Transport Infrastructure Asset Resilience: Managing Government Capabilities

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Abstract

The management of the organisational capabilities needed to ensure the resilience of transport infrastructure assets is a challenge for governments worldwide. However, an absence of critical research in this area has exacerbated this challenge. The upshot, in this instance, has been the inability of governments to engender and enact an effective transport resilience strategy. This paper aims to fill this void and address the following research questions: (1) How do government organisational capabilities interact with one another to determine the resilience of transport projects? and (2) What is the best way to manage these organisational capabilities to aid a resilience strategy? Using Social Network Analysis, seven transport infrastructure case studies that were significantly impacted by natural hazards in the United Kingdom were used to answer the proposed research questions. The analysis revealed five inter-related factors are required to ensure the resilience of transport assets: (1) leadership; (2) reflexive (organisational) learning; (3) support from senior management; (4) a culture adept to resilience; and (5) continuous improvement (also investment) in asset absorbability, adaptability and vulnerability. The original contribution of this research is threefold: (1) a network providing a systematic visualisation of the interactions between organisational capabilities influencing asset resilience; (2) the prioritisation of governmental capabilities; and (3) the development of management framework providing a pathway that can accommodate environmental changes and asset resilience.

Keywords: Transport infrastructure, resilience, governments, organisational capabilities

1.0 Introduction

Worldwide, governments are struggling to ensure their transport assets can adapt to external disturbances (in this case, climate change-related events), especially since the Coronavirus-2019 (COVID-19) outbreak (Sircar *et al*., 2013; Spaans and Waterhout, 2017; Pregnolato *et al*., 2017; Love *et al*., 2018a.b; Van der Merwe and Van der Waldt, 2018; Zhang and Li, 2018; Love *et al*., 2020; Ton *et al*., 2020). In 2009/2010 and 2010/2011, heavy snowfalls led to travel chaos throughout the United Kingdom (UK), adversely disrupting airports, railways and road networks. In 2019 England was subjected to torrential downpours, which resulted in 73 flood warnings and a disrupted transport network, especially its Northern Rail services. Additionally, London's Liverpool Street station was flooded, causing severe track circuit failures and platform closures. Adverse weather conditions have become the norm in the UK and are now anticipated, though many uncertainties reside around such events' severity. In response to increasingly adverse environmental events, the UK Government has developed a dedicated 'Sector Resilience Plan' to mitigate its infrastructure assets' vulnerability and improve its resilience (Cabinet Office, 2019).

Resilience primarily relates to how infrastructure can positively withstand, absorb and respond to changing conditions (Bosher and Dainty, 2011; NCCARF, 2013; Hughes and Healy, 2014). Enabling resilient infrastructure is a sophisticated and systematic process, which integrates engineering, technical and managerial elements over an asset's life-cycle (Desouza and Flanery, 2013; Love *et al*., 2021). Thus, the underlying dynamics of infrastructure resilience are diversified no more so than the capabilities such as the collective skills, abilities and expertise of critical organisations, particularly governments, involved with the delivery of the assets (Bosher *et al*., 2009; Hughes and Healy, 2014; Liu *et al*., 2019). To this end, an organisation's capability refers to its ability to perform a coordinated set of tasks, utilising its resources to achieve a particular end result (Helfat and Peteraf, 2003: p.999).

Organisational capabilities are intangible assets and are “an outcome of investment in staffing, training, compensation, communication and other human resource areas” (Smallwood and Ulrich, 2004, p.119). They are also interdependent assets that comprise technical and social components and emerge when competencies and abilities are combined. There is no “magic list of capabilities” appropriate for governments to provide the intangible value needed to ensure asset resilience (Smallwood and Ulrich, 2004, p.119). Despite their importance, there is limited knowledge about the core capabilities required to underpin and enact a resilience strategy. Lamenting this concern, the Cabinet Office (2017) in the UK acknowledged that a lack of knowledge and understanding of organisational capabilities has contributed to its inability to assess risk and uncertainty. Consequently, transport assets have performed poorly as their fragility to adverse weather conditions has come to the fore (House of Commons, 2019; Department for Transport, 2017; 2020).

While Cabinet Office (2017) in the UK has been cognisant of its inadequate organisational capabilities to provide resilient infrastructure and has put in place policy initiatives to address this issue, there remains limited research examining how they can be better identified and developed. This paper seeks to fill this void in knowledge and thus addresses the following research questions: (1) *How do government organisational capabilities interact with one another to determine the resilience of transport projects*? and (2) *What is the best way to manage these organisational capabilities to aid a resilience strategy*? Understanding the interdependency between capabilities and identifying critical needs is needed to effectively manage them and enable governments to establish a pathway to develop practical actions for future improvement.

The paper commences with a review of the transport infrastructure resilience literature to provide a contextual backdrop for the research (Section 2). Then, the research method used to form the basis of the study's line of inquiry is presented (Section 3). Next, case studies from the UK are used to address the proposed research questions (Section 4). A conceptual framework for managing the organisational capabilities needed to ensure a transport asset's resilience (Section 5) and its implications for research are then presented (Section 6). Finally, the paper's conclusions are presented (Section 7).

2.0 Transport Infrastructure Resilience

The literature is replete with studies that have examined transport resilience (Love *et al*., 2021). Nonetheless, when transport networks are disrupted and/or damaged, the socio-economic wellbeing of an economy can be adversely impacted (Cox *et al*., 2011; Reggiani, 2013; Hughes and Healy, 2014; Reggiani *et al*., 2015; Wan *et al*., 2017; Love *et al*., 2018b; Ton *et al*., 2020). However, such impacts can be significantly minimised if the infrastructure assets are designed, constructed, operated and maintained to adapt and respond to unexpected changes and effects imposed on them (Love *et al*., 2017; Zhang and Li, 2018).

