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Delivering Superior Mega Project Outcomes through Timely Intervention in the Civil Engineering Curriculum

Danielle Lester¹, Jose Torero Cullen² and Chris Greig³

Abstract

Mega projects (>US\$1 Billion) are now commonplace but deception and delusion are ubiquitous and identified as principal issues in decision-making, resulting in poor project performance outcomes. Unethical decision making, leadership and culture are cited as key factors affecting mega project performance outcomes, issues inconsequential to traditional Civil Engineering curricula, yet recognised by global accreditation bodies as crucial to an engineer's education. Whilst the argument of ethics in engineering has become more common in recent years, a discussion of underlying values and the influence these have on decisions made in a current context is less so. This paper provides an overview of current practice and seeks to explore the relationship between social identity & values in engineering education, and leadership & culture in a mega project environment.

Keywords: engineering curriculum, ethics, decision-making, mega-projects, project management.

Introduction

Mega-Project Performance Outcomes

Major cities around the globe are experiencing increased demand for improved major urban transport infrastructure. With this, projects are not only getting larger but also more complex and attracting greater public interest.

As these major infrastructure projects are completed, it is apparent that poor project performance outcomes are consistent across the globe and that cost overruns and schedule slippages are seriously affecting project viability as well as redefining possible economic growth, as potential obstacles to economic growth (Flyvbjerg 2003). Complex projects with budgets greater than USD\$1 billion have a much higher failure rate than smaller projects (Engineers Australia, 2014). In monetary terms, this equates to billions of dollars in losses and an unsatisfactory return on investment for investors and, in the case of publicly funded projects, taxpayers.

Perhaps related to project management failures, 'non-technical' skills have been highlighted as increasingly important by engineering professionals, such as Engineers Australia, The National Academy of Engineering in the United States and the Royal Academy of Engineering in the United Kingdom each of which have independently

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published reports identifying the qualities, skills and attributes required by the engineers of the future. The three reports were unanimous in identifying that principles of business & management, and leadership were equally as important during the under graduate education of future engineers to that of in-depth technical and analytical skills.

But it is not just a lack of good project management skills driving mega projects' failure to produce superior performance outcomes. The problem has been identified, by mega project researchers as behavioural. An ability to identify risk and uncertainty when operating in a complex project environment is crucial in a mega project setting. Acting on that knowledge or understanding of risk is a separate challenge all together and questionable decision-making has been linked to poor mega project performance outcomes (Flyvbjerg 2007). This raises questions around ethical decision-making in a mega project environment.

Objective

As Civil Engineers make up the majority of the wider project team on major infrastructure projects, the education and continuing professional development of these graduates has the potential to impact the future success of mega projects. Project management, business management, and leadership play an insignificant role in current civil engineering curriculum globally. The objective of this paper is to examine how universities can better prepare Civil Engineering under graduates with the skills and attributes required of the engineering leaders of the future and improve future project performance outcomes.

Mega Project Review

There is significant research into the measurement of effective Project Management and the reasons behind project success and failure but this will be the first time a review of industry performance will be concomitant and linked with education delivery. There is little evidence to suggest that the findings of this past research has been acknowledged or acted upon by industry. By applying the findings of project success & failure to future engineering education requirements together with industry engagement, it is hoped that this project will foster a greater relationship between industry and education whilst also supporting the development of future leaders of engineering.

Mega project performance outcomes have been studied across industries for the last 25 years, analysing projects spanning 70 years, from as early as the late 1920's. Edward Merrow carried out one of the first quantitative studies in 1988 as part of a Rand Corporation investigation commissioned by the U.S. Department of Commerce.

Merrow aimed to identify factors affecting success and failure of very large industrial civilian projects. In a study of 52 Projects ranging from \$500m to \$10bn (1984 USD), size of project was found not to be a factor in causing cost overruns and/or schedule slippage. Regulatory conflicts were apparent in projects >\$100m. The use of new technology was found to virtually ensure poor project performance (cost, schedule and performance). The area of world also had no effect; however remoteness had a strong impact on cost growth. Of the 52 projects examined, average cost estimate growth from detailed engineering design until project completion was 88%. Schedule slippage averaged at 17% with only 15 of the projects completed on time. Total cost overrun for the projects totalled \$30 billion USD.

