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LARGE-SCALE PROJECT MANAGEMENT

Naomi J. Brookes

Mankind and Mega-projects

Abstract Throughout history mankind has sought to improve its economic and even its spiritual development through the creation of gargantuan and awe-inspiring infrastructure projects. The twenty-first century has seen the rapid growth of the use of this type of project in providing society's needs: such projects are widely referred to as "mega-projects". Mega-projects are extremely large-scale infrastructure projects typically costing more than $1 billion. Mega-projects include power-plant (conventional, nuclear or renewable), oil and gas extraction and processing projects and transport projects such as highways and tunnels, bridges, railways, seaports and even cultural events such as the Olympics. Mega-projects are united by their extreme complexity (both in technical and human terms) and by a long record of poor delivery. What to do in the face of this dilemma is a question that is still being asked by mega-project practitioners and academics alike.

This paper presents the unique work of the MEGAPROJECT COST Action which brings together a multi-disciplinary network of over 80 researchers from 24 countries to respond to this dilemma. Mega-project's aim involves capturing the existing performance of large infrastructural mega-projects and understanding how their delivery can be improved. In order to do this, the investigation has gathered together the MEGAPROJECT Portfolio. The Portfolio contains meta-data on a wide range of mega-projects from across countries and sectors and acts as a firm empirical foundation for the investigation's activities.

Having assembled the MEGAPROJECT Portfolio, this paper shows how analyzing the Portfolio shatters myths of mega-project management and identifies new areas of fruitful investigation. Mega-project's findings downplay the importance of formal project management tools and techniques in insuring successful delivery. Instead mega-project highlights the need to concentrate on the impact of financing on project governance, the technical modularization of the project and the devastating roles that eternal stakeholders can have on mega-project delivery. Most importantly, it discusses how we can effectively learn across mega-projects in order to maximize their value to their stakeholders and to society as a whole.

Keywords: mega-projects, major projects, project failure

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Naomi J. Brookes PhD DIC FHEA(✉)
School of Civil Engineering, University of Leeds, Leeds LS2 9JT, United Kingdom
Email:n.j.brookes@leeds.ac.uk

1 Mega-projects through history

Throughout history, mankind has sought to improve its economic and even its spiritual development through the creation of gargantuan infrastructure projects. An excellent exemplar of this is provided by the awe-inspiring fortification that runs over 21,000 km from the Jiyua Pass in west of China to the Shannai Pass in the east and is known throughout the world as the "Great Wall of China." The Great Wall was constructed and renewed over a period of tens of centuries from rammed earth and wood and latterly bricks, lime and stone. It required the coordination of millions of workers and could only be built at a great human cost. It had a multiplicity of uses: Although its purpose was initially defensive, it grew to regulate and promote trade, facilitate customs control and even to provide a means of transportation along its length.

It is interesting to compare this ancient Chinese infrastructure project with one that was designed and constructed at the end of the last century and the beginning of this, the Three Gorges Dam. The Dam is similarly awe-inspiring in its scale. It has a height of 181 m and a length of 2,335 m and a reservoir with an area of 1,045 km^2. Its construction used 27 million m^3 of concrete and 463,000 tonnes of steel. However this mega-project was constructed in less than 20 years and with a bewildering and complex set of material, electro-mechanical and electronic technologies. This serves to show that, whilst managing gargantuan projects may well be an ancient endeavour, modern projects provide challenges in complexity of technology and speed that dwarf those faced by our ancient forbears. The successful design, construction and operation of these huge infrastructure projects in the twenty first century provide mankind with what may be termed as “the mega-project challenge”.

2 Mega-projects and their characteristics

Mega-projects are extremely large-scale investment projects involving a substantial construction component. Major projects encompass all aspects of infrastructure provision including power plant (conventional, nuclear or renewable), oil and gas extraction and processing projects and transport projects such as highways and tunnels, bridges, railways, seaports and even cultural events such as the Olympics. Mega-projects, which take place in both the public and private sectors, are united by their extreme complexity, their criticality to society and by a long record of poor delivery (Li & Guo, 2011). Mega-projects are globally recognized instruments of economic growth and urbanization (Altshuler & Luberoff, 2003; Baev &Overland, 2010; Fainstein, 2008; Olds, 2011; Ponzini, 2011) though their benefits are contested (de Bruijn & Leijten, 2007; Jia, Yang et al., 2011; Novy & Peters, 2012; Shatkin, 2011). What to do in the face of this dichotomous dilemma of performance and importance is an issue that remains unresolved by mega-project practitioners and academics alike.

