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BULLETIN 374

FACILITATION OF TRANSPORT AND TRADE IN LATIN AMERICA AND THE CARIBBEAN

The resilience of infrastructure services in Latin America and the Caribbean: a first approach

Background

The physical integrity of infrastructure works has always been a live issue, as the assets in question are constantly under stress owing to their use. However, debates over the continuity of infrastructure services have become more important with the emergence of more complex combinations of hazards, and the heightened frequency and magnitude of extreme events that have major impacts on transport, energy, housing and other infrastructure systems. In many cases, infrastructure is the first line of defence against natural and man-made hazards (Ijjasz-Vasquez, 2017).

This *FAL Bulletin* discusses the concepts that are considered central to infrastructure resilience, and identifies the main challenges in making infrastructure more resilient and thus advance development in the countries of Latin America and the Caribbean. To this end, it proposes an integrated approach not only for constructing new infrastructure but also for enhancing the resilience of infrastructure services and users.

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This bulletin forms part of a longer document on infrastructure resilience, to be published shortly. For comments, suggestions and further background, please contact fabio.weikert@un.org.

In Latin America and the Caribbean there are additional reasons that make the debate over resilience a fundamental part of designing and implementing infrastructure policies. Problems that have affected the region for decades, such as congestion, the infrastructure gap and an imbalanced modal split, pose obstacles to future development and the capacity to respond to hazards and threats and recover from them.

Since logistical services are provided over transport networks and also depend on other infrastructure services, such as energy and telecommunications, the debate on infrastructure resilience is particularly important for trade and economic production. The lack of infrastructure services that are resilient to shocks and stresses, whether natural or anthropogenic, is associated with high infrastructure recovery costs, overburdened assets and loss of competitiveness among businesses, economic sectors and regions. The emergence of value chains, both global and regional, elevates the economic risks of non-resilient infrastructure still further.

Accordingly, this document seeks to launch discussion on the resilience of infrastructure services in Latin America and the Caribbean. Following background information provided in section I, the next section presents the conceptual issues that underpin the topic. Section III then discusses critical infrastructure and its interdependencies; and section IV addresses some of the main challenges faced by Latin American and Caribbean countries in making their infrastructure services more resilient. Lastly, section V sets out a number of recommendations for consideration by the region's decision makers.

I. Infrastructure resilience: conceptual issues

One of the most widely used definitions of resilience is that of the United Nations Department for Disaster Risk Reduction (UNDRR), which defines it as "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management" (United Nations, 2016).[1]

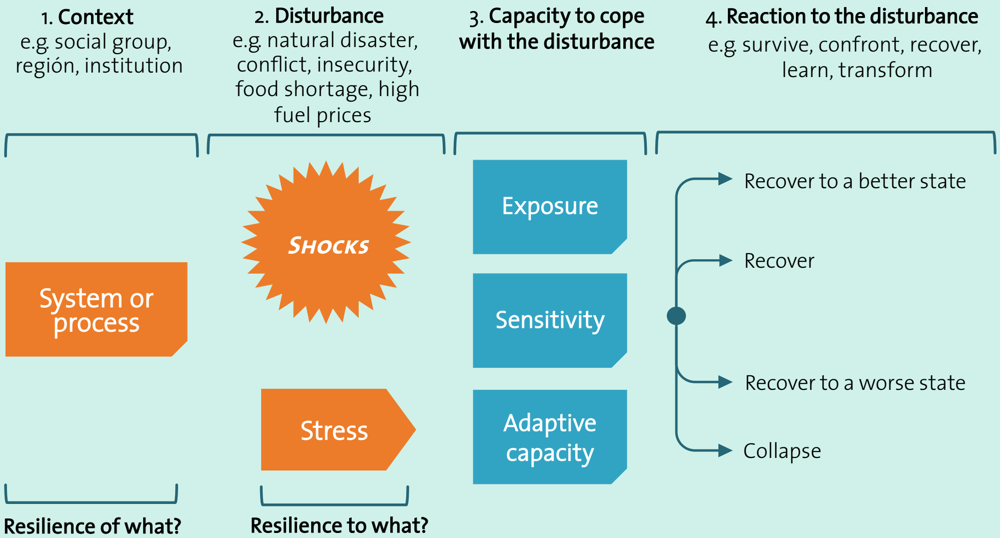
The concept of resilience can be applied on different scales, including individuals, households, communities, institutions, and even States. In all cases, the subject of the analysis needs to

[1] It is theoretically possible to assess the resilience of different components of infrastructure —ranging from a specific asset to a set of networks and systems— in response to shocks and stresses of various types and origins, whether natural or anthropogenic. However, it is also essential to define the system being evaluated and assess its capacity to cope with and react to a specific disturbance.

be identified (resilience of what or whom) along with its object (resilience to what). In other words, the system under analysis and the type of disturbance to which it is exposed need to be defined, along with the effects to which it must react. Adopting the concept of resilience also means identifying the system's capacities, abilities and response times in respect of a given threat (Gallego-Lopez and Essex, 2016).

Diagram 1 below provides a holistic representation of the concept of resilience and how its key elements relate to each other.