Although Merrow's research was primarily analysing the effect of new technology on project performance on industrial projects, the study was able to benchmark project performance assessment criteria and produced a Project Evaluation System that has been used in over 3000 projects and 80 project systems and has produced a predicted investment portfolio of USD one-half trillion dollars (Construction Industry Institute). In a study of

public sector major infrastructure projects in India, delays in project implementation and cost overruns were a regular feature of public sector projects (Morris, 1990). Average cost overruns were 82%. Up to 25% overrun was due to price increase, the further 75% was due to poor project design and implementation, inadequate funding, bureaucratic indecision, and lack of coordination between enterprises.

In the last decade, the work of Bent Flyvbjerg has focussed predominantly on mega projects within global transport infrastructure. Flyvbjerg's initial study in 2003 analysed 258 projects, in 20 nations, executed over 70 years (1927 -1998) with a total value of \$90 billion (USD 1995) and found the following:

1. 9 out of 10 projects experienced cost overruns
2. Actual costs were on average 28% higher than forecast costs
3. The error of underestimating was more common than the error of over estimating
4. Underestimated costs were incorrect by a substantially larger error than over estimated costs
5. Cost escalation has not decreased over the last 70 years

Flyvbjerg concluded that cost estimates used in decision-making for transport infrastructure development are highly, systematically and significantly misleading. The study proposed two main causes for this misinformation, Optimism Bias (appraisal optimism) and Strategic Misrepresentation (lying).

- **Optimism bias or appraisal optimism** *is the demonstrated systematic tendency for people to be overly optimistic about the outcome of planned actions. This includes over-estimating the likelihood of positive events and under-estimating the likelihood of negative events.*
- **Strategic misrepresentation** *is the planned, systematic distortion or misstatement of fact (lying) in response to incentives in the budget process.*

Based on the empirical evidence derived from this study, in 2007 Flyvbjerg developed methods to mitigate the occurrence of this misinformation and proposed the use of Reference Cost Forecasting (RCF). RCF predicts the outcome of a planned action based on actual outcomes from a reference class of *similar* actions being forecast. In 2009 Flyvbjerg speculated that the underlying reasons for forecasting errors in mega projects could be classified either as honest delusions, deliberate deceptions or plain bad luck.

Delusion can be characterized by:

- 'The planning fallacy' or the tendency to underestimate the time taken to complete a task. (Kahneman and Tversky, 1977)
- 'Anchoring and adjustment' or the tendency to allow the first number considered to act as an anchor around which estimates are developed, regardless of whether it is explicitly known. (Kahneman and Tversky, 1986)

Human judgement is generally optimistic (Kahneman and Tversky, 1979) due to the inadequate consideration of distributional information of outcomes. Therefore, people generally underestimate the cost, time and risk of planned actions whilst also overestimating the benefits of those same actions. The natural tendency of optimism bias can be attributed to and exacerbated by an individual's (project sponsor, team member, stakeholder etc.)

motivation to ask framing questions to direct the respondent to provide the desired answer. For example, asking someone if they are able to come up with a budget and schedule for a large project is more likely to produce an honest and trustworthy answer than “can you do this project for \$XX?” (Prieto, 2013).

Deception can be characterized by:

- ‘Principal agent problems’ mega projects are characterised by multiple and complex principal-agent contracts, most of which are resolved by the lowest bid. This incentivises actors (politicians, project champions, EPC firms and sub-contractors) to under estimate costs, only promote benefits and deliberately leave risk unacknowledged in order to ensure the project, or at least their part in it, proceeds over the competition.
- ‘Asymmetric information’ the project champion has access to information that the principal decision maker does not which means the decision maker is more easily deceived.
- ‘Asymmetric accountability’ the agents responsible for cost overruns or schedule slippages may not be the ones held accountable resulting in agents taking more risk than normal.

