

Context

With an annual average of 20 cyclones, the Philippines is recognised globally as the third most disaster-prone country.[58] This is largely attributed to its geographic location. The 7,000 islands that make up the Philippines are situated in what is informally known as the 'typhoon belt' – an area of the world where severe weather systems form more than anywhere else.

In 2017, the country suffered a string of disasters just days apart: Storm Agaton, Storm Tembin, and Marawi all leaving a trail of devastation.[59] In 2013, Typhoon Haiyan killed more than 7,000 people and left 1.9 million homeless. Typhoon Haiyan is estimated to have caused a total economic loss of USD$5.8 billion dollars, as six million employees were displaced and vital rice, corn, and sugar-producing areas in the Philippines were damaged – impacting the country's foreign commerce and farmers' revenues.[60]

Challenges Endured

The Philippines is experienced at providing emergency relief. Nonetheless, resource constraints, infrastructure fragility, and ineffective crisis communication deployment mean that the human and economic cost remains high, whilst the government's reach is limited.[61]

For example, the damage inflicted by Typhoon Haiyan underscored the need for satellite connection. Because the media networks covering the story were equipped with Broadband Global Area Network (BGAN) terminals, government first responders had to resort to the TV news 24 hours after the typhoon hit to view the damage. Even more disastrously, without connection, several areas took weeks to get their request for aid across to first responders.[62]

Employing Satellite Based Communication

An initial five areas in the Philippines have been selected to receive emergency communication services, based on their high susceptibility to disasters, including: Bicol; Socksargen; Mimaropa; Eastern Visayas; and Cordilleras. Inmarsat's high-speed Global Xpress service along with BGAN mobile broadband terminals and IsatPhone 2 handheld satellite phones have been deployed to the respective regions to provide communication during emergency response efforts.[63]

- **Key Insights:** Equipping regional authorities with emergency communication services decreases dependency on strained national assets during a disaster, and ultimately improves relief response times as well as the response coordination at the national level.[64]

AFRICA

4. MOZAMBIQUE - CYCLONE IDAI (2019)

Context

In 2019, Tropical Cyclone Idai made landfall near Beira City, Sofala Province, in central Mozambique. Whilst the extent of the destruction is still unfolding, it is reported that the cyclone killed more than 600 people, injured 1,600, and caused approximately USD$773 million in damages to Mozambique's buildings and infrastructure. Eastern Zimbabwe was also struck as Cyclone Idai continued across land as a Tropical Storm.[65]

Challenges Endured

A disaster report by the World Meteorological Organization on Mozambique highlighted that the country has substantial deficiencies in its emergency preparedness, coordination, and response, with an absence of a backup communication system for alerts and disaster relief operations, as well as a city evacuation strategy, particularly in vulnerable low-lying regions.[66]

At an international pledging conference to secure funding for Mozambique's reconstruction, Petteri Taalas – the WMO Secretary-General, conceded that "Mozambique needs to build resilience."[67]

Employing Satellite-Based Communications
In response to the cyclone, the Copernicus Emergency Mapping Service and the International Charter Space and Major Disasters stepped in to utilize data from multiple satellites so as to provide on-demand imaging of flooded regions to assist relief efforts.[68] TSF deployed and used satellite equipment to assist with humanitarian coordination and to establish broadband-enabled coordination centres.[69]

Given Mozambique's satellite sector had progressively lost backhaul traffic to fibre, the Communications Regulatory Authority, ARECOM, admitted in the wake of Tropical Cyclone Idai that it underestimated their risk potential and resulting need for satellite, stating "It was a mistake to phase out satellite just because fibre arrived."[70]

- **Key Insights:** This case study is a clear example that terrestrial infrastructure is not immune to faults and unavailability, and that to make sure communications are not interrupted, multiple communication links employing different technologies are required. Moreover, the case study illustrates other use-cases of satellite-based technologies in alleviating the consequences of disasters: satellites can provide vital real-time data for monitoring such events and mapping flooded regions for better-coordinated- emergency response efforts.

EUROPE

5. GERMAN FLOODS (2021)

Context
While most of the abovementioned examples took place in countries that are particularly vulnerable to climate-related disasters, developed nations – despite being equipped with more resources, experts, equipment, and infrastructure – are also at risk. In 2021, Germany was battered by severe and lethal floods caused by heavy rainfall. Because the telecoms and power networks had collapsed, "it was extremely difficult for the relief organisations to contact the victims, search for missing people and coordinate their work", reported TSF.

Challenges Endured
The flooding in Germany resulted in at least 184 fatalities and considerable damage to infrastructure, including communication networks. It was reported that over a week after the rain, mobile phone network was still patchy; and operators were still working to rebuild the network and restore coverage in the flooded regions. Due to the disruption caused by the rain on the telecommunication infrastructure, rescue operations were hindered and the impact on human lives was amplified.

Although rescue workers had access to satellite phones, they were not operational, and the German Federal Agency for Technical Relief (THW) and various police authorities were unable to deploy them. Satellite-based communication is banned in the region for fear of interference with a radio telescope used by the Max Planck Society for Cosmic Research in Bad Munstereifel Effelsberg. According to satellite operator Iridium, the 30-kilometre zone around Effelsberg is - apart from North Korea - the only area in the world they are not allowed to transmit signals due to an order by the Federal Network Agency. In addition to Iridium, according to the Federal Network Agency, other satellite communications operators, such as Globalstar and Starlink are also not allowed to provide voice and data connections in the region around Effelsberg.

Employing Satellite-Based Communications
It was not until four days after the devastating floods that the Federal Network Agency, following complaints from the disaster area, arranged for the regional Iridium service ban to be suspended for the duration of the rescue operations. Within few hours, the network operator installed new software in its satellites, which enabled communication in the disaster region. Once this was allowed, TSF partnered with another satellite operator – Inmarsat – to deploy satellite phones.[71] To ensure that communities could be contacted, and rescue needs ascertained and coordinated, TSF sent a specially designed vehicle to the most affected areas, offering telecom support to people on the ground, including relief organisations.[72]

- **Key Insights:** Considering that terrestrial communications are known to fail in large-scale disasters, mostly due to the destruction of a network's physical components or its supporting infrastructure, one of the factors that would have largely improved Germany's response to the natural disaster is having access to satellite-based communication systems. This means not only having the equipment but also interference-free spectrum access to support the network in distress. Electromagnetic-safe environments may be achieved through coordination with the protected entities, such as radio telescope sites, to create an emergency plan that yields part of their spectrum whenever a natural disaster occurs close or within their exclusion zone.