The epistemology of resilience is underpinned by four questions: (1) resilience of what? (2) resilience to what? (3) resilience for whom? and (4) how to be resilient (Vale, 2014; Chmutin *et al*., 2016). While no standard definition of resilience prevails, within the context of infrastructure, four core elements have been identified in terms of an asset's ability to: (1) predict and resist impacts; (2) absorb and accommodate stress and remain functional; (3) be self-organised; and (4) learn, change and adapt (Davoudi, 2012; Thayaparan *et al*., 2016; Wan *et al*., 2017). A recurring theme of resilience, spurred on by calls to respond to global climate change, is its ability to accommodate environmental changes (Bruneau *et al*., 2003; Bosher and Dainty, 2011; Emmanuel and Krüger, 2012; Sircar *et al*. 2013; Balsas, 2014; Spaans and Waterhout, 2017).

The advent of major terrorist incidents has intensified the interest in transport system resilience (Bruyelle *et al*., 2014). Emerging from Cox *et al.'s* (2011) research into the 2005 London bombings were a series of operational metrics that sought to determine a passenger transport system's resilience to terrorism based on its vulnerability, flexibility and resource availability to cope with a terrorist attack or natural disaster. Continuing with the theme of underground rail and buses, Jin *et al*. (2014) focused on developing an integrated multi-modal transport network to improve a system's ability to adapt to increasing population and urban density. In contrast, Venkittaraman and Banerjee (2013) examined the resilience of existing bridges to natural hazards such as seismic activity by taking an ex-post perspective. They identified that there is a need for bridges to be retrofitted to accommodate the likelihood of earthquakes. Similarly, Becker and Caldwell (2015) adopted an *ex-ante* approach by soliciting stakeholders' views to design and develop strategies to ensure a seaport's resilience.

2.1 Organisational Capability and Resilience

An organisation's capability refers to the capacity and resources that enable business functions such as strategic planning, leadership, systems and procedures, human resources, innovation, and network coordination to enact a strategy (Grant, 1991; Teece, 2007; Inan and Bititci, 2015).

Since the 1990s, there have been a wealth of studies that have sought to categorise organisational capabilities and to identify how they impact business performance (Amit and Schoemaker, 1993; Collis, 1994; Teece *et al*., 1997; Winter, 2003; Zahra *et al*., 2006), Ambrosini *et al*., 2009; Saunila *et al*., 2014; Raffoni *et al*., 2018; Khalil and Belitski, 2020). Emerging from these studies is the role that stakeholders, regularly governments and construction contractors, play in identifying the critical needs to construct resilient infrastructure assets (Shaw *et al*., 2019).

Table 1 presents the key studies conducted over the past decade investigating resilience from an organisational capability perspective. A detailed examination of the literature reveals a paucity of research examining the interdependency of organisational capabilities and how they can be managed to ensure resilient transport systems (Blake *et al*., 2019). Thus, acquiring an understanding of how capabilities interact with one another can help policy-makers develop a resilience strategy that can be used to *future-proof* their transport assets. That is, to be better positioned to anticipate future events, changes and needs or uses to prepare appropriately, minimize impact and capitalise on opportunities (Masood *et al*., 2015; Love *et al*., 2018a).

3.0 Research Approach

This study aims to develop new knowledge for managing transport infrastructure resilience from a government's organisational capability perspective. An illustrative case study approach (Gerring, 2006), which draws on the grey literature, is used to address the research questions that have been proposed. The grey literature is defined as sources that are not formally published in books and journals but are found in technical reports, pre-prints, the media, and the like (Schöpfel and Farace, 2010). The use of grey literature to examine policy-related matters is deemed a valid inquiry line (Søndergaard *et al*., 2003).

A total of seven cases have been selected, which were significantly impacted by natural hazards in the UK (Table 2). Additionally, the cases are representative examples that the UK Government has used to demonstrate the need to ensure infrastructure resilience in the future (Department of Transport, 2014; Cabinet Office, 2017; Greater London Authority, 2019).

Table 1. Key studies investigating organisational capabilities and resilience within governments

Organisational Abilities	Research Targets	Authors
Strategies and stakeholder management	Entire built environment	Bosher *et al.* (2009)
Stakeholder and supply chain management	Entire infrastructure system	Steward *et al.* (2009)
Governance strategies	Communication systems	Carmeli and Markman (2011)
Workforce management	Entire infrastructure system	Santos *et al.* (2014)
Decision-making ability	Transport	Giezen *et al.* (2015)
Governance and empowerment in decision making	Community	Fan (2015)
Collaborating and networking, awareness and committing, learning, training and preparedness	City	Gimenez *et al.* (2017)
Performance management/measurement	Transport	Loo and Leung (2017)
Leadership, staff engagement, decision making, situation awareness and strategic planning	Entire built environment	Sapeciay *et al.* (2017)
Community engagement, leadership, finance, organisational structure and human resources	City	Van der Merve and Van der Waldt (2018)
Information management	Transport	Blake *et al.* (2019)
Governance	Community	Lee (2019)
Planning and resource management	Ports	Shaw *et al.* (2019)

Table 2. The transport assets/systems selected for case studies

Transport Assets/Systems	Documentary Sources
Motorway Network (e.g., M1, M4, M5, M18, M40, M50 and M54)	Department for Transport (2014)
A390 (road) at Cornwall	Department for Transport (2014) and Cornwall Council (2019)
London Gatwick Airport	Department for Transport (2014), McMillan (2014) and BBC (2019)
A303 (trunk road) at Deptford	Department for Transport (2014) and UK Parliament (2014)
Wokingham Borough Road System	Department for Transport (2014) and Cabinet Office (2017)

Railway lines at Dawlish	Department for Transport (2014) and NetworkRail (2019)
London Underground	Greater London Authority (2019)

The research questions aim to determine how a government's capabilities can systematically develop a framework to assist policy-makers in formulating a resilience strategy.