Diagram 1
A holistic view of resilience

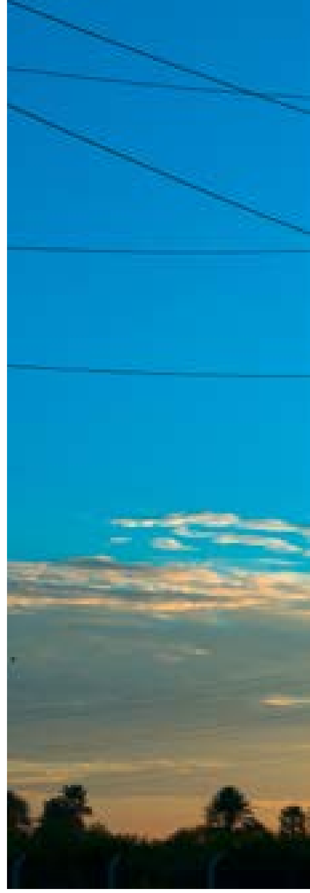


Source: Prepared by the author on the basis of The Department for International Development (DFID), Defining Disaster Resilience: a DFID Approach Paper, 2011 [online] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/186874/defining-disasterresilience-approach-paper.pdf.

As noted by Gallego-Lopez and Essex (2016), the relationship between resilience and infrastructure in the context of development can be viewed from two perspectives: the first is the resilience of the infrastructure itself; that is, the capacity of infrastructure systems to withstand disruption while maintaining their critical functions, and how this provides wider benefits to the users of the infrastructure services in question. The second is how the infrastructure —and its attributes, such as quality, design and operation— affects the resilience of other systems (infrastructure or otherwise) and the livelihood alternatives of individuals, households and communities.

In keeping with the framework represented in diagram 1, the first approach would be to assume a given infrastructure system as the framework of analysis, or the system or process of interest. The second approach is to understand its effects on a system's capacity to cope with and react to shocks. From this standpoint, therefore, infrastructure is one of the factors that influence the exposure, sensitivity and adaptive capacity of other systems; and, to some extent, it determines the state of those systems following a disruptive event.

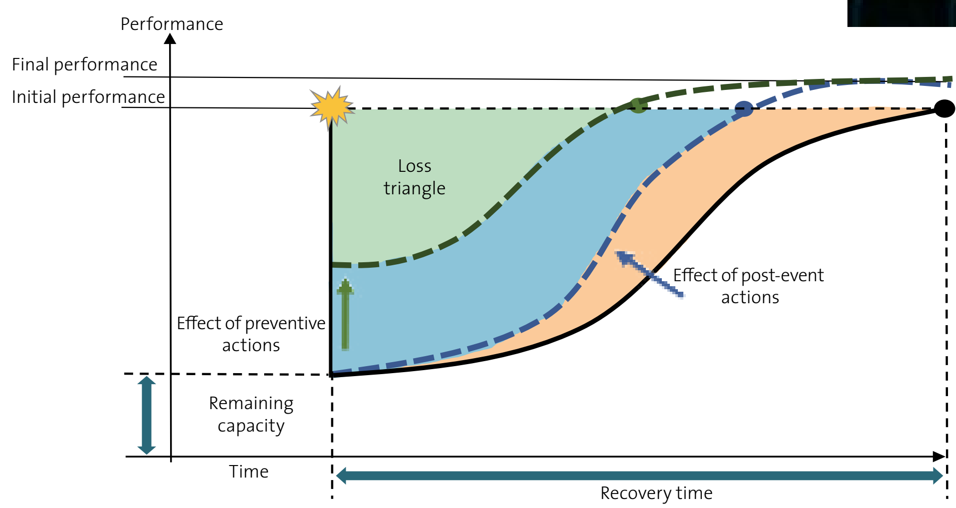
Discussions of infrastructure and resilience have mostly adopted the first of these approaches (Gallego-Lopez and Essex, 2016); and governments have historically paid attention to infrastructure vulnerabilities by focusing on protecting the component assets. However, as Fisher and Gamper (2017) emphasize, the rising costs of disasters and increasingly frequent cyber- and terrorist attacks in the early twenty-first century have fostered a more resilience-oriented approach to critical infrastructures. These include systems considered essential to the proper functioning of society, the collapse of which would cause major harm to social well-being, health, security, or the economy (OAS/Microsoft, 2018).



Bruneau and others (2003) argue that a system's resilience must be based on three complementary measures: reduced failure probabilities; reduced consequences from failures (in terms of lives lost, damage and adverse social and economic consequences); and reduced time to recover the system's "normal" functionality. Diagram 2 represents the behaviour of a hypothetical infrastructure system following a disruptive event. Two main strategies for promoting resilience can be inferred from this diagram: (1) specific post-event actions that speed up the recovery process, thereby reducing the time needed to regain normal system performance; and (2) preventive preparedness and risk mitigation actions that reduce the degree to which system performance is diminished following a shock (such as an earthquake). The combination of preventive actions and post-event measures could, in theory, significantly diminish the "loss triangle", that is, the area representing the loss of system performance resulting from a disruption (De la Llera and others, 2017).