THE ROLE OF SATELLITE-BASED TECHNOLOGY

Due to their unique characteristics, satellite communications have been an integral part of disaster relief and prevention for decades. There are multiple examples of satellite distress and safety systems, such as GMDSS[73] and COSPAS-SARSAT,[74] used either for emergency communications or for search and rescue operations. Meteorological and Earth exploration satellite systems,[75] paramount in everyday weather forecasting, are also crucial in the prediction and monitoring of hurricanes, storms, and other extreme weather phenomena. Moreover, these systems allow us to accurately measure and understand the rate and severity of the climate changes currently facing our planet. With the information transported by satellite networks, governments can better prepare for future changes and create adequate policy to protect their population and infrastructure.

More recently, satellite IoT has also become relevant in the detection and mitigation of natural disasters.[76] Landslides, avalanches, debris flow, and floods in remote areas can be monitored by hundreds or thousands of sensors relaying the collected data to a satellite network. This data can then be processed and interpreted by government authorities so that necessary action is taken before it is too late.

The important role that space-based solutions have in disaster management is no surprise, due to their wide coverage, infrastructure resilience, availability, and ease of deployment. In many disaster relief events, small aperture earth stations, such as fixed VSATs, vehicle-mounted earth stations (VMES) and transportable earth stations are often the only option to quickly restore emergency telecommunication services,[77] for example. In addition to meteorological and IoT applications, satellite-based technologies can be used to enhance existing infrastructure, provide network redundancy, and be used as backhaul for mobile networks. Like all radiocommunication technologies, satellite systems have their strengths and limitations, and therefore they are often used in conjunction with other technologies in a complimentary manner, with the goal of providing adequate relief for those who most need it in disaster affected areas.

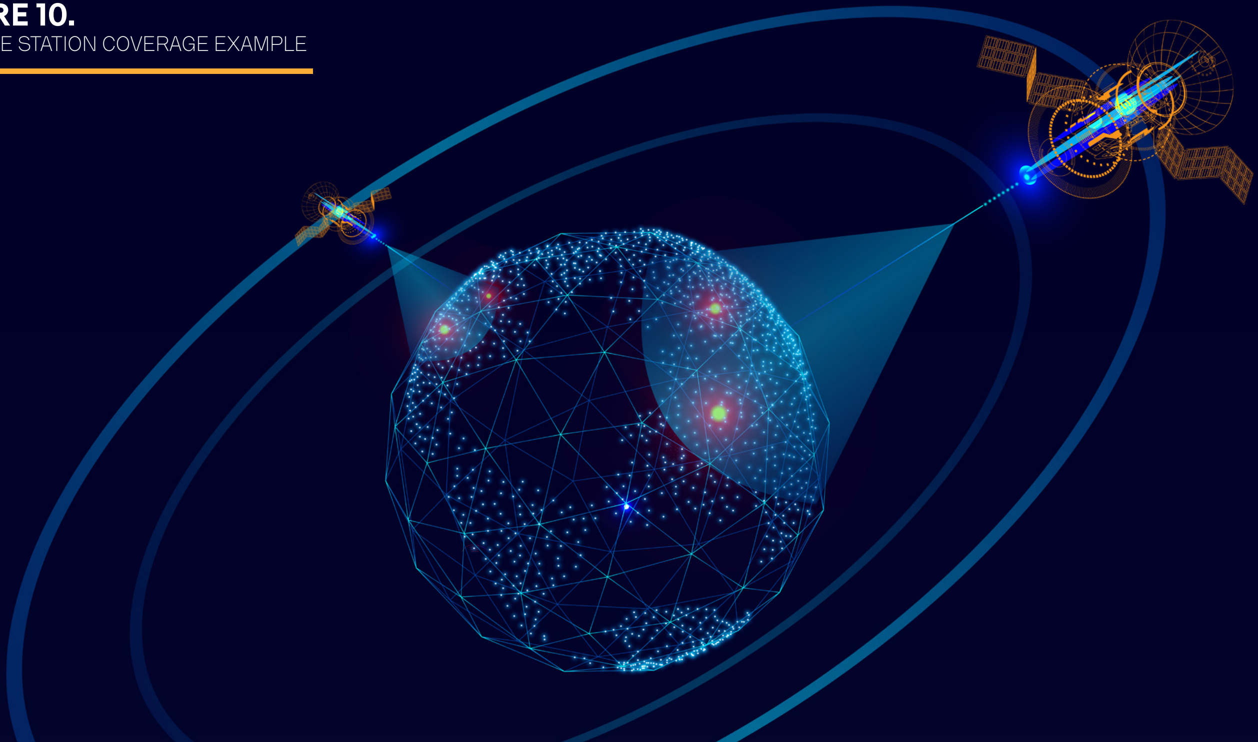
A. ENHANCING EXISTING INFRASTRUCTURE

One of the biggest strengths of satellite connectivity is its capability of reaching remote or underserved areas. While terrestrial-based solutions may only be deployed in regions for which there is commercial justification, space-based technologies can potentially serve large areas, including sparsely populated areas, at the same cost as populated areas. In the case of disasters in remote areas, satellite connectivity may be the only available option to quickly restore or supplement vital communications.

To illustrate why satellite systems usually have a wider coverage than terrestrial systems, Figure 10, shows the coverage of a satellite station. Satellites in geostationary (GSO) orbit, for example, are located at an altitude of approximately 36,000 km above the Earth's surface at the equator. These satellites orbit the Earth at approximately one revolution per day, which means that their orbital speed matches the Earth's rotation speed and, consequently, they appear to be in the same point in the sky when observed from a specific location on Earth. Due to its location in orbit, a single GSO satellite has visibility of more than one third of the Earth's surface and can be designed to provide entire countries or regions with communication services. Since they orbit along the equator, however, GSO satellites have no visibility of the Earth's poles. For polar coverage, non-geostationary orbits (non-GSO) provide better connectivity.