Social Network Analysis (SNA) was utilised to analyse the collected data from various documentary sources identified in Table 2. The concept of SNA is a by-product of graph theory and can be used to: (1) systematically map the interdependencies between the individuals and their activities; (2) empirically interpret how such relationships can impact a network; and (3) prioritise the key 'activities' needed to be focused for management and improvement using the betweenness and closeness centralities (Otte and Rousseau, 2002). The robustness of SNA presents itself as an appropriate technique to address the paper's research questions.

Previous studies have demonstrated that SNA is an effective technique to identify complex network relationships in infrastructure projects (Zheng *et al.*, 2016; Herrera *et al.*, 2020; Wang *et al.*, 2021). For instance, Herrera *et al.* (2019) utilised SNA to understand how a design team's performance affected the quality of project outputs in construction. Contrastingly, Wang *et al.* (2021) used SNA to identify the transmission patterns and underlying dynamics determining the performance of Public-Private Partnerships (PPPs).

A series of 'points' (nodes) and 'lines' (edges) depict individuals' social structure within SNA (Scott, 1988; Otte and Rousseau, 2002). While points represent the observed individuals, lines visualise their interactions. Data acquired from the documentary sources presented in Table 2 was inputted into NVivo 12 to derive and analyse the point and edges of the government's capabilities and interdependencies (Figure 1). Gephi was then adopted to construct an SNA to visualise the identified points and edges for further quantitative analysis.

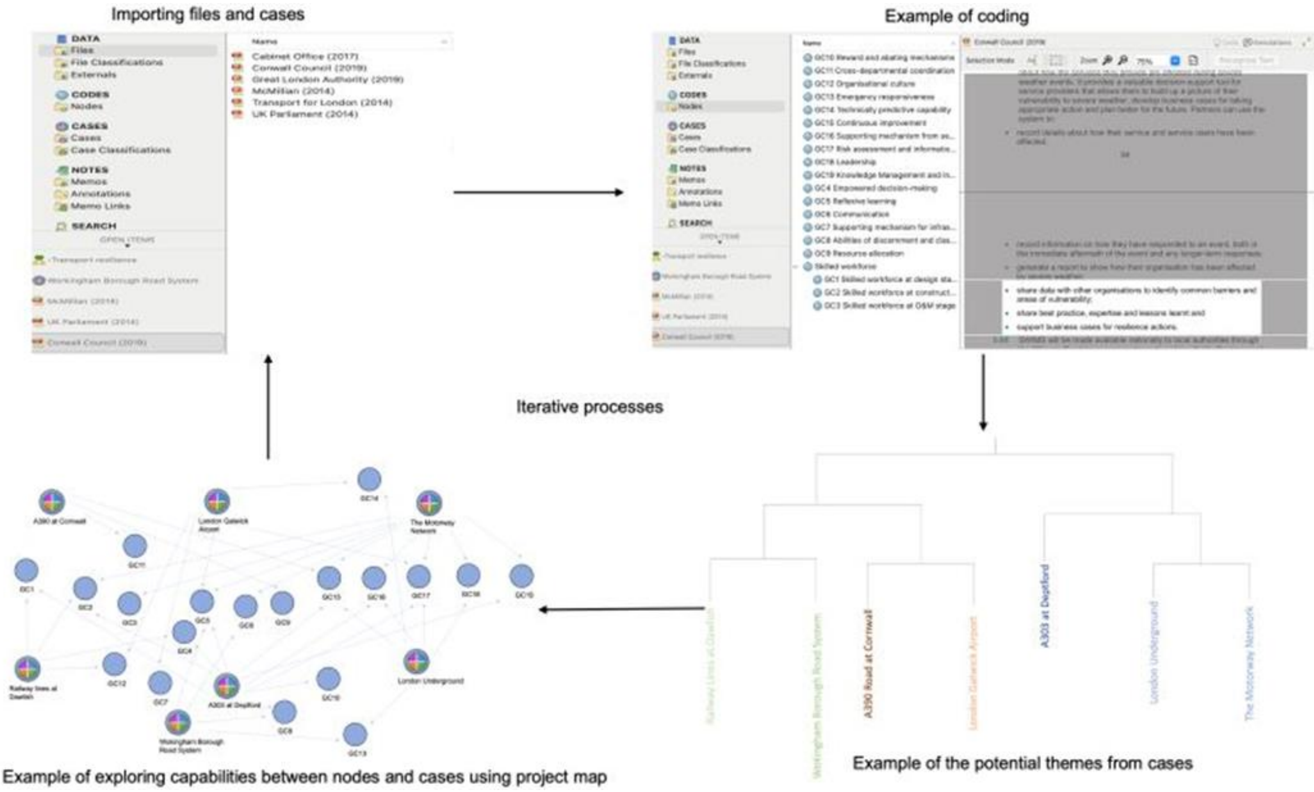


Figure 1. Process of data coding with NVivo

Two quantitative metrics, the ‘betweenness’ (Eq.1) and ‘closeness’ (Eq.2) centralities form the core of SNA and can be expressed as:

$$C_B(v) = \sum_{s \neq v \neq t} \frac{\sigma_{st(v)}}{\sigma_{st}} \qquad \text{[Eq.1]}$$

$$C_c(v) = \sum_{\omega \in G} \frac{1}{d(v,\omega)} \qquad \text{[Eq.2]}$$

Where σ_{st} represents the number of the shortest paths with *s* and *t* as their end vertices. At the same time$\sigma_{st}(v)$ is the number of such paths above, including vertex *v*. The ‘betweenness’ centrality describes the frequency of a node that appears on the shortest path between nodes in the network (Freeman, 1978). Similarly, the ‘closeness’ centrality is the average distance from a given starting node to all others in a network (Borgatti, 1995). Thus, it is used to indicate how close a node is to another one.