In 2008, Allport et al., reviewed 22 case studies in response to a commission from KPMG for an evidence based study on “How to Define Success of Transport Projects, and How Important to Success is Having Good Funding and Procurement Strategies in Place at an Early Stage?”. The report defined success from the viewpoint of the public authority promoting the scheme and did not therefore consider whether the project was the best that could have been identified. A project was considered a success against its objectives and those objectives were assessed through both independent evidence and stakeholder opinion. The three measures of success were financial (outturn verses forecasts), policy (outturn versus intentions held at commitment; economic, social, development and environmental impact), and durability (ability to maintain its service delivery and suitability of development process/procurement form). The report concluded that the six factors most likely to influence success on major infrastructure projects are:

1. *The project environment, and its turbulence evidenced by showstopper events and ‘windows of opportunity’ (policy change/the state of the economy/poor planning).*
2. *Strong political control or sponsorship. Clear objectives and leadership during implementation; then during operations.*
3. *Strong Guidance from central government – appropriate, strategic and providing predictability.*
4. *Good infrastructure planning and transport planning – providing a sound basis for the commitment decision.*
5. *Good procurement and funding structure in place at the appropriate time – a strong financial structure (providing survivability) a contract that incentivises effective delivery and good operations, realistic risk and competition.*
6. *Strong operator contract that permits proactive management of the operational business.*

All points focus on the planning and implementation of the project and highlight the impact of decision-making during and between critical stages of the project. This suggests that these factors will indeed impact a project’s success but that it is in fact the decisions made during these phases that determine a project’s success. The report states that

weaknesses in the project planning stage are universal but could be mitigated with ‘reality checks’ by a Project Development Group or Peer Review.

In 2014 Engineers Australia produced a green paper reviewing principles for success and reliable performance entitled *Mastering Complex Projects*. The green paper invited industry experts and academics to provide their opinions on the success factors of mega projects and offer recommendations for industry and education. Poor planning and decision-making were notably cited as factors affecting the performance of mega projects along with uninformed clients. The recurring theme that emanated was the need for excellent project leadership, during both the shaping (development) stage and then during the construction (implementation). Ryan et al. (2014) offered an operational perspective and indicated that project leaders face many challenges on mega or complex projects over smaller, traditional projects. The first temptation is to revert to traditional command and control management styles and demand fail safe business plans with defined outcomes. A complex, or mega project requires a more experimental style of management and a project leader who does not recognise this, may become discouraged when expected results are not achieved (Snowden & Boone 2007). This experiential style of management may also make it difficult for traditional ‘Project Managers’ to tolerate failure. Leaders who try to over-control the project will fail. Ryan concluded that all major infrastructure projects are complex and therefore require a different style of leader, and successful project leaders consistently experiment, throw away templates and confront everyone and everything. This suggests that a successful leader’s attitude to risk is far less adverse and a good project leader’s time should be spent concentrating on the culture on a project as opposed to focussing on predetermined outcomes.

It is apparent that current project management thinking, and project managers are challenged by the new wave of complex projects and that project management theory requires appraisal and improvement. It is apparent that mega project performance outcomes remain poor. Mega projects are complex and involve greater uncertainty and risk than smaller projects. It is clear that the decision-making as a result of this risk and uncertainty can be attributed to poor performance outcomes. Complex relationships teamed with often complex technical design within mega projects offers an ideal opportunity for delusion and deception to occur in an effort to confuse and/or conceal risk. Interpreting risk and uncertainty requires skill and knowledge; however the decision-making that is a result of that knowledge and understanding brings to bear behavioural issues and ethics.

The Project Management Discipline

It was the late 1980’s before substantial research studied the Critical Success Factors of projects. Morris and Hough (1987) evaluated 1653 projects and found the key challenges were such things as; unclear success criteria, changing sponsor strategy, poor project definition, inappropriate contracting strategy, poor control and lack of top management support. The start of the 21st century was a turning point in Project Management research, with two Critical Success Factor studies (Miller & Lessard, 2001 and Flyvbjerg et al. 2003) making a major impact on our thinking of the management of projects. Miller & Lessard’s study of 60 ‘Large Engineering Projects’ differentiated between the effective performance (meeting the ‘business’ goals of the sponsor) and efficient delivery (on time, in budget, to scope). The study found that performance was poor on effectiveness more so than efficiency. This can be explained by the fact that most projects are assessed on their efficiency as

opposed to their effectiveness. The key issue impacting the projects was the sponsors' abilities in:

1. *Shaping strategy and coping with political, economic, and social turbulence*
 2. *Dealing with partnership and contractual turbulence*
- (Miller & Lessard, 2001)

Flyvbjerg also showed the danger of sponsors' abilities, particularly the issue of public sector projects often knowingly pitching low budgets (Strategic Misrepresentation & Optimism Bias).