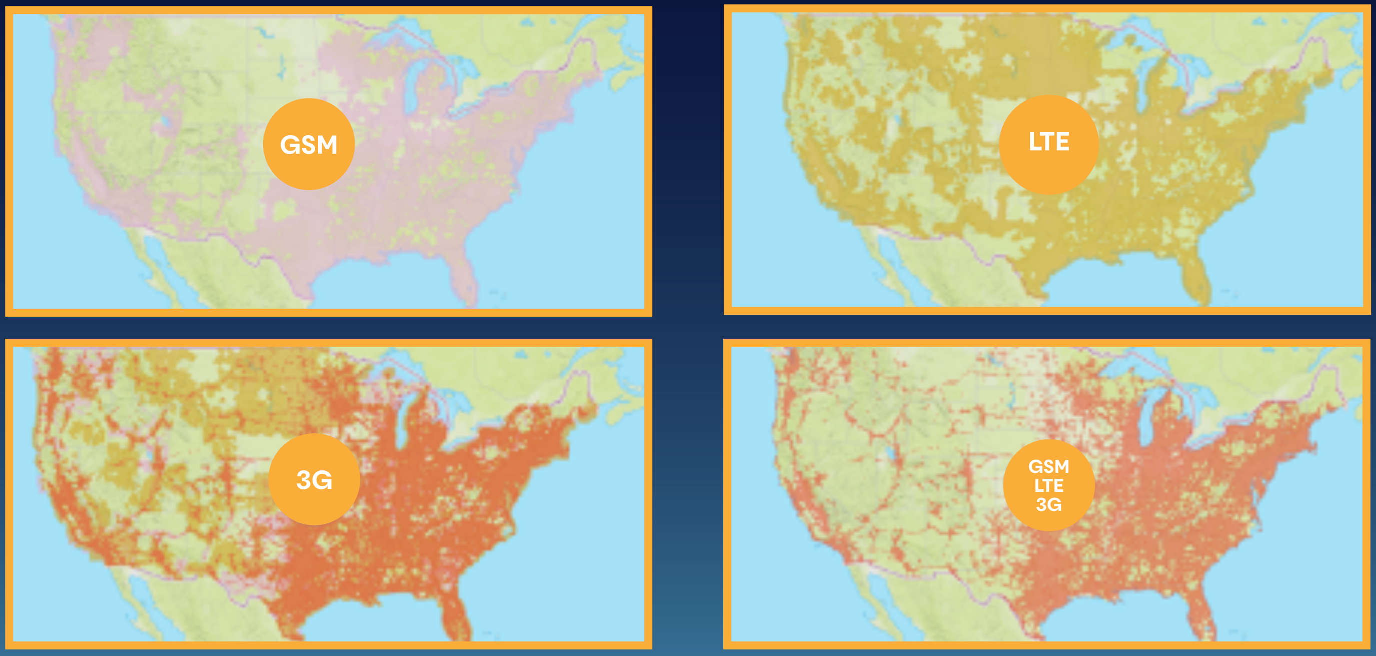
At lower orbital altitudes (400 to 20,000km), non-GSO satellites do not necessarily orbit the Earth around the equator and do not appear to be in the same position in the sky if always viewed from the same position on the globe.[78] Instead, they transition across the sky from horizon to horizon and need to be tracked by earth station antennas. A single Low Earth Orbit (LEO) satellite at 1,000 km altitude

FIGURE 10.
SATELLITE STATION COVERAGE EXAMPLE



has visibility of approximately 6.7% of the Earth's surface,[79] so entire constellations of non-GSO satellites are often used to provide true global coverage, including in the poles. It is this capability of providing a very wide area of coverage that makes satellite systems so useful in disaster relief. This wide coverage of satellite systems enhances the capabilities of terrestrial-based solutions and allows governments to provide communications in disaster relief situations wherever they happen.

In contrast with satellite stations, a single 4G macro base station, operating in frequency ranges between 1 – 3 GHz, has a typical coverage radius of 5 km.[80] Even with hundreds of thousands of base stations, coverage gaps in mobile networks are inevitable due to challenging terrain, lack of backhaul infrastructure, or low expected investment return. As an example, Figure 11[81] shows the GSM, 3G and the LTE coverage of a single mobile operator in the US. The coverage gaps demonstrate that, in the event of a disaster in an unserved area, alternative communication services would be necessary.



An interesting comparison can be made when the "cost per area covered" is evaluated among different technologies. Even though prices can vary significantly, the cost to launch a GSO satellite can be up to USD 30,000 per kilogram transported to the geostationary transfer orbit,[82] from which satellites manoeuvre to the geostationary orbit. Launches to low Earth orbit can vary in the order of a few thousands to tens of thousands of USD per kg.[83] Development costs can reach hundreds of millions of dollars for GSO satellites, but nano-LEO satellites are starting to be manufactured at less than USD 1 million.[84] At the same time, equipment, and deployment of a single 5G mobile cell site has been estimated as approximately USD 57 000.[85]

With this information, the development and deployment cost per km2 covered by a mobile base station, a LEO satellite and a GSO satellite is calculated in Table 2. **Satellite technologies are more expensive than individual mobile base stations but can cover much wider areas. For that reason, their deployment cost per covered km2 is significantly lower.**

	MOBILE BASE STATION	NGSO SATELLITE (1,000 KM ALTITUDE)	GSO SATELLITE (36,000 KM ALTITUDE)
COVERAGE RADIUS	**5 – 50 km**	50km+	50km+
COVERAGE AREA	**78.5 – 7854.0 km2**	34m km2	217m km2
DEPLOYMENT COST	**57 000 USD**	11m USD	150m USD
DEPLOYMENT COST	**725.7 - 7.3 USD/km2**	**0.32 USD/km2**	**0.70 USD/km2**

TABLE 2: COMPARISON OF COVERAGE VERSUS COST FOR DIFFERENT TECHNOLOGIES

An example of isolated regions, which often lack terrestrial telecommunications infrastructure and can only be reached by satellite, are small and remote islands. Due to lack of backhaul infrastructure and low demand, deploying mobile networks in small islands is sometimes not profitable or attractive for telecom network operators. Added to the fact that islands may be particularly affected by climate change[86] and subjected to an increasing number of environmental disasters, such as tropical storms and hurricanes, satellite connectivity is paramount for the protection of their population. It is clear, however, that even in areas where there is already terrestrial coverage, satellite systems are crucial for the mitigation of natural disasters.