4.0 Data Analysis

As identified in Table 2, seven cases were used to examine the UK government’s capabilities contribution to implementing an asset resilience strategy. As previously mentioned, the cases were subjected to severe impacts due to extreme weather events (Table 3). For example, in July 2007, the road network comprising several critical motorways, including the M1, M4, M5, M18, M25, M40 and M54, was adversely affected by closures resulting from unprecedented downpours. Similarly, the electrical switchgear serving the North Terminal of London Gatwick Airport was inundated by the flooding, which caused a cloudburst in December 2013.

Over the last five years, the UK Government has undertaken several investigations (presented in Table 2) to determine the issues that have contributed to the poor resilience of their assets to extreme weather events. We inputted the reports into NVivo 12 to code the data (Figure 2). We then identified the organisational capabilities influencing the government’s inability to ensure an asset’s resilience, as noted in Figure 3.

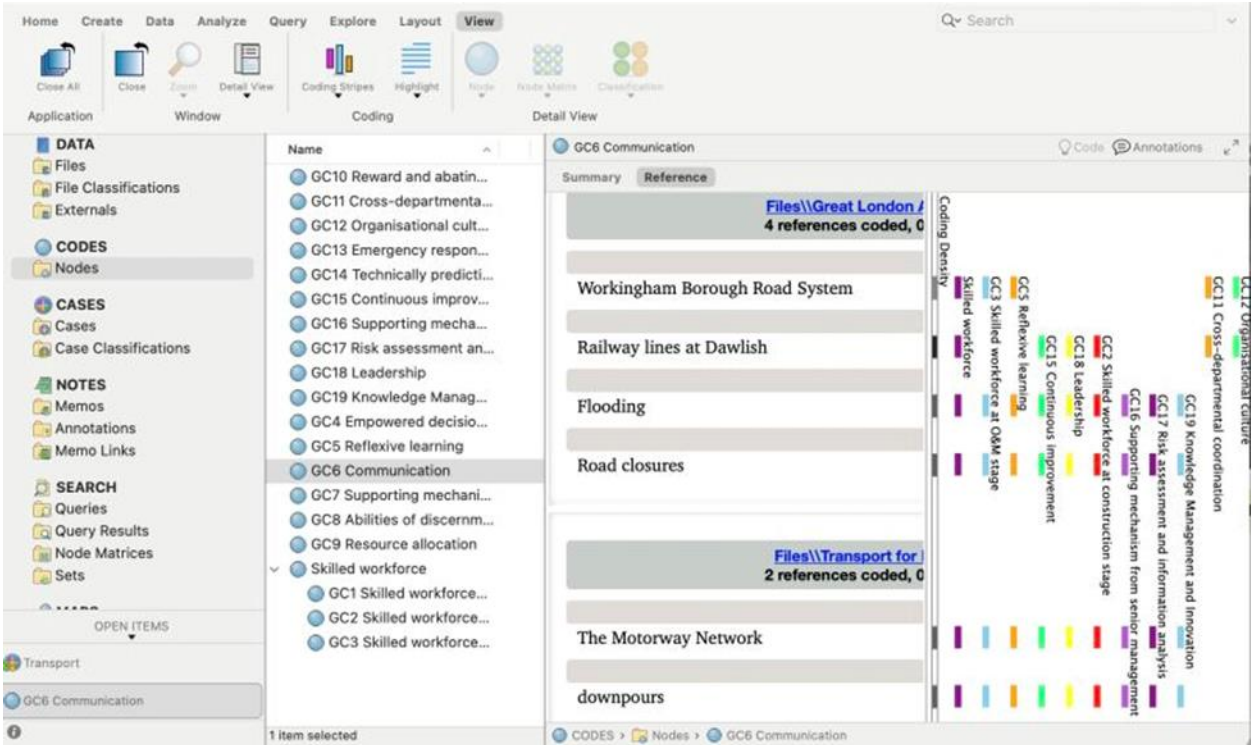


Figure 2. Coding for categorising the UK Government's capabilities in determining resilience

Adapted from: Department for Transport (2014), McMillian (2014), UK Parliament (2014), Cabinet Office (2017) Cornwall Council (2019) and Greater London Authority (2019)

Figure 3. Government's capabilities in determining asset resilience

Serial codes were then assigned to the identified capabilities (presented in Figure 3) so that further analysis could be undertaken (Table 3). As illustrated by Figure 1, thematic analysis was then performed using NVivo 12. Then, 'Queries' using the 'Search' function were run to map the identified capabilities (Figure 3) with each transport case. The mapping results are presented in Table 4.

Table 3. Description for the capabilities being observed

Codes	Identified Capabilities	Definitions
GC1	Skilled workforce at design stage	The workforce of governmental departments that engage in the delivery of the transport projects
GC2	Skilled workforce at construction stage	
GC3	Skilled workforce at operation and maintenance stage	
GC4	Empowered decision-making	The power delegated to the teams or groups responsible for operating transport assets so that they can make decisions more efficiently when disasters/crisis happen
GC5	Reflexive learning	The learning mechanism of government for reflecting and capturing lessons learnt for organisational development
GC6	Communication	The communications between different departments in the government for works or actions initiated for enabling and/or ensuring resilience
GC7	Supporting mechanism for infrastructure system operations	The mechanisms across the departments of the government to support the operations of transport assets (i.e., the resilience planning workshops organised by the Department for Transport)
GC8	Abilities of discernment and classification	The organisation's ability in justifying and classifying the actions and/or initiatives essential for maintaining critical services during extreme weather
GC9	Resource allocation	The allocation of resources that are useful for developing, operating and maintaining the transport assets
GC10	Reward and abating mechanisms	The mechanisms placed for rewarding or abating the government's authorities that can or cannot address resilience in the delivery of transport assets
GC11	Cross-departmental coordination	The coordination across the departments within the government when a crisis occurs
GC12	Organisational culture	The organisational culture of resilience
GC13	Emergency responsiveness	The availability of practical guidance or procedure (i.e., the Local Resilience Fora and Strategic Co-ordinating Groups) in responding to an emergent situation (i.e., extreme weather incidents)
GC14	Technically predictive capability	The technical abilities of the government (e.g., systems, techniques and technologies) in effectively forecasting the risks (i.e., natural hazards) impacting the assets