Diagram 2

Conceptual framework of resilience in infrastructure

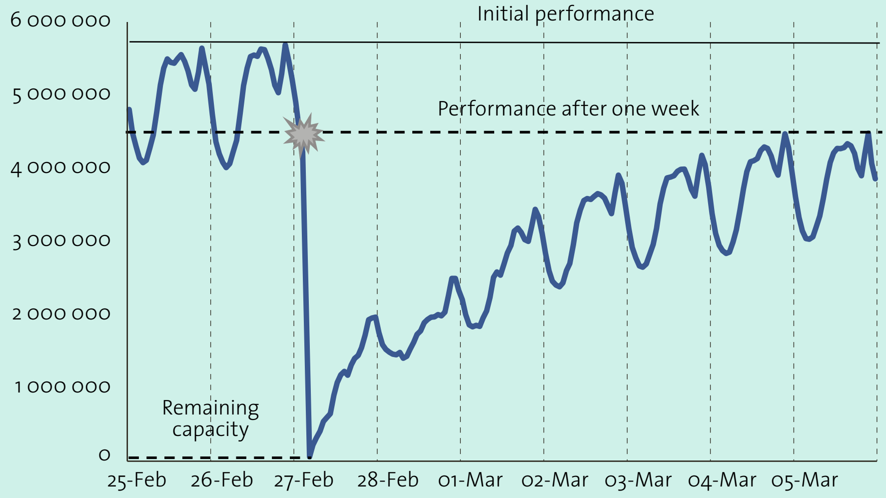


Source: Prepared by the author on the basis of J. C. De la Llera and others, "Infraestructura resiliente: lecciones del caso chileno", *Integration & Trade Journal*, vol. 21, No. 41, 2017.

In some cases the measures adopted may result in the system performing better than before the event; alternatively it might take a long time or even be impossible to restore its initial functions. An example is shown in Figure 1, which represents the net demand for electricity (in kilowatts dispatched by the national electric power grid) following the earthquake that struck Chile on 27 February 2010. One week after the event, the initial performance of the system (here considered as the maximum daily level of net electricity demand) had not yet been regained. However, the preventive and post-event measures adopted in Chile enabled normal service to be resumed approximately one month after the earthquake.[2]

[2] Notwithstanding the high costs caused by the 27 February earthquake in sectors and systems such as manufacturing industry, tourism, housing, health and electric power distribution, various international agencies viewed the small loss of human lives as an example of resilience in Chile's reaction to the earthquake. This is mainly attributed to the anti-seismic building codes in force in the country. According to De la Llera and others (2017), the exposure and current resilience of infrastructure to earthquakes in Chile were largely determined by institutional and regulatory decisions made in the past.

Figure 1
Performance of the Chilean national power grid following the earthquake of 27 February 2010
(kW dispatched)



Source: Prepared by the author on the basis of data from National Electric Power Coordinator (2019).

In this connection, Gay (2016) notes that resilient infrastructure is not infrastructure that never fails; but rather, after suffering a natural or anthropogenic failure event, it is capable of sustaining a minimum level of service and regaining its original operating performance within a reasonable time and at a reasonable cost. The approach to infrastructure resilience is therefore no longer simply a question of preventing the occurrence of a disruptive event, but of emphasizing the system's ability to recover and minimizing the consequences of failure.

II. Critical infrastructure: vulnerabilities and interdependencies

Owing to their complex nature and high degrees of interconnectedness, "critical infrastructures" are particularly vulnerable to chain-reaction effects in crisis situations. For this reason, if not constructed and managed properly, they can act as vectors in spreading the negative impacts of disasters, multiplying the risks and adding additional layers of complexity to the disruption which hamper response activities (Fisher and Gamper, 2017). For this reason, some countries have mapped the dependencies and redundancies of these infrastructures (United Nations, 2016). The set of sectors considered critical infrastructure components varies widely according to the national context. Table 1 lists the sectors identified as part of critical infrastructure for two selected groups (members of the Organization for Economic Cooperation and Development (OECD) and the countries of Latin America and the Caribbean).[3]

Table 1

Critical infrastructure sectors for a group of OECD and Latin American and Caribbean countries

Sectors	OECD countries					Latin America and the Caribbean				
	Germany	Australia	Canada	United States	United Kingdom	Brazil	Chile	Colombia	Costa Rica	Jamaica
Energy	■	■	■	■	■	■	■	■	■	■
Food (and agriculture)	■	■	■	■	■			■		■
Water (and wastewater)	■	■	■	■	■	■	■	■	■	■
Transport	■	■	■	■	■	■		■	■	■
Health	■	■	■	■	■			■	■	■
Banking and finance	■	■	■	■	■	■		■		■
Communications		■	■	■	■	■	■	■	■	■
ICT	■	■	■	■	■	■	■	■	■	■
Government	■		■	■	■			■		
Emergency services	■	■	■	■	■					■
Manufacturing and other industry	■		■	■				■ a		
Protection			■							
Social infrastructure							■ b			
Laboratories		■								
Chemistry		■		■						
Defence / security		■		■				■		
Commercial facilities				■				■		
Dams				■						
Nuclear				■						
Law enforcement and compliance	■									
Airports							■		■	■
Ports							■		■	■
Education								■	■	
Mining-energy								■		
Environment								■		

Source: Prepared by the author on the basis of M. Fisher and C. Gamper, Policy Evaluation Framework on the *Governance of Critical Infrastructure Resilience in Latin America*, Washington, D.C., Inter-American Development Bank (IDB), September 2017, and national documents.

[a] Includes tourism services.

[b] In addition to health and education, also includes public spaces and prisons.