B. NETWORK REDUNDANCY IN CRITICAL FACILITIES

Satellites in space are unaffected by disasters on Earth, so they provide resilience unmatched by terrestrial services. Hurricanes, storms, earthquakes, and other natural disasters have no impact on space infrastructure and, thus, satellites are crucial in providing redundancy in critical facilities such as hospitals, fire stations and police stations.[87] Critical facilities need to have stable, reliable communications virtually 100 per cent of the time, otherwise relief operations can be severely impacted. No telecommunications system, however, is immune to faults and unavailability, which means that these facilities require alternatives in case their main communication links become unavailable. Multiple communication links, often using different technologies from different providers, are used in conjunction to make sure communications are not interrupted. This is known as network redundancy.

It is well recognised that network and IT redundancy is crucial for modern hospital operations,[88] especially in the management of patient records. Redundancy can become even more important in the event of a disaster when hospitals need to be able to communicate amongst themselves and with disaster response teams to coordinate patient care. Loss of communications with critical facilities can impact the disaster response as a total, causing response teams to become isolated and unable to coordinate efforts. Therefore additional, redundant communication links, often **satellite links, can literally save lives in disaster affected areas where terrestrial-based communications become unavailable.**

C. MANAGING TRAFFIC AND CONGESTION UNDER EMERGENCY SITUATIONS

A key reason why terrestrial-based communications may become unavailable during disaster events is congestion.

Mobile networks are usually the first resource used by affected communities, responders, and government.[89] In these situations, people resort to mobile networks to contact the authorities or simply to check on friends and family. For example, call levels increased by a factor of 60, compared with normal traffic volume, in the aftermath of 2011's tsunami in Japan. To deal with this spike in network traffic, operators had to impose restrictions on up to 95% of voice calls. Even during the COVID-19 pandemic, network congestion was an issue in different parts of the world. During India's first lockdown, in March 2020, telecom traffic grew by half while maintenance staff had difficulties addressing the congestion due to social isolation measures.

Mobile networks often work in conjunction with Wi-fi traffic to Wi-Fi and other internet-based systems.[90] In the event of disasters, however, this option might not be sufficient or even available due to outages and infrastructure damage, so this is when **satellite networks can be used to handle part of the traffic overloading mobile networks**. Mobile communications offloaded through satellite solutions are a valid topic of research,[91] but very little or no information on real life uses of satellite communications in this context is available. Therefore, there is an important opportunity for the satellite industry in these applications. Satellite phones can handle the additional calls and data traffic rising in the aftermath of a disaster, while small aperture earth stations can provide broadband access, in an increasingly "over-the-top" oriented world.[92]

D. PROVIDING BACKHAUL CONNECTIVITY TO MOBILE CELLULAR NETWORKS

A telecommunication system can be hierarchically described by the means of three segments: access (which connects users to the network), core (routes the data to same and other subnetworks) and backhaul (connects the access and core segments). Usually, a backhaul is implemented via fibre optics or point-to-point microwave links due to the necessity of a large transmission capacity. However, such solutions are susceptible to natural disasters, as a fibre optics cable can be broken during an earthquake or a fire, and point-to-point towers can fall during a storm, for example. Additionally, in an emergency, such links are hard to deploy fast enough to serve the affected region.

To overcome these issues and substitute the faulty backhaul, a satellite link can be used. Existing satellites can and do manage the traffic for the affected areas until the main link is re-established. Figure 12 shows an alternate scenario where one radio-base was broken during a wildfire and the access to other network segments was compromised. Then, a satellite backhaul was deployed to guarantee the service to the users and provide emergency communication at the affected area. In disaster relief situations, with seriously damaged, not existing, or overloaded terrestrial communication infrastructures, satellite communications are already used to provide connectivity with unaffected remote terrestrial trunked radio (TETRA) core networks.[93]

For these and other reasons, many satellite companies include backhaul for mobile and cellular networks as part of the services they provide[94,95]. During the June 2019 wildfires in Portugal, main communication systems were affected and unavailable, so the telecommunications company Altice Portugal deployed a satellite backhaul to provide service during the time the main terrestrial core network was restored.[96] Another example of satellite communications being used as backhaul in mobile networks was on the 20th of August 2019, when the mobile communication bureau of China Telecom in Sichuan established a 4G backup network for emergency response command and control office staff as a consequence of torrential rainfall and mudslides in Wenchuan, China. The link was established by the means of a portable Ka-band satellite station. Sometimes it can take many months or even years to restore terrestrial links such that a satellite backhaul link that may have been intended as a temporary gap-filler has remained in place for a much longer period of time.

FIGURE 12.
SATELLITE BACKHAUL WORKING DURING A SYSTEM DISRUPTION GENERATED BY A NATURAL DISASTER

E. PRACTICAL LIMITATIONS TO SATELLITE-BASED SOLUTIONS: USER, COST, DELAYS, AND PROHIBITIONS

Even though they provide unique advantages, satellite-based technologies have their limitations. These limitations include limited popularity and user familiarity, as well as lower data rates than other technologies. From an economic perspective, mobile data costs vary widely across the globe, so satellite communications can both be cheaper or more expensive than mobile data depending on the location. In the US, for example, satellite services charge customers between USD 1.30 and 4.00 per gigabyte per month,[97] while mobile data is usually between USD 1.00 and 3.33 per gigabyte per month.

Designing, building, and launching a satellite network can also take years. Without pre-existing space infrastructure, satellite communications are not viable options for disaster relief missions. On the other hand, terrestrial based infrastructure, such as cells-on-wheels[98] and microwave links,[99] are commonly deployed in emergency situations. **The use of satellite systems in disaster situations relies on the existence of space infrastructure but, if such infrastructure exists, satellite communications deployment is relatively quick and straightforward.**

Compared to other technologies, some satellite links are more affected by rain and other atmospheric phenomena that communications during storms and hurricanes. Communications latency can also be a limiting factor in space services, especially when GSO satellites are involved. The sheer distance between these satellites and the surface of the Earth means that messages transmitted from a disaster affected area take longer to reach the satellite in space. Therefore, latency in GSO satellite networks can be higher than half a second and affect voice and video applications. By employing satellites at much lower orbital altitudes, however, non-GSO systems advertise latencies comparable the ones experienced in fixed broadband connections.[100]

Finally, there are regulatory and logistical limitations of satellite communications that could be overcome through better regulations and better planning. Satellite importation and installation process take time and cause delays especially in critical times after disasters. Lack of trust or in some cases negative perception of satellite phones may create problems on expedite deployment. Even after all the necessary permits are granted, transportation of the large equipment in bulks or training the staff to operate them could cause losing time.