GC15	Continuous improvement	The investment and efforts spent for continuously improving the practice in delivering resilient transport assets
GC16	Supporting mechanism from senior management	Effective and efficient supports from the government's top management for improving the practice in building resilient assets.
GC17	Risk assessment and information analysis	Climate Change Risk Assessment and the analysis of information collected from transport systems, such as the signalling and customer information systems.
GC18	Leadership	The styles of the leadership of the public authorities handling the delivery and operations of the assets
GC19	Knowledge Management and Innovation	The systems for managing the knowledge and innovation (i.e., training system) essential for enabling and ensuring resilience

Sources: Department for Transport (2014), Cabinet Office (2017) and Greater London Authority (2019)

Table 4. Coding for the government's capabilities determining the resilience of the assets

Assets	Incidents	Impacts	Disruptions	Capabilities
The Motorway Network (e.g., M1, M4, M5, M18, M40, M50 and M54)	Unprecedented downpours, 2007, 2013	Flooding	Road closures	GC2; GC3; GC5; GC6; GC15; GC16; GC17; GC18; GC19
A390 (road) at Cornwall	Extremely heavy rainfall, 2010	Flooding	Road closure	GC9; GC11; GC15
London Gatwick Airport	Cloudbursts, 2013, 2019	Flooding in the basement	(1) Partial closure of the North Terminal closure; (2) key power and IT systems failure; (3) airport express service delay	GC5; GC7; GC12; GC14; GC17
A303 (trunk road) at Deptford	Heavy rainfall, 2014	Large volume of groundwater	(1) Overwhelmed drainage system; (2) Eastbound carriageway closure; (3) Traffic diversion	GC1; GC2; GC4; GC5; GC8; GC10; GC15; GC16; GC17; GC19;
Workingham Borough Road System	Prolonged, persistent and heavy rainfall, 2013/14	Flooding from the River Thames and the River Loddon	(1) Road and bridge closures; (2) Difficult access to business parks and town centre	GC3; GC5; GC6; GC8; GC11; GC12; GC13
Railway lines at Dawlish	Wind, 2014	Wind, tidal surge and landslips	(1) The washing away of track ballast and foundations; (2) Severe breach of sea wall; (2) Severe damage to station track and platforms	GC1; GC2; GC4; GC6; GC7; GC8; GC9; GC11; GC12; GC13; GC15; GC18
London Underground	Cloudbursts, 2019	Flooding	(1) Flooded tunnels; (2) Electrical failures; (3) Mainline services at a standstill; and (4) platform closure.	GC1; GC3; GC5; GC9; GC11; GC13; GC14; GC15; GC16; GC17; GC18

Sources: Department for Transport (2014), McMillan (2014), UK Parliament (2014), Cabinet Office (2017), Cornwall Council (2019) and Greater London Authority (2019)

4.1 Findings

Based on the data collected from various sources and the coding above, we generated a network presented in Figure 4 using the Gephi 0.9.2 software package. The nodes connected by multiple edges in the developed network represent the UK government's organisational capabilities, which align with Figure 3. As there are both unidirectional (A → B) and bidirectional (A → B and B → A) links, the directed graph is chosen at the outset (Herrera *et al.*, 2020).

The network developed in Figure 4 comprises several nodes and edges relating to transport resilience. The network contains 19 governmental capabilities illustrated in Figure 3, connected by 245 unidirectional and bidirectional links. Overall, the graph density of the constructed SNA model is 0.716 out of 1. The relevant degree is 12.895 on average, indicating a relatively high degree of the observed capabilities, represented by the number of links connected to a node. As the network was constructed from the data of real-world transport assets, the systematic interactions between organisational capabilities and resilience provide a sound basis for developing a framework for policy development.