[3] According to O'Rourke (2007), also closely related to critical infrastructure is the concept of "lifelines", which was developed to evaluate the performance of large, geographically distributed networks during earthquakes, hurricanes, and other hazardous natural events. Lifelines are grouped into six principal systems: electric power, gas and liquid fuels, telecommunications, transportation, waste disposal, and water supply.

Critical infrastructure vulnerabilities are a source of wider systemic risks that need to be assessed and managed. When directly affected by a variety of disruptive events —such as extreme weather or cyberattacks— infrastructure networks can become channels through which the impacts spread to a wider group of users, sectors and systems. Thus, in addition to the direct impacts of a disaster event (such as those affecting infrastructure assets and the health of users), the communities exposed are also subject to indirect impacts, generally associated with potential economic disruption. These knock-on effects of disasters are often more costly than the direct ones, since they affect a larger number of people spanning entire networks and logistics chains and are more difficult to prevent (Obolensky and others, 2019).

Floods provide an example of events that cause major disruptions to transport systems in urban areas. The congestion resulting from this type of shock generates direct impacts (in terms of the cost of fuel and the extra time spent by users of the transport network) and indirect impacts (such as increases in the prices of goods transported over the congested network). By disrupting traffic on segments of urban road networks —with consequent repercussions on business operations— floods also affect the functioning of labour markets and the ability of people to access basic goods and services, such as food and health care, which are particularly important in disaster aftermaths (Obolensky and others, 2019). In Guatemala, for example, Baez and others (2017) found that urban poverty increased by about 18% following Tropical Storm Agatha in 2010, largely as a result of higher food prices caused by interruptions to the transport network and food supply chains.

There is also increasing concern at the severe impacts that technological shocks can have on infrastructure services and their users. As modern infrastructure assets (such as power generation plants, water supply systems and electricity transmission and distribution grids) have become interconnected systems integrated into information and communication technology networks, they have also become more vulnerable to sophisticated cyberattacks (Génge, Kiss and Haller, 2015). It is estimated, for example, that the cost of cybercrime in terms of lost productivity and global growth will rise to US$ 3 trillion per year by 2021 (Morgan, 2019).

Corroborated by these figures, the current climate of uncertainty, in conjunction with the importance of systems such as transport, energy and telecommunications networks for social, economic and environmental development, has led to the concept of "resilience" being applied to critical infrastructure systems, not just as a buzzword, but also an optimal course of action (Linkov and others, 2014). Debates on this concept can contribute a shared and more practice-oriented development agenda by fostering links between different disciplines and areas of knowledge, such as climate-change adaptation and disaster-risk management (Sturgess and Sparrey, 2016).

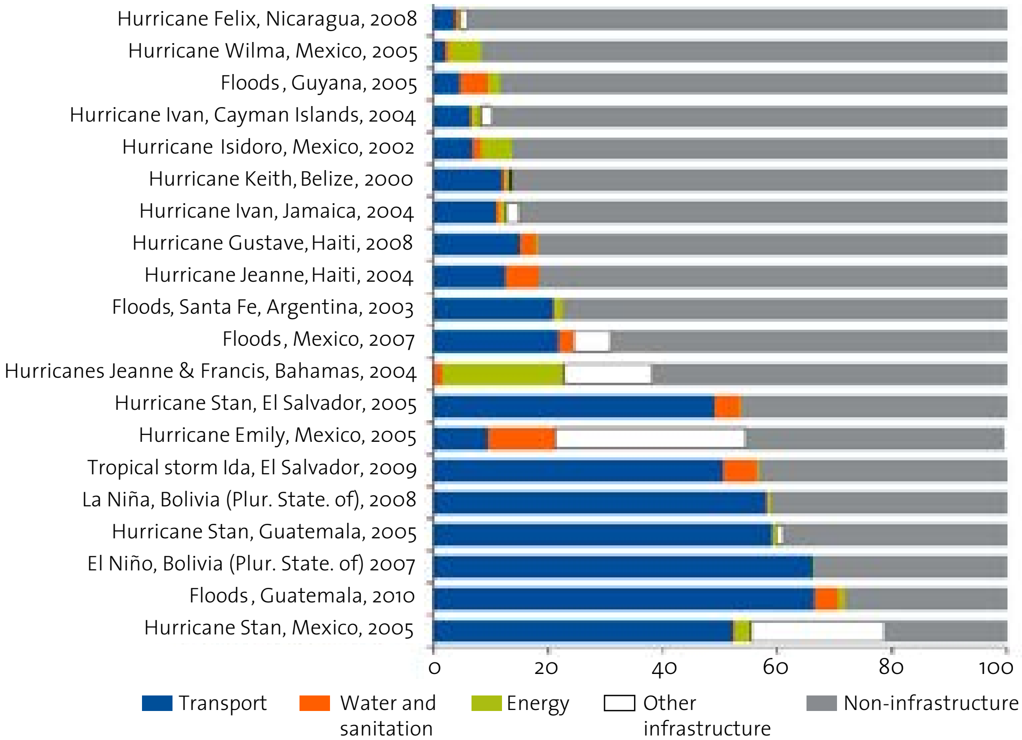
III. Infrastructure resilience in Latin America and the Caribbean

The debate over resilience is fundamental for the design and implementation of infrastructure policies in Latin America and the Caribbean for several reasons, owing to the combination of factors that make the region's systems highly vulnerable to a variety of hazards. These may be natural (for example, droughts, earthquakes and extreme weather), technological (such as the collapse of structures or cyberthreats) or socioeconomic (such as social conflicts, labour strikes, or supply crises). Moreover, these factors hinder the development of greater responsiveness and resilience to such threats —by the infrastructure networks themselves and, more broadly, by their users.

