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by Kieran Duck

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INFRASTRUCTURE RESILIENCE - A TALE OF TWO COMPLEX PROJECTS

Written by:
Tunde Ajia
Project Consultant

London Underground

London Underground is one of the oldest functional relics of history still serving today's modern world. Back in 1854 it was called the Metropolitan Railway and was granted permission to build the first underground railway between Farringdon Street and Paddington. Construction cost at the time was estimated at £1 million, over £142 million as of today; evidently a massive complex project of scale at the time.

Because of the war in Crimea, Metropolitan Railway struggled to raise the initial money needed to commence work and construction was delayed until March 1860. Since then, the line, now dubbed London Underground, spans further than the traditional boundaries of the English capital. With a network spanning around 400 km, the Tube serves 272 separate stations, owning 262. On a typical pre-Covid working day, it would courier over 5 million people, and all its trains travel a combined annual distance of about 69 million kilometers; about halfway to the sun.

But asides from conveying people daily, the underground tunnel found its most important use in the 1939 bombings of London when it sheltered thousands of people from the bomb raids of World War II. Interestingly, the system was not designed to serve this purpose but shouldered it with relative ease when necessity came knocking.

Over the years, the London Underground may not be the world's biggest or newest underground system. However, it is debatably the most resilient and sustainable; serving for over a century and a half and still expanding to cater for a growing population, an expanding user spread and a warming climate.

The Ciudad Real Central Airport

Reasonably related to London's transport infrastructure project is another modern complex transport infrastructure project which could have done better. The Ciudad Real Central Airport (CRCA), this was meant to be the pride of Spain, an overflow airport for Madrid. However, it was wrecked by poor planning from the get-go. The $1 billion (£891 m) project was planned to cater for 10 million passengers annually but attracted only three low-cost airlines and several thousand travelers within one year of opening in 2008. Worse, the airport's principal partner went belly-up in 2012, halting all operations. Three years later, a Chinese-led consortium of investors acquired the CRCA for a meagre $11k (£8,900). In 2018, it was sold for $65.9 million (£50.7 million) to Ciudad Real International Airport SL and welcomed its first flight a year later, albeit empty. Although the new owners tried rebranding it as Madrid Airport South, the name did not stick as Madrid was over 240km away. No thanks to its gross underuse and lack of patronage, Forbes, in 2019, dubbed it the "ghost airport".

What makes infrustructure resilient?

Between 2010 and 2022, several complex

> "So what keeps a 150-year-old piece of infrastructure relevant through several economic, political and social shocks when its modern-day counterpart struggles to survive after a few years of construction?
>
> Your answer is resilience.

infrastructure projects failed. From power infrastructure to nuclear plants, failed projects are no longer news. The failure of the 4,700-megawatt Fukushima Daiichi nuclear power station in Japan, the Subansiri hydropower dam in India, the Nagarjuna oil refinery and the Ciudad Real Airport are clear testaments. While some of these projects failed because of natural disasters, others, such as the CRCA, imploded from internal issues such as gross mismanagement, poor planning and age-old project politics. Many others failed from adverse market forces, political influences and the covid-19 pandemic today.

Therefore, an infrastructure project becomes resilient when it can withstand stressors, adapt to changing circumstances and recovers positively from sudden shocks. This way, it can continue functioning as expected even when some vital elements do not survive. A classic example is the London Underground which, after about a century of operation, still sheltered thousands of Londoners from the German bomb raids of World War II.

Why is infrastructure resilience necessary?

Although traditional infrastructure projects such as roads, bridges and (some) dams may not be susceptible to new modern day risks of cyber-attacks; new powerplants, oil refineries, subways, airports and other facilities that depend on the Internet of Things (IoT) are vulnerable. Threats from natural disasters are no less worrying. According to its 2017 Global Risks report, the World Economic Forum revealed that warming global climate and natural disasters are two of the most impactful risks facing major projects today. This is not farfetched. The global cost of natural disasters from 2003 to 2013 alone was $1.5 trillion. With these in perspective, undertaking a significant infrastructure project without prioritising resilience and sustainability concerns will be like building on quicksand.

Steps to Resilience

Any attempt to describe resilience in infrastructure projects ultimately leads back to the works of systems expert Scott Jackson. In his 2010 book, Architecting Resilient Systems: Accident Avoidance and Survival and Recovery from Disruptions, Jackson opined that Capacity, Flexibility, Tolerance and Cohesiveness form the core of resilience.

Capacity

The most critical determinant of resilience for an infrastructure project is the capacity to withstand known disruptions from natural disasters and man-made attacks.

It transcends shock absorption. A resilient project must survive disruptions larger than expected. For instance, although the World War II bombings damaged some parts of the London Underground rail system, they did not decimate the structures completely.

Capacity also involves physical and functional redundancy, which means the project has alternative means to survive. For instance, when the CRCA fell short of its anticipated user traffic, project planners could have found other viable means to engage the facility other than letting it lay dormant and deteriorate. Typically, a piece of infrastructure should be designed to deliver essential functions even during and after a doomsday scenario.

Flexibility

Resilience is bending to adversity but not being broken by it. This means the piece of infrastructure can rise back up when the storm subsides. For instance, when the CRCA failed from poor planning and user projections, what other parts of the facility were used to make up for the shortfall? Could it have served more purposes that being a hub for outbound and inbound flights?

A study following the 2005 London Train bombings revealed that *"the flexibility of London's protocols for interagency coordination helped minimise major problems in emergency* *coordination."*

Tolerance

Resilient projects are also tolerant of disruptions, i.e. their core does not wholly collapse at the slightest sign of trouble. Tolerance runs on what Scott Jackson termed "loose coupling." i.e. system failures do not instantly proliferate into other sections of the system.

Cohesiveness

Cohesiveness involves the connectedness of the project's nodes. Like tolerance, it also explains how detachable each node is from the other. For instance, can the damage be contained if the project faces critical damage on one part, or will this ripple freely through the entire system? Could certain portions of the CRCA have been adapted for other uses while the rest served commercial purposes?

It is a strength when the individual parts of infrastructure can communicate with each other in record time. However, it counts as a weakness when they cannot be detached rapidly enough to avoid a spread of damage. In a report published in 2006 on the essential characteristics of infrastructures, David Woods refers to this as "cross-scale interactions." He explains that cross-scale interactions occur on three levels.
First communication, the nodes talk to one another. Then second is cooperation. He also argued that the various nodes of a piece of infrastructure should possess the initiative and capabilities to cooperate with each other without formal ties. Inter-element collaboration is the third and highest level of cohesiveness, which involves formal agreements between the nodes to help and provide resources to each other.

In conclusion, while most infrastructure projects are structurally and functionally resilient, they buckle under pressure from politics, black swans, a changing user base and new demands posed by a warming planet. Therefore, complex projects of the future must prioritise systems that enable them to withstand the environmental, political and digital threats of the 21st century. Anything short of that would not neccessarily count as resilient or sustainable.

About the Writer

Tunde Ajia is a project management consultant and strategy advisor and has managed the delivery of complex projects and major programmes across diverse industry sectors. he is an active APM and ICCPM volunteer, a board member of the PMI UK Chapter and Oxford Urbanists (OU) and currently researches the copmlexity of megaprojects at Cranfield School of Management at a doctoral level.

Connect with Tunde on LinkedIn @TundeAjia and Twitter @Tuibaj