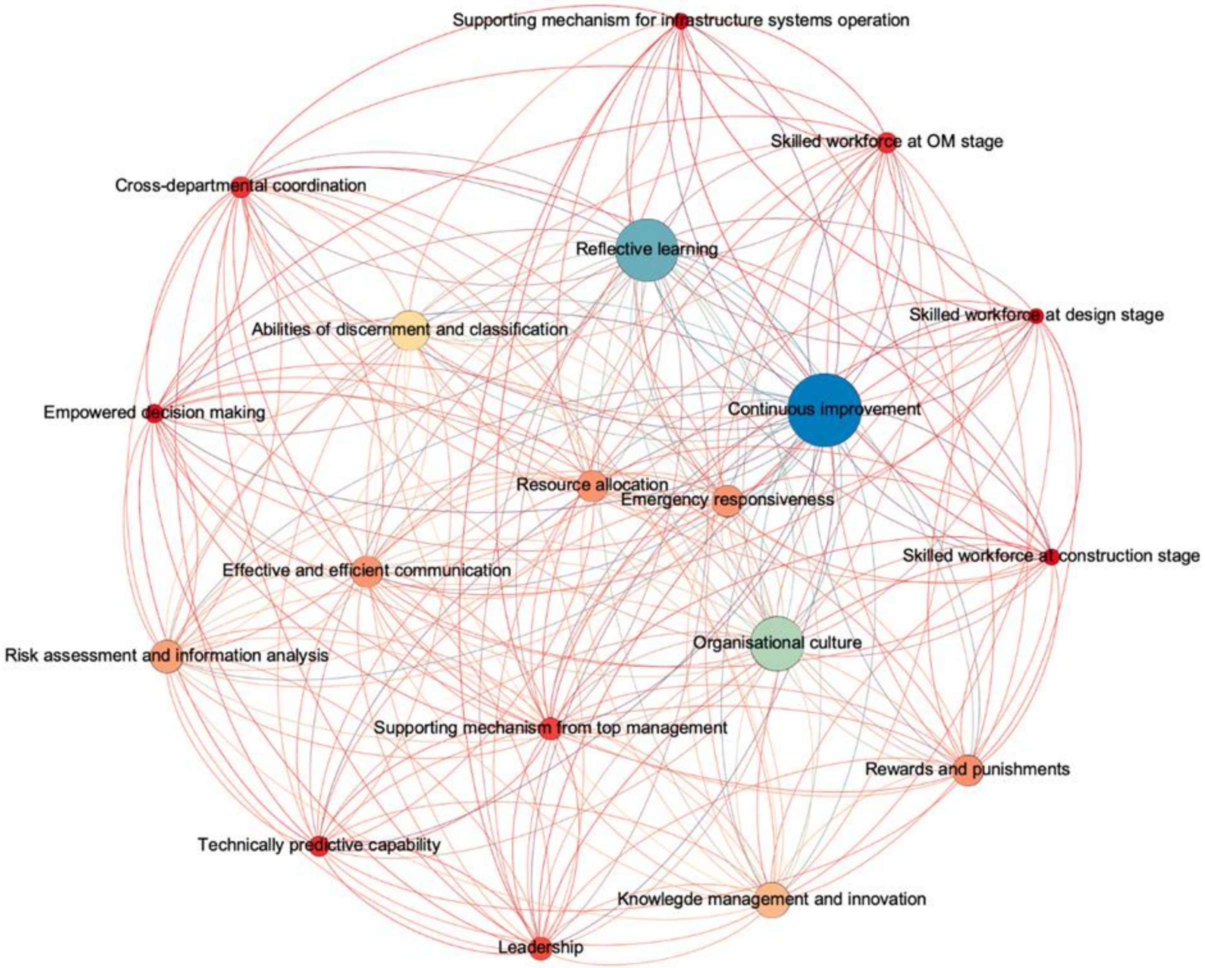


Figure 4. SNA of the government's capabilities determining the assets' resilience [1]

The size of the nodes in a network represents different levels of importance of the individuals being observed. In this case, a larger node denotes a higher level of an individual's impact on the network. It can be seen from Figure 4 that the size of nodes in the network varies, implying that their effects on the resilience for each case are different.

Based on the betweenness centrality (left panel of Figure 5), the top three capabilities that determine the resilience of the transport assets are: (1) 'continuous improvement' (15.546), 'Reflexive learning' (a mechanism); (12.834); and (3) 'organisational culture' (10.683). The

[1] There are different layouts of network based on the types of metrics. This graph is visualised through degree.

betweenness centrality indicates which nodes are ‘bridges’ within the network (Disney, 2020). As addressed above, betweenness centrality indicates which ‘nodes’ are the ‘bridges’ between nodes within a network. When a node has a higher betweenness centrality, it is viewed as a ‘hub’ that transmits the influences of other nodes on the network.

In terms of closeness centrality[2] (right-hand panel of Figure 5), it can be seen that the ‘supporting mechanism from top management’ (1.000), ‘Reflexive learning’ (1.000) and ‘leadership’ (0.947) are the ‘shortest’ distances to all other nodes in the network. Therefore, the nodes with high closeness centrality are those ‘factors’ that dominate the network and can influence the entire network more significantly and efficiently than others. Put simply, the capabilities such as ‘supporting mechanism from top management, ‘Reflexive learning’ and ‘leadership’ are standing in the ‘best position’ to influence the resilience of a transport infrastructure system) (Disney, 2020).

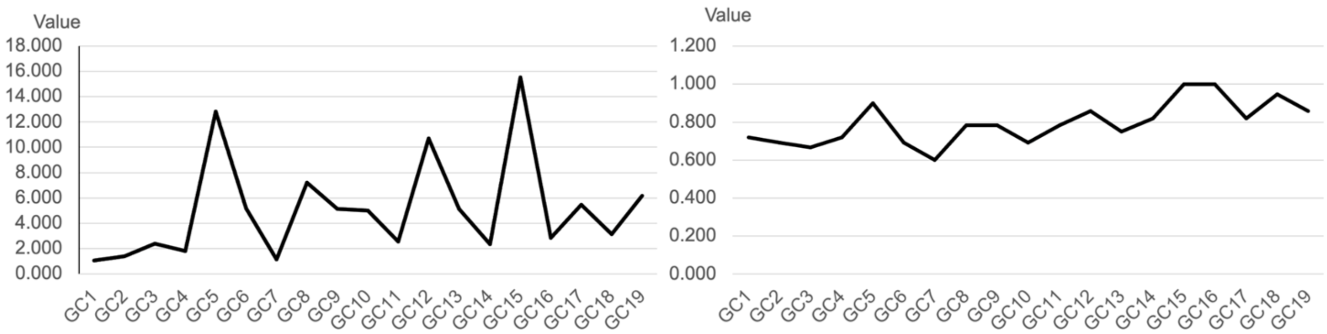


Figure 5. Distribution of the government’s capabilities in determining transport resilience

5.0 Managerial Framework

The UK government has been confronted with an array of challenges in its quest to ensure it can provide the organisational capabilities needed to ensure its transport assets’ resilience. However, the process of enhancing transport resilience from the perspective of organisational

[2] A measure showing the degree of the individuals' closeness to others, the variables,

capability is ambiguous. The SNA can be used to examine the interactive impacts of the individual organisational capabilities on the resilience of a transport network. In the cases above, the SNA modelling has identified and visualised the patterns about how the: (1) capabilities interacted with each other in determining transport resilience; and (2) key 'actors' transmit the impacts of other factors within the network. Accordingly, the SNA findings from the case studies are significant as they enable an understanding of the key capabilities that the government needs to improve its ability to enact an infrastructure resilience strategy.