The region's high levels of exposure and vulnerability to natural hazards and extreme weather events, need to be highlighted. For example, data from the World Risk Index show that over 60% of the region's countries present medium to very high levels of risk in the face of disasters (ECLAC, 2018). Although only direct effects are considered (excluding systemic interdependencies), the consequences of disasters for infrastructure can be considerable. Figure 2 shows each infrastructure component's share of the damage generated by some of the main disasters in the region's countries between 2000 and 2010, with transport infrastructure being the most affected component in most cases, sometimes absorbing more than 50% of the total impacts.

Figure 2

Infrastructure damage caused by disasters in Latin America and the Caribbean (2000-2010)



Source: M. Fay, and others, *Rethinking Infrastructure in Latin America and the Caribbean: Spending Better to Achieve More*, World Bank, 2017 [online] http://documents.worldbank.org/curated/en/676711491563967405/pdf/114110-REVISED-Rethinking-Infrastructure-Low-Res.pdf.

The magnitude and frequency of extreme events are expected to increase as a result of heightened climate variability, which will have serious consequences for critical infrastructure in Latin America and the Caribbean (Fisher and Gamper, 2017; BNamericas, 2018). According to ECLAC (2015), the effects of climate change are estimated at between 1.5% and 5% of the region's current GDP by 2050. Moreover, authors such as Fay and others (2017) note that the capacity of current infrastructure in Latin American and Caribbean countries to deliver services is already being impaired as a result of climate change-related shocks and stresses. Hydroelectric power generation and the navigability of canals, for example, are compromised by the increased frequency and intensity of droughts, and also by the melting of glaciers. Other transportation assets, such as roads and bridges, are also highly susceptible to the impacts of landslides, storms and floods.

In Latin America and the Caribbean, infrastructure is made even more vulnerable by the fact that its quality and quantity in most of the region's countries are generally inferior to those of the advanced economies and the emerging Asian countries, owing to the low levels of public and private investment in this sector.[4] In the case of transport infrastructure, for example, indicators such as road network density reveal the region's backwardness: in 2015, the average length of the road network relative to area in Latin America (16 countries

[4] The region's total investment in infrastructure averaged 2.2% of GDP per year from 2000 to 2015. Estimates of investment needs (including maintenance and repairs) range from 3.7% to 7.4% of GDP according to the scenarios projected for the trend of regional GDP (Sánchez and others, 2017).

considered) was 22.8 km per 100 km^2, compared to 180.3 km in Germany, 108.7 km in the Republic of Korea and 71.5 km in the United States. In terms of quality, only 23% of roads in Latin America are paved; and secondary and tertiary roads account for roughly 85% of the total network (Sánchez and others, 2017).

In addition to the infrastructure gap prevailing in Latin America and the Caribbean, it is well known that many of the region's infrastructure services do not operate adequately, thereby causing bottlenecks that hamper sustainable growth. Examples include: transport congestion on roads or in the region's cities; occasional or frequent interruptions of various services, such as water, electricity and telecommunications; flooding owing to a lack of investment in new facilities or a failure to maintain and upgrade ageing water infrastructure; and adverse environmental impacts due to the use of inefficient or obsolete technologies in the infrastructure sector. The fact that current infrastructure is neither sufficient nor adequate for the region's needs is even more worrying in the light of demographic projections: by 2030, the population of Latin America and the Caribbean is expected to be 58 million larger than in 2019 (Sánchez and others, 2017; ECLAC, 2019).

The infrastructure quality and quantity gap raises persistent obstacles to greater resilience (CAF, 2016; Cerra and others, 2016; Sánchez and others, 2017; BNamericas, 2018). This not only affects the infrastructure itself (for example, the capacity of transport assets and services to withstand and respond to shocks), but also has impacts on the response capacities of economies, communities and individuals. Aside from the maintenance of vital societal functions, the existence of adequate channels for the supply and distribution of basic services and products is crucial for minimizing disaster impacts and recovery times. Moreover, non-resilient critical infrastructure can serve as a hazard multiplier, heightening the severity of a shock through cascading effects across different sectors (Fisher and Gamper, 2017).

A lack of infrastructure also puts additional stress on existing assets, which are often overburdened and more exposed to the risk of disruption. In addition to the increased vulnerability of systems, faster wear and tear from overuse generates higher maintenance costs, thus aggravating the scarcity of funding for investment in new infrastructure and trapping the region's countries in a vicious circle. Moreover, since there is often excessive reliance on specific infrastructure assets and insufficient systemic redundancy, the scope and intensity of the impacts from disruptive events are generally magnified.

The impacts of infrastructure shocks and their effects on users have been evaluated by Rentschler and others (2019) and by Hallegatte, Rentschler and Rozenberg (2019). These authors used World Bank surveys (covering 143,000 firms in 137 low- and middle-income countries) to estimate the costs imposed by vulnerable infrastructure on firms in various countries, considering factors such as the effect on sales of electric power outages. As the authors note, this is only one of the ways in which businesses can be affected by the lack of resilience of infrastructure to disruptive events: a reduction in basic services forces firms to operate at below capacity, to reduce their sales and to delay product delivery. Apart from these immediate effects, innovation and investment decisions by firms also depend on the reliability of the infrastructure services they use.

