Utilities Policy 36 (2015) 57–66

Contents lists available at ScienceDirect

Utilities Policy

journal homepage: www.elsevier.com/locate/jup

Power plants as megaprojects: Using empirics to shape policy, planning, and construction management

Naomi J. Brookes**, Giorgio Locatelli*

The University of Leeds – School of Civil Engineering, Leeds, LS2 9JT, UK

ARTICLE INFO

Article history:
Received 15 February 2015
Received in revised form
6 September 2015
Accepted 6 September 2015
Available online xxx

Keywords:
Megaprojects
Power plant economics
Capital intensive
Project management
Construction management
Budget
Schedule

ABSTRACT

Megaprojects are historically associated with poor delivery, both in terms of schedule and cost performance. Empirical research is required to determine which characteristics of megaprojects affect schedule and cost performance. Capital-intensive power plants can be understood as megaprojects and time delays and cost escalation during the construction phase can undermine their overall economic viability. This paper presents a systematic, empirically based methodology that employs the Fisher Exact test to identify the characteristics of power plant megaprojects (PPMs) that correlate with schedule and cost performance. We present the results of applying this methodology to a dataset of 12 PPMs using nuclear, coal, and renewable resources as case studies. The results highlight the importance of modular technologies, project governance, and external stakeholder involvement. Key findings both support and contradict the literature. The paper provides two major original contributions. First, we present and apply a systematic, empirical and statistical approach to understanding PPMs planning and construction. Second, we show how this approach can be used to inform public policy and project management with regard to PPMs.

1. Introduction

Over the next twenty years, an unprecedented level of investment in energy infrastructure is predicted. The capital investment required to keep pace with the world's energy needs to the year 2035 has been estimated by IEA (2014) as $48 trillion: $40 trillion of this sum will relate directly to investments in new and replacement energy infrastructure. IEA (2014) predicts that Europe alone will invest more than $3 trillion in the energy sector over this period and the vast majority of this (69%) will be in new power plants. Increasing energy demand fosters the development of energy infrastructures (power plants, electrical grid, pipelines, energy storage etc.). Part of this energy demand will be satisfied by "small-scale projects" (e.g. gas turbine or rooftop photovoltaic plants) but some will be satisfied by large-scale and complex "megaprojects" due to their capital nature; these include long pipelines, nuclear power plants, large wind farms and large dams. Of the new power plants, indications are that three-quarters of the spending will be on plants using nuclear power and renewable resources, with the remainder of the investments taking place in fossil-fuel power plants (IEA, 2014). A description of the risks and challenges in building large infrastructure projects is available from Van de Graaf and Sovacool (2014) and Sovacool and Cooper (2013).

Decisions related to energy investment, even in the so-called "de-regulated markets", are generally guided by government policy rather than market signals (de la Hoz et al., 2014; Locatelli et al., 2015a). Interventions related to investments in new power plants, therefore, represent a highly significant and influential tool of any government's energy policy and, in many cases, a substantive level of public expenditure (see for instance the detailed case of France from Maïzi and Assoumou (2014)). Power Plant Megaprojects (PPMs) are often seen as too late, too costly, and fail to provide for society the promised benefits. The essential nature but poor performance of energy infrastructure megaprojects in general suggests room for improvement. Effective energy policy is thus also predicated upon improvement in megaproject design and delivery.

We present the results of a rigorous and systematic investigation to identify megaproject characteristics that contribute to the effective design and delivery of new PPMs and thus provide guidance for policy-making and decision-making about future projects.

2. Literature review

2.1. What is a Megaproject

Gellert and Lynch (2003, p.16) show that "Mega-projects can be

---

* Corresponding author.

** Corresponding author.

E-mail addresses: n.j.brookes@leeds.ac.uk (N.J. Brookes), g.locatelli@leeds.ac.uk (G. Locatelli).

http://dx.doi.org/10.1016/j.jup.2015.09.005
0957-1787/

divided analytically into four types: (i) infrastructure (e.g., ports, railroads, urban water and sewer systems); (ii) extraction (e.g. minerals, oil, and gas); (iii) production (e.g. industrial tree plantations, export processing zones, and manufacturing parks); and (iv) consumption (e.g. massive tourist installations, malls, theme parks, and real estate developments)". There is not a single accepted definition of megaproject in the literature and different criteria can be adopted toward this end. For instance, from the investment point of view, megaprojects have budgets above $1 billion with an high level of innovation and complexity (Flyvbjerg et al., 2003; Locatelli et al., 2014a; Merrow, 2011; Van Wee, 2007). Looking at the operations phase, megaprojects are projects having long-term and far-reaching effects on their environment (Orueta and Fainstein, 2008; Ren and Weinstein, 2013; Warrack, 1993).

With respect to the economical dimension, Warrack (1985) argues that $1 billion is not a constraint in defining megaprojects, as sometimes a relative approach is needed because in some contexts, a much smaller project (such as one with a $100 million budget), could constitute a megaproject. Warrack (1993, p.13) also presents ten main features of megaprojects: "joint sponsors, public policy, uniqueness, indivisibility, time lags, remoteness, social environmental impact, market impact, risk, and financing difficulty". van Marrewijk et al. (2008, p.591) define megaproject as "multibillion-dollar mega-infrastructure projects, usually commissioned by governments and delivered by private enterprise; and characterized as uncertain, complex, politically-sensitive and involving a large number of partners". This latter definition emphasizes the organizational complexity that comes with the presence of multiple private firms in connection to the political stakeholders (namely, the government).