According to the betweenness centrality, the empirical evidence suggests that 'organisational culture', 'reflexive learning' and 'continuous improvement' act as bridges to enable resilience. Other capabilities, including the 'supporting mechanism from top management', 'reflexive learning' and 'leadership', also influence resilience as indicated by the closeness centrality measure. Naturally, support from the top management is needed for enhancing resilience. For example, the UK's Cabinet Office (2021) has developed a national resilience strategy to help "understand our vulnerabilities, pre-empt challenges before they arise, ensure we are prepared for them, and mitigate the impacts. Then, when events do occur, we should be ready to withstand and recover." (p.12)

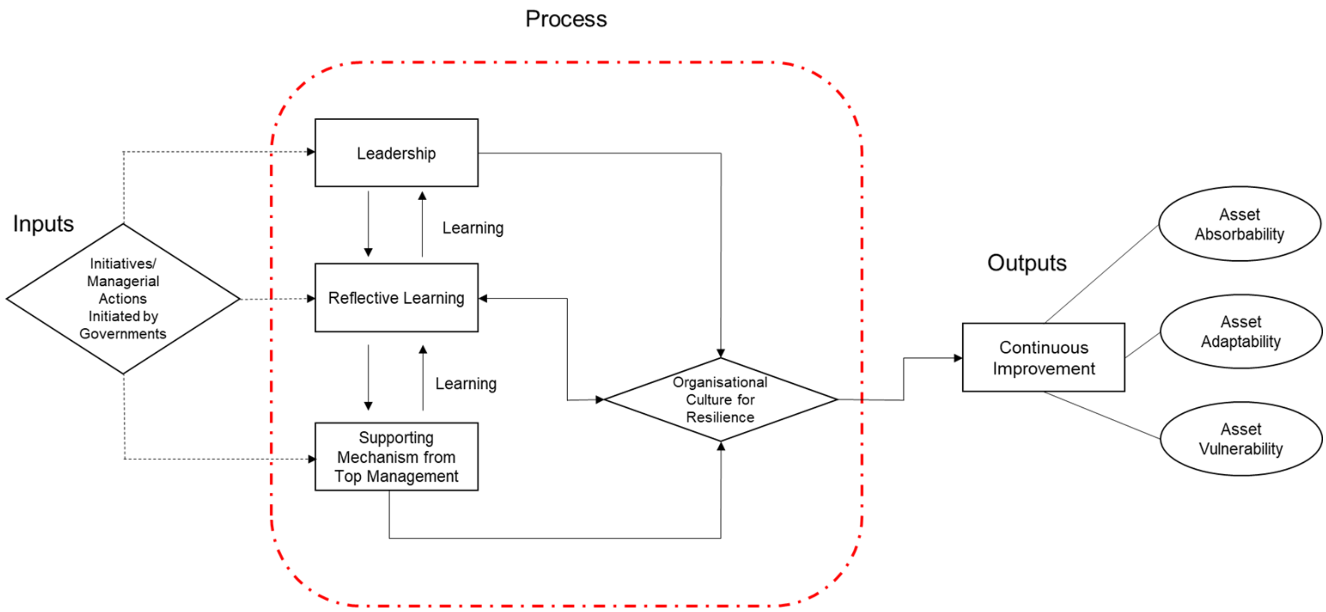
Additionally, a robust learning mechanism provides organisation's (i.e., governments) with an ability to capture well and reflect the issues of their businesses, enabling them to actively engage in continuous improvement and address a transport asset's vulnerability (Elliott, 2020). Notably, both the betweenness and closeness centralities of 'Reflexive Learning' are ranked the highest by the SNA. This ranking suggests that the government's learning mechanism is an efficient capability enabling resilience and is a significant 'hub' for transmitting the impacts of other capabilities on the entire network. Based on the findings above, a managerial framework is developed to determine the needs and actions required by the government to ensure they have the organisational capability to deliver resilient transport assets.

The provision of resilience is a challenge, but with top management support and leadership, which is transformational, governments will be well-positioned to enact a process of innovation and continuous improvement (Figure 6) (Bednall *et al.*, 2018). The reason for doing so is that a significant relationship exists between leadership style and organisational changes in an organisation (Matzler *et al.*, 2008). For instance, transformational leadership is essential for business and project success, boosting organisational and technological innovation (Aga *et al.*, 2016).

Technological innovation and development play a critical role in driving asset management forward (Baker *et al.*, 2019), which is pivotal for delivering resilient transport infrastructure assets (Love *et al.*, 2021). In addition, transformational leadership is often required to: (1) manage technology-enabled change to improve business processes and a transport asset's adaptability and resilience; and (2) generate vision to guide the change process changes (Bednall *et al.*, 2018). It is proffered that government departments that oversee the procurement, management and operation of transport assets should have in place a programme to develop the skills of their leaders so that they have an: (1) awareness of the increasing natural and human-made impacts on their assets; (2) ability to predict future impacts and a create a strategy to implement the change needed to accommodate natural and human-made impacts; and (3) interpersonal capability to develop a business network (Trevor and Hill, 2012; Hamdani, 2018).