Even though we now have a much greater knowledge base and framework to improve our understanding in the field of Project Management, evidence from project outcomes suggests the robustness of the claims that we know how to manage projects is questionable. One reason may stem from the genesis of project management within the social sciences rather than natural sciences and social science is not independent of context or value systems: people bring ideas, values, and sometimes, unexpected behaviours (Morris 2013). Despite this social science association, the project management tools that provide the knowledge and guidelines, for example, PRINCE2 or the PMBOK Guide exist in a positivist and absolute format. Whilst certain topics within project management may fit this format well (scheduling and estimating), we are still unable to determine the effects of human behaviour on most project management knowledge areas (Morris 2013).

Project management knowledge has advanced throughout time but it still has no safeguard against the human factors that affect its application in industry. The delivery of project management education and training has the potential to have a significant impact on the delivery of mega project outcomes. If a focus were made on effectiveness over efficiency when measuring mega project performance the likelihood of optimism bias and strategic misrepresentation affecting performance outcomes would be greatly reduced. Complexity, uncertainty, risk management and ethical decision-making are critical factors in mega projects' success that could be embedded within the 'knowledge areas' of project management education. By incorporating these factors into project management education, a key requirement of educating the engineering leaders of the future could be delivered through engineering education.

Entrepreneurship and Ethics in Engineering Curricula

As the discipline of Civil Engineering advances to address the challenges faced in current and future mega-projects, the demand for a breadth of knowledge, both technical and professional, has risen sharply, alongside the need for creativity and innovation. Sustainability is now being integrated in to engineering syllabuses globally, and in the USA, sustainability goals have been linked to innovation and entrepreneurship (Oswald, 2014).

The Kern Entrepreneurship Education Network (KEEN) Program was established to transform the U.S workforce by equipping graduate engineers with an entrepreneurial mindset. Driven by changes in the global economy, a focus on entrepreneurship has developed rapidly in the US at many of its engineering schools. The KEEN program's aim is to not only include the technical fundamentals of engineering in to the curriculum, but also incorporate insight into the importance of customer awareness, an introduction to business principles, as well as a focus on societal needs and values (Kriewall & Mekemson, 2010).

It is important to establish the difference between *Entrepreneurship* and *Entrepreneurial Mindset*.

Entrepreneurship – self-employment through business ownership, which has significant elements of risk, control and reward.

Entrepreneurial Mindset – A specific state of mind which orientates human conduct towards entrepreneurial activities and outcomes. Individuals with entrepreneurial mindsets are often drawn to opportunities, innovation and new value creation.

Characteristics include the ability to take calculated risks and accept the realities of change and uncertainty, opportunity orientation, technical empowerment, business fundamentals, interpersonal dynamics and forward thinking as well as possessing skills in teamwork, leadership, written and oral communication.

The purpose of entrepreneurial engineering is to design value-added products and processes that create demand through innovation, resulting in positive cash flow, revenue and regenerative profits. (Kriewall and Mekemson, 2010).

Whilst incorporating this program in to the civil engineering curriculum will develop skills in communication, team work and business, it does not address the more sophisticated concepts of complexity, uncertainty, risk and ethics. One might argue that developing an entrepreneurial mindset in an undergraduate engineer may lead to greater risk taking creating an adverse effect in a mega project environment. These concepts will also have a significantly different context for a start-up venture than a multi-billion dollar transport infrastructure mega project.

The argument of ethics in engineering has become more common in recent years but the discussion of underlying values and the influence these have on decisions made in a current context is less so.

Values guide our action – what we choose and how we choose. Our values are the lens through which we view the world: they stem from our underlying beliefs and assumptions, which are generally neither articulated nor questioned (Mitchell and Baillie, 1998).

Baillie and Levine 2013 argue that the values underlying the ethical decision-making process can develop very different responses to the same issue. These underlying values, defined by political, social and cultural influences are often socially constructed and based on dominant discourse. Values evolve from human interactions with the external world and are related to, but more abstract, than norms (Santrock, 2007). In any society and culture there are ways of thinking that are common sense or ‘hegemonic’ that result from norms and turn in to values (Gramsci, 2008). An example of hegemonic culture and enculturation comes from the U.S. Military and is the result of cadets’ “preferences” and “identities” to enable them to identify themselves ‘above all else, as officers in the U.S. army’ (Akerlof and Kranton, 2005).