Frick (2008) provides an interesting way of capturing the essence of mega-projects. She refers to the six “C”s as being important in characterizing mega-projects: colossal, costly, complex, captivating, controversial and control issues. Mega-projects are indeed colossal, costly and complex. They have a physical stature that dwarfs the humankind that they seek to serve and cost more than the GDP of certain countries. For example, Shell’s Pearl GTL (gas-to-liquid) mega-project with the state of Qatar represents the world’s largest GTL plant. It encompasses 22 development wells, two unmanned platform heads, two 60 km offshore pipelines and a state of the art processing plant that uses technologies with 3,500 patents. It will process 1.6 billion cubic feet of gas per day and cost $24bn dollars (according to 2013 World Bank figures, this cost is higher than the GDP of 88 countries). Mega-projects can be considered as captivating as is evidenced by their role in television series provided by the Discovery Channel and the National Geographic Television Channel such as ‘‘Mega-structures” and “Mega Engineering”. A stylised version of the Oresund Bridge (a bridge mega-project joining Denmark and Sweden) even formed the set for a Pan-European song context! Mega-projects are frequently associated with controversy. For example, the MOSE mega-project in Italy was established to provide flood protection in Italy. This project began in 1975 and has taken nearly thirty years to arrive at a final design because of controversies. It is now embroiled in a corruption scandal.

3 The importance of mega-projects to mankind

Mega-projects play a crucial role in society. They are fundamental to both the supply side and demand side of the mankind’s energy equation. Over the next twenty years, an unprecedented level of investment is predicted in energy infrastructure. The capital investment required to keep pace with the world’s energy needs has been estimated as $48 trillion to the year 2035: $40 trillion of this sum will relate directly to investments in new energy infrastructure. Europe alone will invest 2012 $ billions in the energy sector in this period, the vast majority of this (69%) will be in new power plants. Of those new power plants, indications are that three-quarters of this spend will be in nuclear power and renewable with the remainder of the investments taking place in fossil fuel power plant. It is important to note that these decisions relating to energy investment, even in so called “de-regulated markets”, are guided by government policy rather than market signals (whole-sale prices frequently run at 20% less than feasible cost-recovery levels). Interventions relating to investments in new power-plant therefore represent a highly significant and impactive tool in any government’s energy policy and, in many cases, a substantive level of public expenditure.

In addition to an increasing level of global spend, the complexity and scale of the design and delivery of individual power-plants means that increasingly new electricity generation provision is being delivered in the form of large infrastructure investments known as ‘mega-projects’. Mega-projects have been defined, in financial terms, as large projects that have a total cost of between $0.5~1 billion (Flyvbjerg, Bruzelius, & Rothengatter, 2003; Van Wee, 2007). They can also be considered as having long-term and far reaching effects on their environment (Ren et al., 2013). Mega-projects are characterized by levels of complexity and organizational networks that are an order of magnitude greater than smaller investment projects. All nuclear and most gas and coal power-plants can be considered as mega-projects. In Europe, 58 nuclear power-plant mega-projects are currently planned or proposed. Even investment in renewable energy power-plants frequently takes place in the form of a “mega-project”. Large-scale offshore wind farms and photo-voltaic solar farms both fall into the category of a wind farm. In the UK alone, 13 wind farm mega-projects are under consideration. Understanding the effective design and delivery of mega-projects is therefore increasingly important to electricity generation and to energy policy as a whole.

Mega-projects not only create energy: they have a substantive role to play in its usage. Over a third of the world’s energy consumption occurs in transportation of which mega-projects in the forms of airports, aircraft development, road and rail systems (including bridges and tunnels), ports, and the construction of sea-going transportation lie at the heart. A further quarter of the world's energy usage takes place in the industrial sector and, again, mega-projects can be found at the heart of this in the form of large chemical and pharmaceutical processing plants, new mass-assembly systems and extraction processes.