In summary, a transformational leadership training programme aims to prepare leaders for self-awareness of risk and an ability to predict and execute change (Trevor and Hill, 2012). Noteworthy, predictability is an element of the definition of resilience, according to the US Environmental Protection Agency (2015). As also noted in Figure 4, the transport agencies need to continuously learn and improve by enacting lessons learned and engaging in reflexive practice to engender resilience capabilities (Love *et al*., 2015; Liu *et al*., 2018).

A life-cycle resilience performance measurement system (PMS) can improve transport resilience from the perspective of 'organisational learning' as it can provide organisations with an insight into: (1) the outputs of their business, specifically their adaptability and vulnerability; and (2) a vision about what aspects could be improved in the future (Bourne, 1999; Neely *et al.*, 2001). As pointed out by the UK's Cabinet Office (2017), resilience measurement is a prerequisite for building resilient infrastructure assets. However, the development of specific PMSs has received limited attention (Sun *et al.*, 2020). Thus, a resilience PMS would focus on measuring transport asset's (1) adaptability to changes, (2) efficiency of a process leading to adaptability, and (3) vulnerability (Liu *et al.*, 2019). With a PMS in place, governments would be better positioned to understand the vulnerabilities of their assets and the actions needed to ensure they are resilient.



Note: The arrows with dot lines indicate the possible effects of the organisation's initiatives and actions on developing their capabilities

Figure 6. A conceptual framework for managing government's organisational capabilities to ensure transport asset resilience

As noted in Figure 6, a change to the 'transformational leadership' from a 'transactional style', which is common in governments, can help shift the culture to be resilient and support a process of 'learning through' (i.e., how to disasters) instead of 'learning from disasters (Hofstede *et al.*, 2010; Valero *et al.*, 2015; Love and Matthews, 2020). Developing an organisational culture of resilience in the public sector is a necessary part of the future-proofing process (Everley, 2011; Love *et al.*, 2017). Noteworthy, there is a reciprocal relationship between organisational culture and organisational capability. A culture of resilience, as a result of the skills development programme, will, in turn, support the development of other organisational capabilities such as the continuous improvement for an asset's adaptability, vulnerability and absorbability (Figure 6) (Chang *et al.*, 2017; Cropley, 2017). To this end, culture is an integral part of shaping a resilience strategy enacted by employees (White, 2013; Hughes and Healy, 2014).

6.0 Implications for Future Research

Research examining the underlying dynamics of resilience abounds the literature, emphasising the development of paradigms to enable positive responses to environmental changes (Figure 5) (Wan *et al.,* 2018). For example, the extant *known-what* research tends to focus on understanding and determining the elements to include in the definition of resilience, focusing on robustness, recoverability and vulnerability and identifying the barriers to developing resilient infrastructure, which includes resource availability, inflexibility, and unsupportive policies (Markolv *et al.*, 2018; Kermanshachi *et al.*, 2019). However, the *known-what* paradigm eschews insights about improving an asset's ability to adapt and respond to external disturbances.

Future research, therefore, needs to focus on identifying how to enhance the business processes leading to resilient infrastructure assets (*known-how*) (Chmutina *et al.*, 2016; Liu *et al.*, 2019) by engaging in a collaborative asset delivery model and utilising digital technologies (Love *et al*., 2021). Furthermore, within the *know-how* paradigm, an investigation into the organisational capabilities that impact resilience is emerging (Blake *et al*., 2019). Despite the significant role of such capabilities in determining resilience, studies have tended to shy away from identifying how to manage them (Dubey *et al.*, 2021). This has led to, for example, an inability of the government in being able to develop resilient assets; thus, future studies need to address the void above to enable the public sector to have robust capabilities in ensuring their assets can adapt to changes (Blake *et al.*, 2019). For example, the developed managerial framework places a 'strategic' (macro) emphasis on enabling continuous improvements for asset's adaptability, absorbability and vulnerability *via* leadership, learning, supporting mechanism and organisational culture. At a 'micro-level, the future research places emphasise re-engineering governmental business processes to improve their ability to adapt and respond to risks, manage uncertainties and respond to crisis events (Chmutina *et al.*, 2016).

7.0 Conclusions

Transport infrastructure is critical for supporting societies daily activities and businesses. However, the infrastructure functionality is being impacted by external disturbances resulting from climate-related, health, economic and social changes. Thus, transport resilience has been prioritised by many governments worldwide. Yet, there is a widely accepted view that the organisational capabilities of governments, particularly in the UK context for this research, are critical to ensure infrastructure resilience. Still, they have received limited study within the transport context. There is also an absence of research that attempts to identify how government's capabilities determine resilience, leading to a knowledge void about managing them to ensure resilient transport assets. This paper has sought to address this issue and thus aims to generate knowledge to manage the government's capabilities for enabling transport resilience.

Based on the constructed SNA network and results presented, a managerial process, which incorporates five components, has been proposed to provide governments with an avenue to systematically improve their organisational capabilities and the resilience of their transport infrastructure assets. The components embrace (1) leadership; (2) organisational learning; (3) supporting mechanism from senior management; (4) a culture adept to resilience; and (5) continuous improvement (also investment) for asset's absorbability, adaptability and vulnerability.

The contribution of the study presented in this paper to the literature is threefold: (1) a network providing a systematic visualisation of the interactions between organisational capabilities influencing asset resilience; (2) the prioritisation of governmental capabilities; and (3) the development of a management framework providing a pathway that can accommodate environmental changes and asset resilience. In summary, this research output provides the public sector authorities with the underlying knowledge required to develop their abilities to further predict risks, thinking ahead and post-crisis learning, which aid in designing and implementing a robust resilience policy.

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