F. CELLULAR-SATELLITE COMPLEMENTARITY IN NEW TECHNOLOGY

As discussed, when compared to terrestrial systems, space infrastructure can provide more coverage, resilience to disasters, ease of deployment (excluding launching), and other advantages. Their limitations, though, mean that they can operate in a complimentary manner with other technologies, including mobile cellular networks. Additionally, most cellular telephone users can afford devices around USD 200, whilst satellite telephone prices start from USD 1,000,[101] which is why most people are familiar with smartphones but have never used a satellite phone. 4G base stations can be deployed for tens of thousands of dollars to cover small areas permanently or temporarily, while a satellite system could incur in higher deployment costs.[102] These and other strengths and weaknesses of satellite and mobile communications are summarized in Table 2.

Regarding International Mobile Telecommunications (IMT), regulatory bodies, such as ITU (International Telecommunications Union) and 3GPP, determined that 5G networks should guarantee more resilient and redundant services to provide mission-critical applications.[103] For these and other reasons, satellite systems have been recognized as an integral part IMT.[104] Satellite links may even be a key feature to reinforce current networks in a fast and reliable way and could be essential for future IMT-2030 systems.[105] This recognition is evidence of the unique characteristics of satellite communications and their important role in complimenting cellular and other terrestrial-based communication systems.

	STRENGTHS	WEAKNESSES
SATELLITE COMMUNICATIONS	• Large area coverage, • Resilience to disasters on Earth, • Easy deployment in disaster relief, • Coverage in remote and underserved areas.	• Lower data rates, • More expensive equipment, • Less user familiarity, • High latency (for GSO systems), • Expensive design and launch.
MOBILE COMMUNICATIONS	• Higher data rates, • Cheap, accessible user devices, • Large technology adoption, • Cheaper for local coverage.	• Limited coverage per base station, • No true national/global coverage, • Terrestrial infrastructure vulnerable to disasters, • Harder to deploy,

TABLE 2: STRENGTHS AND WEAKNESSES OF SATELLITE AND CELLULAR COMMUNICATIONS

EXISTING POLICIES AND REGULATIONS

Preventing natural disasters arising from sea level rise or the increased intensity of typhoons and hurricanes cannot be successfully addressed by one country or a single individual alone. Instead, solving the climate crisis necessitates carefully managed policy coordination among multiple levels of stakeholders (national, regional, and multilateral).[106]

Effective disaster preparedness and response is only possible with adequate policies and regulations. For resilient networks in times of disaster, general telecommunication regulatory frameworks and disaster-specific policies and regulations are equally critical. Public authorities are obliged to be the designers and implementers of last resort connectivity solutions required during disaster management. In worst case scenarios, setting principles and imposing obligations on private sector players may not be enough.

Picard and Pickard state that in disaster communications, communication policies have two priorities:

i. enabling the public to communicate with authorities,

ii. enhancing communication among authorities themselves.

There could also be an additional goal of keeping/recovering user-to-user communication to enable affected communities to stay connected with each other or with the outside world. However, this would be the case only after necessary resources are allocated to the first two priorities dependent on the conditions after the specific disaster.[107]

Saving lives becomes the priority when managing disaster recovery, and unfortunately, existing conventional regulatory frameworks are often a burden to this objective due to their inadequacy for the specific conditions of a disaster. Decision-makers need to be pragmatic with regulatory silos and priorities. Competition, consumer rights, or privacy frameworks create additional challenges for next generation connectivity and disaster response solution. Authorization frameworks with long assessment and public comment periods that are developed to ensure competitive and transparent environments are ideal in non-emergency times but slow to respond to urgent needs in emergencies. As such, Having a well-understood and flexible system of issuing waivers or recognizing exceptions in the operation of emergency telecommunications isnecessary in emergencies, such as to enable additional connectivity until service providers recover their networks or when location information in a device could mean saving a life. It is advisable to establish a system that ensures that government decisionmakers' authority to quickly issue temporary waivers and exceptions in expressly and clearly set forth in a country's law or regulations, it is clear how and to whom to request waivers and exceptions when normal government operations are compromised, and does not require waiting periods, multiple layers of review, or the submission of documents that would be impossible to provide in the middle of disasters.

The preparedness element in disaster management is not solely dependent on strengthening state control and regulations. Enabling means to keep the telecommunications industry resilient is equally important. In times of disaster, public authorities, particularly regulators, are required to take immediate actions, including:

i. orchestrating public and private stakeholders, primarily operators, to readily adapt disaster-ready protocols;.

ii. ensuring redundant networks;

iii. encouraging operators to pursue cooperation, for example, for providing technical support to each other, national roaming when necessary, or satellite operator-mobile operator interconnection.

For instance, in Australia, the Strengthening Telecommunications Against Natural Disaster Package developed after the 2019/2020 bushfires aims to increase and improve resilience of affected communities. The package includes connectivity solutions such as satellite supported cells on wheels.[108]

Finally, it is important that telecommunications regulators, emergency response authorities, and customs/border authorities coordinate on emergency response procedures long before emergencies occur. This coordination is important because in past emergencies, a lack of coordination has left critical emergency response personnel or equipment unable to enter the effected country, or blocked by local emergency response authorises when attempting to deploy within a country to the most affected areas. This coordination should include a declaration that emercency telecommunicaitons is a critical element in response activities, so it is afforded priority treatment.

A. NATIONAL EMERGENCY TELECOMMUNICATIONS PLANS

The ITU's Strategic Plan for 2020-2023[109] sets as one of its targets that "by 2023, all countries should have a national emergency telecommunication plan as part of their national and local disaster risk reduction strategies" under the wider goal of sustainable telecommunications/ICT. National Emergency Telecommunication Plans (NETP) are the main policy tool for emergency preparation and communications response. Through the NETP, governments can assess the risks and capabilities specific to their territories, assign responsibilities, engage with stakeholders, and establish a framework for governance in managing emergencies. The ITU assists member states in developing NETPs through its Guidelines for National Emergency Telecommunication Plans.[110]

Operators have business continuity plans[111] for various kinds of emergencies including disasters, however, NETPs should serve as the public umbrella guidance for operator plans. Ideally, NETPs should move beyond imposing obligations on operators, and instead focus on identifying roles and responsibilities during disaster management. Additionally, countries should share disaster response and management experiences with each other to establish best practice archives.