Therefore, megaprojects are temporary endeavours (i.e. projects) characterized by: large investment commitment, vast complexity (especially in organizational terms), and long-lasting impact on the economy, the environment, and society. Large energy infrastructures are typically delivered through megaprojects. The working definition of an energy megaproject adopted in the current research is: "an energy infrastructure with an a budget of at least $1 billion with an high level of innovation and complexity with, in operation, a long-term and far reaching effects on their environment".

2.2. *Megaproject performance*

Merrow (2011), analysing a dataset of 318 industrial megaprojects from several sectors, shows that as many as 65% of them can be considered a failure. The oil and gas production sector is the worst, as 78% of megaprojects in this industrial sector are classified as failures. Therefore, there is a huge scope for the study and application of a risk framework specific to megaprojects, as presented in Kardes et al. (2013).

Focusing on the electricity sector, infrastructure PPMs are no exception to this pattern. Ansar et al. (2014) analysing a sample of 245 large dams (including 26 major dams) built between 1934 and 2007 found that actual costs were on average 96% higher than estimated costs and actual implementation schedule was on average 44% (or 2.3 years) higher than the estimate. Koch (2012) shows that budget overruns range from 0% to 65% and lead-time overruns range from 9% to 100% for offshore wind farms. Sovacool et al. (2014a) shows that three-quarters of megaprojects are over budget with an average overrun of 66%.

PPMs suffer from large differentials of cost to budget both in absolute and relative terms. Hydroelectric and nuclear power plants are the worst performers. Sovacool et al. (2014b) test six hypotheses about construction cost overruns related to (1) diseconomies of scale, (2) project delays, (3) technological learning, (4) regulation and markets, (5) decentralization and modularity, and (6) normalization of results to scale worldwide. They discover that different technologies generally exhibit different behaviour (with again nuclear as worst performer), but smaller, decentralized, modular, scalable systems have less cost overruns in terms of both frequency and magnitude and both in absolute and relative terms. Kessides (2010 and 2012) provides an extremely critical analysis of nuclear power plants. He discusses risks, cost escalations, delays, and safety issues of this technology. He shows that, with current project management performance and system issues (such as grid and fuel cycle), large nuclear power plants are not suitable for most countries. Locatelli and Mancini (2012) focus on two nuclear projects in particular (Olkiluoto 3 and Flamanville 3), discussing how budget costs have been underestimated despite historical evidences. All nuclear and most gas and coal power plants can be considered megaprojects. In Europe, 58 nuclear reactors are currently planned or proposed (WNA, 2014). Even investments in renewable energy power plants (such as large-scale offshore wind farms and solar plants) frequently take the form of megaprojects. In the UK alone, 13 wind-farm megaprojects are under consideration (Pierrot, 2014).

Given the prominent role that megaprojects will play in the provision of new power plants, it is concerning that they are renowned for their poor delivery record in terms of timeliness and budget (Flyvbjerg, 2006; Merrow, 2011; Sovacool et al., 2014b). Furthermore, their planning and construction plays a fundamental part in securing their effective operation and intended life-cycle benefits. Too often, megaprojects are seen as providing a solution that is too late, too costly, and fails to provide promised benefits to society. In sum, more effective design and delivery of infrastructure megaprojects is becoming increasingly important to effective energy policy as a whole.

3. Methodology

3.1. *Cross-case analysis*

The research methodology used here is an inductive cross-case analysis, a technique that takes similarly constructed cases and uses a structured process to review the cases to arrive at "cross-case" patterns. These "patterns" are the used to generate theoretical propositions. The approach adopted is based on the seminal work of Kathleen Eisenhardt (1989), who derived a process where theoretical generalizations could be generated from reviewing a set of cases of a particular phenomenon. Eisenhardt (1989, p.545) also discusses "reaching closure," i.e., "*when to stop adding cases, and when to stop iterating between theory and data*". She advises researchers to stop adding cases upon reaching theoretical saturation and/or when the incremental improvement to quality is minimal. Four to ten cases usually work well because too few cases will be insufficient for empirical grounding and generalization and too many cases will be overly complex in terms of data management. In our effort to generate statistical evidence across several variables, we reached 12 cases. It was extremely difficult to increase this number of cases because of the lack of availability of primary and secondary data. Regarding the geographic constraint (Europe), we note that the research is enclosed within a broader research stream initiated and supported by the Megaproject COST Action.[1] The main objective of this Action is to understand how megaprojects can be designed and delivered to ensure their effective commissioning within Europe.

---

[1] The Megaproject COST Action is funded by COST Programme. (COST is an intergovernmental framework aimed at facilitating the collaboration and networking of scientists and researchers at European level.) The Megaproject COST Action focuses on improving the design and delivery of megaprojects across sectors in Europe.