The results of the model used by Rentschler and others (2019) and Hallegatte, Rentschler and Rozenberg (2019) show that a low level of resilience in any economic infrastructure service harms business sales and reduces capacity utilization rates.[5] In particular, interruptions to transport infrastructure services account for a large proportion of total utilization-rate losses: globally, more than two-thirds of such losses are due to unreliable transport infrastructure. It is estimated that disruptions in transport infrastructure generate losses on the order of US$ 107 billion, equivalent to about 0.42% of the GDP of the countries analysed.

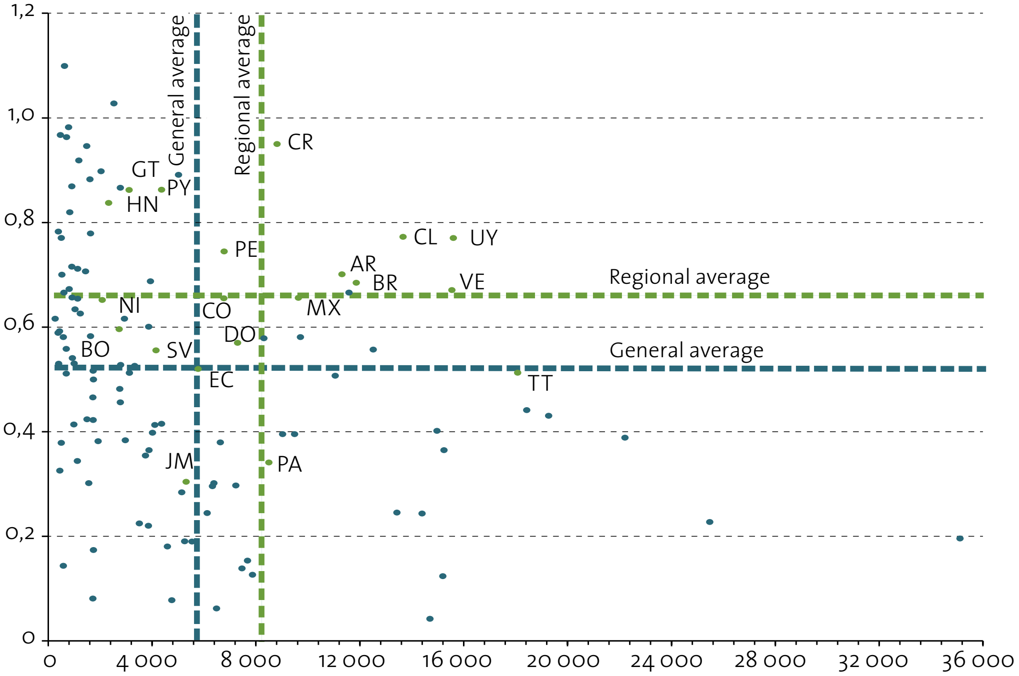
5 The capacity utilization rate is widely used as an indicator to measure the productivity of firms or the aggregate productivity of the economy. As Rentschler and others (2019) explain, the indicator measures the effectiveness with which a firm converts its resources into outputs. In a firm, lower capacity utilization rates affect sales and factor productivity.

Figure 3 illustrates the loss of firm utilization rates caused by disruptions in transport infrastructure for a universe of middle- and low-income countries. Although the average per capita GDP of the countries of Latin America and the Caribbean is higher than the average for all the countries analysed (US$ 8,196 compared to US$ 5,484), the utilization-rate losses associated with interruptions to transport services are greater for the countries of Latin America and the Caribbean than for the sample of countries analysed (0.66 and 0.52 percentage points, respectively). Countries such as Argentina, Brazil, Chile, Costa Rica and Uruguay have utilization-rate losses that are higher than the regional average, even though their per capita GDPs are above the average of all countries considered and also higher than the regional average. When combined with other evidence, these indicators can be interpreted as reflecting the poor quality and low levels of resilience of the infrastructure in question.

Figure 3

Utilization-rate losses owing to interruptions in the transport network

(Percentage points)



Source: Prepared by the author on the basis of J. Rentschler and others, "Underutilized potential: the business costs of unreliable infrastructure in developing countries", *Policy Research Working Paper*, No. 8899, Washington, D.C, World Bank, June 2019 and S. Hallegatte, J. Rentschler and J. Rozenberg, "Lifelines: the resilient infrastructure opportunity", *Sustainable Infrastructure Series*, Washington, D.C., World Bank, July 2019.

Note: The green dotted lines represent the averages of per capita GDP and utilization rate losses for the countries of Latin America and the Caribbean. The black lines represent the averages for all countries analysed.