4 Mega-project performance

A substantive proportion of the research that has been undertaken to review the performance of mega-projects has been case-based. There have been few extensive and statistically rigorous investigations into mega-project performance. Two investigations that are of note in this respect are provided by Flyvbjerg et al. (2003), Merrow (2011). Merrow looked at 318 industrial mega-projects from upstream and downstream oil and gas, mining, pharmachem and power generation sectors. He divided the mega-projects into two clear categories of success and failure. Those mega-projects which can be considered as a success under-ran budgets by 2% and completed on-time: those which he considered a failure over-ran budgets by 40% and underwent a schedule slippage on average of 28%. Only 35% of the 318 mega-projects that Merrow reviewed could be considered as a success. A similar situation was identified in the transport sector by Flyvbjerg. He identified that cost overruns of 50%~100% were common with cost overruns of over 100% happening frequently. Mega-projects also demonstrate poor performance in their overall effectiveness. Miller and Lessard (2000) reviewed 50 mega-projects (32 power plant, 16 transportation, 4 oil production, 8 other). Less than 50% met most major objectives with nearly 20% of projects being complete failures or even abandoned.

An exemplar of extremely poor project performance is provided by the Central Artery/Tunnel Project, known unofficially as the Big Dig, was a mega-project in Boston involving a highway system (including tunnels and bridges) in Boston, U.S. The Big Dig was the most expensive highway project in the U.S. and experienced cost and schedule overruns and a large number of operational problems including leaks, design flaws, charges of poor execution and use of substandard materials, criminality and even four deaths. The project was scheduled to be completed in 1998 at an estimated cost of $2.8 billion. The project was not completed, however, until December 2007, at a cost of over $14.6 billion and it is estimated that its total costs may eventually escalate to Esrimates $22 billion. Furthermore, the client consortium and other subcontractors have needed to pay restitution sums of over $450 million.

5 The causes of poor performance in mega-projects

The causes and cure of poor mega-project performance have been under review since the 1970s. Three streams of investigation have emerged to explain why mega-projects so often fail.

5.1 Lack of shaping and "front-end loading"

Some researchers (Merrow, 2011; Miller & Lessard, 2000) identify that poor performance in mega-projects is due to a failure to suitably plan the mega-project at the very early stages in its lifecycle. They suggest that failures are due to insufficient exploratory work being carried out prior to construction to identify and eradicate uncertainties or that the business case for the project has been insufficiently investigated. Performance problems could therefore, they suggest, be overcome by spending by having a clearly articulated business case and by carrying out more planning and designing work at the start of a mega-project.

5.2 Strategic misrepresentation

Some researchers (Flvbjerg et al., 2003; Liu et al., 2010) suggest that poor performance in mega-projects is due to those involved in decision-making for mega-projects significantly over-estimating the benefits of the mega-project whilst simultaneously significant under-estimating the resources required to implement the mega-project. The reason behind this failure to forecast accurately either lie in the relatively benign sphere of "optimism bias" (the tendency of humans always to think that the best rather than the most likely outcome will happen) or more malignly, strategic misrepresentation where decision-makers in the mega-project are deliberately lying in order that the mega-project should be pursued for their own personal reasons rather than the holistic good. These investigators suggest that "reference class forecasting" (a technique that constructs a reference sample of previous similar projects) could be a way of avoiding this type of misrepresentation.

5.3 Lack of structured decision-making

Other researchers (Hertogh et al., 2011; Semolic et al., 2010) consider that mega-projects often are initiated in a way that destines them to fail because of the lack of a structured and rigorous decision making process. Thus mega-projects are given the go ahead which do not have a sufficiently cogent business case. The solution to poor mega-project performance, these researchers argue, is to use better decision-making tools in the design and construction of mega-projects.