ITU suggests that effective NETPs are built on 4 principles:[112]

1. Multi-phase

An NETP requires that all four phases of disaster management be addressed. These include prevention and mitigation, preparedness, response, and recovery. The mitigation phase includes any type of activity that seeks to prevent an emergency, reduce the likelihood of its occurrence, or limit the negative effects of unavoidable threats. The preparedness phase involves the planning and preparation needed to respond to an emergency. The response phase entails the execution of the plans and procedures established during the preparedness phase. Finally, the recovery phase occurs after the disaster and involves providing the help needed by the community to return to pre-emergency levels of safety and functionality. To be effective in disaster management, the plan should be able to address the different links among these phases, thereby leading to a cohesive approach.

2. Multi-hazard

National NETPs should adopt a strategy that addresses all potential hazards that a country is exposed to. This is especially true for countries in the Pacific, which experience the threat posed by increasing climate disasters while also facing topography-related calamities such as earthquakes and volcanic eruptions. During the implementation of the plan, decisions should be based on the most accurate information available about all likely disaster types. For instance, in India, different parts of the country are vulnerable to a diversity of disasters: earthquakes, floods, cyclones, landslides. Its policy on disaster management is cognizant of these differences, and the appropriate response to each kind is laid out in its plan.[113]

3. Multi-technology

A comprehensive evaluation of all telecommunications/ICT infrastructure to be used in all phases of disaster management is a critical component of the NETP. Different types of tools and technologies may be appropriate for various types of disasters; hence the response strategies must adapt to specific kinds of threat. Standard operating procedures should be in place to determine which type of technology is appropriate for a specific emergency. Satellite-based communications have been used in disaster recovery for over 50 years.[114] Recently with the improvements in satellite connectivity, use cases with satellite connectivity increased such as satellite-based M2M for alerting and detection. The first documented use of drones for disaster response was in Hurricane Katrina in the USA. Underwater drones were used in 2018 in Hurricane Florence.[115] Drones are expected to be deployed even more primarily in search and rescue operations, which would require reliable and mission-critical connectivity. Assessment of the input of the data collected by drones would also require other technologies such as deep learning.[116] The work of the World Food Programme, the leading agency of the Emergency Telecommunications Cluster, uses even more cases of drones in disaster and humanitarian response areas,[117] which would need connectivity.

4. Multi-stakeholder
Getting the participation of multiple stakeholders is essential for an NETP. This entails increasing their awareness and obtaining commitments to participate, contribute, and agree on a strategy, as well as fostering coordination and dialogue among each other. Appropriate disaster responses can be structured at various levels: individual, team, department, or community. Across these levels, the NETP could then be targeted to include trainings and drills that are ideal for all phases of disaster management. Bahrain's Telecom Emergency Response Plan, prepared by Telecommunications Regulatory Authority, includes a draft Memorandum of Understanding to be signed by operators. This MoU states that operators shall jointly prepare and share resources during emergencies as a Regulator oversees the implementation as a dispute resolver. The MoU leaves room for operators' discretion in areas such as settlement of accounts or definition and implementation of techniques and systems.[118]

B. SECTOR COORDINATION

The ability of institutions to respond to disasters is not always enough to orchestrate the use of ICT/ telecommunication. For instance, regulators, often detached from executive branches, might be in a better position than any single executive agency for an orchestrator role in the communications elements of response. This coordinating position may be beyond management of interaction between operators but also coordinating other governmental agencies such as customs officers, utility providers, international organizations and the wider public. This is especially important before emergencies, where the regulator can ensure that all government agencies and non-governmental entiites understand the importance of communications systems and how to integrate them into overall emergency response plans. In Puerto Rico, after hurricanes Irma and Maria in 2017, 95 percent of the cell towers lost service, not because of the hurricane itself, but because there was no power supply stemming from a lack of coordination between electric provider and telecommunications operators.[119]

Regulators may need to increase their human resources, administrative and technical capabilities for this coordinator role. During Tropical Storm Erika, operators reported their network status updates to the regulator who then conveys it to the main disaster response center. There have been delays in the reporting chain causing network failures.[120]Hence, the post-disaster assessment document of the Government of Dominica suggested a direct communication channel between the operators and the main disaster response centre instead of through the regulator.[121] However, in most cases, increasing the regulator's capabilities would be more reasonable rather than increasing the responsibilities of disaster response centres.

In some jurisdictions, ministries in charge of telecommunications may also be responsible for regulating mass communication, such as television broadcasting and radio stations, having a critical role that overviews public information channels. Transmitting trustworthy and timely information to all affected individuals and communities is a critical aspect of disaster management. When the institution in charge of telecommunications – either a Ministry or the regulator – are different than that in charge of mass media, a very close coordination mechanism between the two is essential.

C. AGILE AUTHORIZATION AND SPECTRUM ALLOCATION SCHEMES

Regulators should assess licensing frameworks with due attention to the urgent nature of disaster response. Regulatory or policy practices, which are acceptable or justifiable for a normal licensing procedure, like public notice and objection periods, might turn into a barrier during emergency situations. The legal frameworks should enable the regulators the flexibility to deal with time-sensitive authorizations and forego certain parts of the standard procedure as they deem necessary.

Additionally, in disaster response, easing documentation and integrating different processes into one procedure is necessary. Relaxing documentary requirements could be done by granting exemptions or deferrals from certain timeframes that would be deemed suitable by the regulator. The main goal in the expedited authorization after disaster hits must be starting provision of service as soon as possible, with requirements as minimum as possible. A close contact such as a hotline for operators and other stakeholders that requires authorization should be maintained to provide administrative support and clarification in the time-sensitive application procedure.