Various factors can be associated with high capacity-utilization losses among enterprises in Latin American and Caribbean countries due to disruptions in transport networks, including insufficient investment to conserve this type of infrastructure. In Latin America and the Caribbean, as in other developing regions, the maintenance of existing infrastructure has been neglected in favour of greenfield projects, with clear cost implications (Fay and Morrison, 2007). According to Donnges, Edmonds and Johannessen (2007), the annual conservation cost of a road during the lifetime is small relative to the initial investment (generally 2%–3% for main roads and 5%–6% for rural areas without paved roads). However, without proper infrastructure conservation, the benefits to society are lost over time. This rapid deterioration also increases vehicle operating costs, shortens the assets' useful life, and generates refurbishment and reconstruction that could be avoided, costing between

1% and 3% of GDP per year. When other factors are taken into account, such as the loss of production or the impossibility of delivering products to markets, together with higher accident rates, this figure could rise to levels similar to the growth rates of the economy as a whole (Bull and Schliessler, 1994). However, authors such as Rioja (2003) have found that, in a group of Latin American countries, a 1 percentage point increase in the proportion of GDP spent on infrastructure maintenance could increase GDP growth by about 1.87% relative to a business-as-usual scenario.

The way infrastructure is configured —both technologically and spatially— continues largely to determine the patterns of construction of new infrastructure assets and networks. An emblematic example is provided by the modal distribution of transport in Latin America and the Caribbean, which is highly concentrated in road transport and generates significant negative externalities, such as heavy congestion and high greenhouse gas emissions. In addition to having direct implications for the resilience of the transport system and logistics chains, which are highly dependent on road infrastructure and devoid of redundant systems, imbalanced modal split increases stresses that may affect the infrastructure itself in the future.

IV. Recommendations for decision-makers

Given their crucial role in fostering development and enhancing the quality of life of populations, it is essential to ensure that infrastructure services are reliable and efficient. In particular, infrastructure systems need to be operated properly to provide firms with the predictability they need to implement their investment plans and maximize their production capacity, without excessive costs resulting from unreliable technologies. Unreliable infrastructure services can hamper the operation of value chains, thereby diminishing aggregate productivity and compromising the competitiveness of the economy at large (Rentschler and others, 2019).

Transport infrastructure networks, in particular, consist of long-lived assets and play a key role in determining the spatial dimension of development, affecting patterns of cargo and passenger movement, as well as the resulting externalities —both positive and negative. The current capacity of infrastructure to respond to adverse events is thus ultimately linked to policy decisions made in specific historical contexts, reflecting a phenomenon of path dependency associated with the lock-in of the infrastructure and the technologies on which it is based.

Similarly, depending on how it is built, the infrastructure can either facilitate or obstruct specific development paths, by supporting the establishment of systems that are either more or less resilient. It is therefore essential that the investments currently being made in the countries of Latin America and the Caribbean incorporate resilience considerations at the system design stage. It has also been argued that building resilience considerations into a system from the start of its life cycle is cheaper than doing so later or in reaction to a disruptive event (Della Rocca, McManus and Toomey, 2019).

In view of the above, a number of recommendations for building resilience into infrastructure projects are presented below.

Evaluate resilience at the systems level

As Gallego-Lopez and Essex (2016) note, it is essential to view the behaviour of infrastructure as part of a wider system, taking into account its impacts on the livelihoods of individuals and society as a whole. Thus, El Nakat and others (2015) stress that, "When planning and designing resilient infrastructure, the focus should not just be on the artefact but also the people and processes, governance structures, resources, and knowledge that set and shape its resilience."

Similarly, the building of resilience into infrastructure should start at a higher level, covering the institutions, policies, regulations, processes and practices that determine where, how and what infrastructure assets are planned and designed. Thus, prior to analysing the characteristics of an existing infrastructure asset and deciding how to make it resilient, the elements that need to be identified include: the purpose of the infrastructure project in question; its spatial and temporal attributes (its location and time of implementation); and the resilience of the other components of the system to which the new project belongs. Ultimately, a system is only as strong as its weakest link, be this physical, environmental, social, economic or institutional (El Nakat and others, 2015). In this context, ECLAC's proposal on integrated and sustainable logistics and mobility policies provides a methodology for incorporating these elements and aligning them appropriately with the Sustainable Development Goals (Jaimurzina, Pérez and Sánchez, 2016).

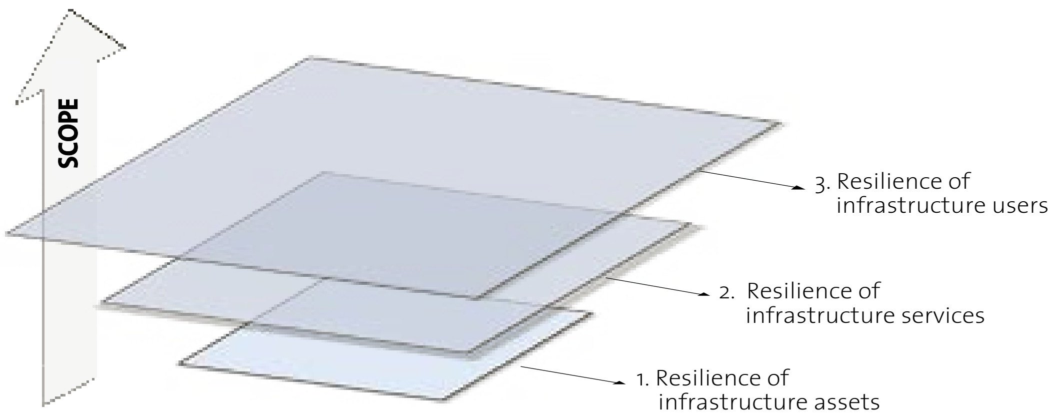
Accordingly, infrastructure resilience should be analysed at three levels. As Hallegatte, Rentschler and Rozenberg (2019) note, the most basic level of analysis concerns the capacity of infrastructure assets such as roads, dams and power transmission lines to withstand external shocks. The intermediate level corresponds to the resilience of infrastructure services —a more systemic approach that emphasizes the importance of services provided over networks based on the infrastructure assets. In this sense, rather than talking of a "resilient bridge", for example, one should think of a resilient "crossing" of such a structure (El Nakat and others, 2015). A third, broader level consists of the resilience of infrastructure users. This perspective seeks to emphasize the responsiveness of the users of the services provided by the infrastructure in the event of interruptions, whether those users are individuals, communities, firms or supply chains.[6]