It is interesting to note that, until very recently, no attempts to link mega-project characteristics with mega-project performance using techniques involving statistical analysis had been undertaken. This means that all of the above should be considered only as untested theoretical explanations for mega-project performance. A research investigation that has taken up the challenge of investigating the link between mega-project characteristics and mega-project performance is the MEGAPROJECT COST Action[①]. This is a network of over 80 researchers from 24 countries that have come together to create a portfolio of over 50 mega-project cases which they are using to understand mega-project performance. The MEGAPROJECT Portfolio has used a non-parametric statistical technique, the Fisher Exact Test, to undertake the statistical analysis between the independent variables of mega-project characteristics and the dependent values of mega-project performance. In order to increase the reliability of the conversion of qualitative to quantitative data, independent and independent variables alike were reduced to binary data (e.g. a mega-project characteristic was either present or it was not present; the mega-project either was on time or not on-time). Whilst binary data was commensurate with the use of the Fisher test, the investigation could only identify if a relationship between an independent and dependent variable was present: it could not describe the nature of the relationship. Finally, the investigation only chose to evaluate the mega-project's performance in terms of its planning and construction (both lead-time and cost). This enabled an unambiguous characterization of performance but had the drawback that the tradeoff between construction costs and lead-time and operational efficacy could not be investigated.

By using this approach, the MEGAPROJECT network established the following factors demonstrated statistically significant relationships on mega-project performance (Table 1).

It is interesting to note that the factors identified by MEGAPROJECT as correlated with mega-project performance do not relate to those identified by existing theoretical research streams. MEGAPROJECT indicates that the success of failure of a mega-project is determined by factors that lie in its external context particularly in terms of the regulatory environment in which it operates and the way in which it interacts with external stakeholders (those actors who are influenced by or can exert influence on the mega-project but have no formal or legal relationship with the mega-project). Mega-project's results also indicate that formal and informal structures within the mega-project are key to its success either in terms of the relationship between the mega-project client (often the owner) and the organisations responsible for designing and constructing the mega-project and the formal governance structure that exists within the mega-project.

6 Mega-project and mankind: the future?

If those responsible for commissioning and delivering mega-projects do want to increase their chances of success, the findings of the MEGAPROJECT investigation indicate that they must look beyond the propositions that have currently been expounded for mega-project performance. Those seeking to enact policy through mega-projects need to be very aware of the regulatory environment in which they are placing their mega-projects (often this will be a regulatory environment over which they will have substantive influence). They need to understand the perspectives of the wide communities into which mega-projects will be placed and convince them that mega-projects will bring about the greatest

Table 1 *Impact of Mega-project Characteristics on Mega-project Performance*

		Cost	Planning schedule	Construct. schedule
Relationship between client and EPC	The client is both the EPC/main contractor			●
	The client and EPC have the same nationality	● (grey)		
Strength of regulatory environment	A regulatory authority fined the project	●		●
	A regulatory authority changed the scope of the project		●	
External stakeholder involvement	A pre-existing environmental organization raised public objections to the project			●
	No public protests occurred at national level			● (grey)
Governance structures	An SPE was present in the project		●	

●-Characteristic is harmful ● (grey)-Characteristic is beneficial

① More information can be found at www.mega-project.eu possible good for the greatest number of people. Internally, the formal and informal nature of the relationships between mega-project actors is crucial for the successful design, delivery and operation of a mega-project.

Furthermore, in the face of what still may be considered an immature research area, investigators must acknowledge that understanding of mega-projects and the enhancement of their delivery performance is a societal imperative. Researchers need to work together with a spirit of cooperation to pool their knowledge and data in the light of this important challenge.

This paper began by highlighting the longevity of experience of mankind in creating gargantuan construction projects but also the challenges in designing and delivering these mega-projects in a twenty-first century context. Given the projected levels of investment in global infrastructure over the next 30 years, it is highly unlikely that the number of mega-projects that mankind instigates will decrease. It is far more likely that the implementation will occur of more and more costly and complex mega-projects. The poor performance of existing mega-projects (and the lack of understanding of the provenance of that poor performance) demands humility in those responsible for commissioning, designing and delivering mega-projects. It is an act of hubris on the part of governments if they ignore the current statistics on mega-project performance that indicates that their intended mega-project is far more likely to be a failure than a success.

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