Integrated and expedited authorization and spectrum allocation is especially needed when it comes to installation of earth stations in disaster areas. Thus, while satellite connectivity is the best solution in most of the disasters, the attendant processes needed in the licensing of earth stations—which may include a service offering license, a radio frequency license, or construction permits, among others—tend to be generally complex and time-consuming procedures. As such, the installation of temporary facilities such as small satellite earth stations[122] could help in emergency situations or disaster recovery operations.[123]

Exemptions and temporary measures

Satellite M2M is increasingly being used for emergency equipment tracking and emergency messages. ITU's dedicated expert group noted that this technology particularly suffers from complex licensing procedures.[124] There are two different methods that governments can establish to expedite licensing procedures for emergency communications:

1) Providing exemption clauses in the legislation that delivers a fast-track application and issuance procedures with the possibly for omission of certain steps and exemption from certain fees. The FCC issues Special Temporary Authority Licenses for limited terms for extraordinary or temporary situations including natural disasters. Fee exemptions are also provided for emergency communication providers.[125] In Barbados, the Minister may grant a special spectrum licence in the case of an emergency under the circumstances specified in the Spectrum Plan for 10 days.[126]

2) Alternatively, the regulator could be equipped with temporary authority to issue emergency licenses that are valid for a limited period. In Mongolia, Regulation on Licensing Procedure for Activities in the Field of Communications grants the Regulator a right to make temporary arrangements that would expire after the disaster.[127]

Spectrum usage planning

Spectrum usage planning for emergency communications should aim to start at the preparation phase of disaster management. Mobile networks are designed efficiently for normal times, which would not be sustainable for mission critical communications during disaster response and recovery times. They are resilient for single-point failure yet in cases of multiple simultaneous link failures (such as disaster conditions) they need to be supported by alternative backhauls. As a solution, a temporary additional connectivity provided by another network might be an answer.[128]

In order to provide backhaul resilience, different channels such as fibre, satellite or micro-wave need to be integrated in the network design. During the early days of an emergency, most of the traffic is carried on satellite links.[129] Flexible spectrum allocation that considers possible alternative network designs after disasters need to be developed in this regard. There are already scientific studies that look at the possibility of borrowing additional spectrum from terrestrial networks to support drone-based networks.[130] Particularly, redundancy in satellite communication bands is critical since most of the disaster connectivity solutions are expected to be based on satellite telecommunications.

Finally, apart from flexible spectrum allocation, derogations on spectrum monitoring rules such as allowing increases in power level in the stations that are still able to operate might be needed in certain cases to make effective use of functioning infrastructure.

D. BALANCING COOPERATION AND COMPETITION CONCERNS

The flexibility of competition policy in responding to existential threats is nothing new, as evinced during the height of the COVID-19 pandemic. The sweeping economic impact of this public health emergency has led to a temporary relaxation of competition rules to keep prices from becoming prohibitive and to ensure the survival of millions of businesses.[131] Coordination between competitors – which would have ordinarily amounted to anti-competitive behaviour— has been sanctioned as a legitimate policy tool to combat the adverse effects of the pandemic across markets. For instance, the United Kingdom has temporarily suspended stringent rules on anticompetitive agreements by allowing cooperation among grocery retailers, suppliers, and logistics providers to prevent food shortages, as well as information sharing in relation to capacity for providing health services to help alleviate the impact of the pandemic on healthcare delivery.[132]

There are multiple levels of collaboration that can be explored, which could possibly pave the way for innovative green solutions in climate emergency responses. For example, sharing of information among emergency communication providers could facilitate the development and quick rollout of life-saving technologies. Rules to facilitate network sharing in times of emergencies could also be established to aid in the aftermath of post-disaster situations, and to preclude firms from gaining competitive edge over a weakened rival by taking advantage of such a delicate situation.[133] These areas serve as opportunities wherein competition policy can help shape a more robust response to climate change-induced emergencies.

Nonetheless, as firms strive to innovate and outpace each other to deal with the impact of climate-induced disasters, regulations may have to be more adaptable to these scientific advances. The prevalence of the use of various satellite-powered technologies in disaster communications may bring about poor interference management issues among different satellite operators, which could in turn have adverse impacts both on competition among satellite operators and on the welfare of millions of end-users relying on their services.[134]

Flexibility during an emergency in antitrust enforcement does not necessarily mean a permanent reprieve from the applicability of long-standing competition principles. In this regard, it can be noted that both the UK Office of Communications[135] and the UK Competition and Markets Authority[136] have opened separate investigations of Motorola's dual role of operating the existing mobile radio network for emergency services while simultaneously being a key supplier in the rollout of its replacement, the Emergency Services Network (ESN). These developments underscore the need to maintain fair competition in the delivery of these critical services, as anti-competitive conduct can potentially impact their effectiveness and can restrict their abilities to save lives.

As climate change and the heightened risk of catastrophes continue to bring about transformative challenges, competition policy needs to be more adaptable in providing appropriate regulatory interventions. While this does not entail a complete rewriting of established competition norms, governments and businesses may have to be flexible and employ an increased level of cooperation in the application of these rules.

E. ENABLING REGULATORY FRAMEWORKS

Regulators need to be ready to switch to a different set of priorities and assumptions in disaster response swiftly and open all connectivity alternatives by reducing barriers. Some regulatory measures are necessary and justifiable in normal times, but not under emergency situations. Some regulatory facilitation measures could be:

i. providing temporary licenses or waivers on a fast track;

ii. derogations from competition and operation obligations such as quality of service or traffic management/local gateway rules;

iii. permitting rapid importation and temporary use of telecommunications equipment through waivers of customs regulations, license fees, and equipment certification; and

iv. signing memorandums of understanding (MoU) with international private actors to create possible frameworks of cooperation and capacity building in disaster response initiatives.

Traffic Management Obligations
Regulations on how to route traffic geographically, or in a service-based manner, could be put in place in some jurisdictions to use the network in an efficient, profitable or a secure way.

In times of disaster, it goes without saying that calls between disaster response stakeholders need to be prioritized. The ITU have already standardized priority routing in documents ITU-T Recommendation E.106 and provide a set of rules that could be adopted or used as a starting point for preferential treatment of priority traffic in networks with limited capacity after disasters. Such regulations would also release the operational burden on the operators and help them as guidelines.

Traffic management regulations that require local gateways or certain routes that call to be carried may not be functional or may create unnecessary delays. Regulators should act swiftly on issuing measures ex ante or sometimes ex post for uninterrupted communications. In the case of border zones especially, traffic may be carried through the networks of the neighbouring country, or in cases of cross-border disasters, cross-border network collaboration might be necessary. A good case study can be found in the Cook Islands: when the mobile core became dysfunctional in the Islands due to wildfires, satellite connectivity provided from American Samoa[137] has been[126] Such measures are not beyond the usual duties and responsibilities of regulators, including consumer protection.