Whatever the level of analysis, there is consensus that increasing the resilience of an infrastructure system generates benefits relative to a baseline scenario: at the asset level, it means reducing the cost of the infrastructure's useful lifecycle; at the next level, a resilient infrastructure means providing more reliable services; and lastly, at the user level, resilient infrastructure mitigates the impact of disruptive events on people and economies.

Identify and prioritize critical infrastructure, its services and users

Many countries in Latin America and the Caribbean have established official definitions for "critical infrastructure" in their laws (14 of the 17 countries in the region surveyed in the IDB's Index of Governance and Public Policy for Disaster Risk Management). Some have also formally identified the sectors that comprise their critical infrastructure. For these countries, logically the next stage would be to perform a criticality assessment, to identify the assets, systems and networks that are essential for the maintenance of vital societal functions. The criteria for making such an diagnostic assessment may vary according to the jurisdictional level of government and the evaluation of the impacts of shocks (Fisher and Gamper, 2017).

Diagrama 3
Levels of analysis of infrastructure resilience



Source: Prepared by the author on the basis of S. Hallegatte, J. Rentschler and J. Rozenberg, "Lifelines: the resilient infrastructure opportunity", *Sustainable Infrastructure Series*, Washington, D.C., World Bank, July 2019.

6 The user-resilience level corresponds, to some extent, to the second perspective mentioned by Gallego-Lopez and Essex (2016)..

In keeping with the foregoing recommendation, the criticality assessment should also consider infrastructure services and their users —including include households and value chains that depend on the services. Ultimately, the logistics services which underpin these value chains are provided over the transport networks and depend on other economic infrastructures, such as the provision of energy and telecommunications services..

Consider the costs of the lack of resilience

Despite the above, resilience is not currently the most influential factor in infrastructure investment decisions. One of the reasons for this is that the costs of "non-resilience" are not always taken into account —either because the risks are underestimated or because of the multiple difficulties involved in estimating them. In fact, quantifying the benefits of resilience involves a raft of challenges, such as identifying the disruptive events, estimating their probability of occurrence and assessing and costing their potential impact on users (ITF, 2018).

However, when it is possible to consider the costs that a potential interruption of a system would impose on all users of its services, building resilience measures into the life cycle of infrastructure projects becomes the preferred course of action. As Chopra and Sodhi (2014) note, underestimating disruptive risks (or assuming that there are none) is more costly than overestimating them: since rare events do occur at some point in time, the average cost of disruptions outweighs the savings that could be made by not investing in greater resilience.

Hallegatte, Rentschler and Rozenberg (2019) estimate the cost of direct disaster damage to power generation and transport infrastructure at US$ 18 billion per year in low- and middle-income countries. If the knock-on effects of disasters are also considered, interruptions to the functioning of infrastructure cost households and firms in low- and middle-income countries between US$ 391 billion and US$ 647 billion annually. In contrast, the net benefit of investing in more resilient infrastructure in low- and middle-income countries is estimated at US$ 4.2 trillion —a US$ 4 benefit for each dollar invested.

According to Ijjasz-Vasquez (2017), over the next 20 years, humans will build more infrastructure than has been built over the last 2,000 years. Thus, decisions on the design, size and location of infrastructure systems are critical for determining the extent to which communities and economies will follow more or less resilient paths. Future investments therefore have the potential to generate multiple dividends if they adopt best practices and enhance the resilience of the services provided to their users (Murray, 2019).

V. Bibliography

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VI. Publications of interest

FAL Bulletin 354

Gobernance of infrastructure for sustainable development in Latin America and the Caribbean: an initial premise

Azhar Jaimurzina
Ricardo J. Sánchez

This *FAL Bulletin* presents an initial approach to the topic of infrastructure governance, which was the main theme of discussions during the Governance Week on Natural Resources and Infrastructure organized by ECLAC in Santiago, from 7 to 11 November, 2016.

Available in: Spanish English

FAL Bulletin 367

Road transport in Latin America: evolution of its infraestructure and impact between 2007 and 2015

Pablo Chauvet
Baptiste Albertone

This issue analyses data on investments in Latin American road infrastructure between 2007 and 2015, examines the subsector's evolution and emphasizes the negative repercussions of accident fatalities and carbon emissions. It aims to raise awareness about the importance of this mode of transport in the region and to underscore the need for socioeconomic evaluations of road projects and for additional, better and more transparent data and information on the sector, using a cross-cutting approach in pursuit of sustainable development.

Available in: Spanish English