Data protection flexibility during emergencies
Exceptions regarding data protection and processing rules may be necessary for missing individuals or groups of individuals. For instance, turning on location functions of a mobile device over the air could be justified if there is an urgent need to locate the person and save their life. In other cases, analysis of social media data for groups or individuals might be needed to identify trends or group movements across a territory.[138] During the 2010 earthquake in Haiti, operator Digicel shared call data record (CDR) information with the researchers from the Karolinska Institute and Columbia University who worked on movement patterns of displaced people to provide improved disaster response.[139] During the Ebola outbreak that started in 2013 in Western Africa, the lack of data sharing policies and practices hindered coordination between authorities and caused further spread of the disease.[140] In particular, mobile operators were not able to share CDR data that could have been used for containment since the data protection and exception rules were not clear about whether operators would be liable against a user complaint or a regulatory investigation.[141] Using these past lessons, data access and sharing in disaster response should be recognized as a clear legitimate exception to user consent and other data protection regulations, especially for geospatial data.

Numbering waivers
Elements of quality of service and tariff regulations may be relaxed during disaster management. For instance, as a precaution against Hurricane Ida, in September 2021, the FCC issued various waivers from numbering regulations, number portability, rural health care as well as a permit for higher symbol rate data transmissions for Hurricane Ida traffic.[142]

F. ICT EQUIPMENT PRIORITIZATION AND STANDARDIZATION

Fast deployment of equipment and trained staff in a short time could be a barrier when institutional responsibilities across government entities are not well defined. There might be various causes of delays such as lack of communication between the stakeholders, red tape or duties and tariffs imposed on importation of the equipment. The Importation and Customs Clearance Together Working Group (IMPACTT) established by UN-system organizations and international aid organizations such as Save the Children and the Red Cross, focuses on streamlining and mitigating barriers against humanitarian aid material.[143]

The Tampere Convention
The Tampere Convention on the Provision of Telecommunication Resources for Disaster Mitigation and Relief Operations[144] is a multilateral treaty governing the provision and availability of communications equipment during disaster relief operations. It focuses on the transport of radio and v related equipment across borders. The Tampere Convention was concluded at the First Intergovernmental Conference on Emergency Telecommunications (ICET-98) in Tampere, Finland, in 1998, and went into effect on the 8th of January 2005. Currently, 49 states are full parties to the Convention while a further 11 signatory states continue to on the full ratification processes. Cabo Verde is the most recent joining member (2018).[145]

Before Tampere, the trans-border use of telecommunication equipment by humanitarian organizations was often impeded by regulatory barriers that make it extremely difficult to import and rapidly deploy telecommunications equipment during emergencies, without the prior consent of the local authorities. The treaty simplified the use of life-saving telecommunication equipment by expedited measures such as recognition of foreign-type approval or exemptions from taxation, duties or other charges for equipment and other relevant materials. The United Nations Emergency Relief Coordinator (UNERC) was designated as the operational coordinator for the Convention with the support of other agencies, including the ITU. State Parties may request telecommunication assistance from the operational coordinator or from another State Party directly.

Type approval waivers

The Tampere Convention sets a clear framework, yet even without being signatories of the Convention, regulators could take steps to ease equipment standardization and importation procedures. In urgent cases, specific waivers for type approval could be issued for critical equipment. For instance, pre-approved equipment could be deployed with the regulators enacting a relaxation of the necessary documentation for type approval, for example, by utilizing the supplier's declaration of conformity.[146]

Alternatively, regulators may recognize foreign type approvals for a limited amount of time in situations of crisis. In the long run, further harmonization of type approval and standardization processes would serve both developers and regulators to streamline such efforts. Regarding non-GSO satellites, developments such as multi-orbit antennas or multi-functional devices would help developing more resilient disaster response frameworks.[147]

CALL TO ACTION

Given the importance of upgrading national planning for emergency and disaster management communications to prepare for the effects of Climate Change, regulators and policymakers should critically assess:

1) their overall disaster communications response strategy (preparedness)
2) the degree of national infrastructure and logistic inclusiveness for satellite-enabled emergency responses.
3) the adaptability of their licencing frameworks, as well as expanding their capabilities by partnering with the satellite operators.

A call to action is needed in 4 priority areas, focusing on (i) designing clear strategies, (ii) increasing speed of response, (iii) regulating for future technology, and (iv) multiplying resources by integrating the private sector. The below recommendations require a prompt timeline, for it address elements of coordination, facilitation and innovation policy affecting multiple telecommunications players and government bodies.

1. PROVIDING CLEAR STRATEGIES TO MINIMISE DAMAGES

- Integrating of NETPs as a Climate Change, Climate Adaptation policy priority
- Defining the role of public institutions, Telecommunications operators and other stakeholders clearly in NETPs
- Designing appropriate system communications re-activation protocols (system-user)
- Benchmarking best practices against experienced jurisdictions that are considered high risk
- Seeking expert and stakeholder advice on NETP designing, including ITU's 4-principles integration

2. INCREASING SPEED OF RESPONSE IN CRITICAL TIMES

- Preparedness Facilitating emergency response capabilities by planning and factoring-in logistics including the availability of / access to necessary satellite equipment and trained personnel to install/use it
- Developing expedited licencing for emergency communications
- Guaranteeing flexibility measures to facilitate emergency communications deployment
- Facilitating good-faith partnerships with international satellite network operators

3. REGULATING FOR FUTURE TECHNOLOGIES

- Channelling the effective assessment of new tech for disaster management adequacy
- Enabling M2M solutions as search and rescue alternatives
- Envisioning satellite IoT as part of emergency communication systems
- Assessing next generation connectivity models
- Prioritise user-centred and widely accessible solutions

4. MULTIPLYING RESOURCE BY PARTNERING WITH THE PRIVATE SECTOR

- Delivering activation protocols known to industry
- Promoting national and international coordination and collaboration
- Empower satellite-based planning aiming at shielding populations during disasters
- Considering the future role of LEO constellations
- Moderating competition concerns to enable network complementarity and redundancy

FOOTNOTES

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