Social Identity – A person’s sense of who they are based on their group membership(s) (Tajfel, 1979)

Thought Collectives - A community of persons mutually exchanging ideas or maintaining intellectual interaction (Fleck, 1935)

Thought collectives can become fixed and formal in structure if a large group (such as professional engineers) exists for long enough. The longer a thought exists within a collective, the more certain it appears (Fleck, 1979).

If engineering is considered a community of practice, with an associated common sense and thought style then in order to reframe engineering practice, a critical repositioning

of engineering itself is needed. Enlarging what it means to be an engineer is to understand the responsibility of a professional to see beyond what ethics means within the contemporary pressures and measures of success, and to know what the available choices are and which among them are morally justifiable before making a decision (Baillie and Levine, 2013).

In *Engineering & Social Justice (2008)* Donna Riley suggests engineers tend to abdicate responsibility for problem definitions to others, and state instead, that they are working on “given” problems and yet autonomy and the ability to make independent ethical choices is an essential element of what defines professions in sociological terms (Riley, 2008).

Current ‘silo-effect’ practices in education are preventing students from identifying with ‘being an engineer’ and the absence of context in many fundamental courses constrains undergraduate engineers from critically thinking about “*what is engineering?*” and restricts critical thinking to a “given” problem. One could argue that we are producing technicians as opposed to educating professionals.

This is similarly reflected by attitudes in industry. In a term coined by project participants themselves, a “project slut” (project mercenary) will go from project to project, working on “given” problems with little or no interest in the greater project or the implications and impact of the commercial decisions they make. Furthermore, these project participants are receiving incentives incongruent with project performance outcomes, and are present in all stages of the project life-cycle and across all levels of the organisation.

‘Managing’ Ethical Decision Making

Though the construction industry is the key driver for economic growth in many countries, the industry faces many challenges related to ethical behaviour including: bid shopping, payment games, lying, unreliable contractors, inflated/false claims, threats, conflicts of interest, collusion, fraud and professional negligence (Ho, 2011). In a comprehensive review of ethics decision-making literature (1980s to 2008), Ho found that the gap between theory and practice is expanding as the overall body of ethics management related work continues to grow.

The construction industry is a sector of the economy which differs in many ways to other economic fields. Major distinguishing factors include; it’s large size, the influence of government as a client, the high cost of construction items, the nature and variety of construction work and the structure of the industry (Ofori, 1990). The organisational structure of the industry is unique. Project participants vary from one project to the next and, particularly in the context of mega projects, can be described as “temporary multi-organisations” yet little research exists focussing on ethical decision-making at a group or organisational level.

In ethical decision-making ethics refers to “*the rules or principles that define right and wrong conduct*” (Davis and Frederick, 1984). The field of business ethics is commonly divided in to two realms – normative and descriptive ethics theories

- **Normative** – what decision makers *should* believe to be right and wrong
- **Descriptive** – what decision makers *actually* believe to be right and wrong

To understand the factors influencing engineers’ ethical decision-making in a mega project environment, this study focusses on descriptive theories, specifically theory relating to individual and situational factors but focussing on the impact a change in environment, specifically culture, can have on an individual’s decision-making.

‘Managing’ ethics is considered a management discipline and has been since the start of the business ethics and social responsibility movement of the 1960’s (Ho, 2011), but it is as much a “bottom-up” issue as it is a “top-down” responsibility.

Ethics and Psychological Connectedness to Future Self

Most individuals recognise that their identity (personality, interests, values, goals and beliefs) changes over time. Some believe that this can happen only marginally and feel quite connected to their future self; these people represent a high level of psychological connectedness. Others who feel their identity will change dramatically over time represent low levels of psychological connectedness, or ‘discontinuity’ with their future self. (Parfit, 1984).

An individual’s connectedness to their future self can impact many aspects of their lives, both personally and professionally. To establish the impact a level of connectedness to the future self can have it is important to recognise the affects low or high connectedness has to behaviours through previous research. Consequences and indicators of discontinuity of future self include; unethical behavior and consideration of future consequences (Hershfield, Cohen and Thompson, 2012), and temporal discounting and delayed gratification (Bartels and Urminsky, 2011). High self-continuity has been linked to autonomy and resulted in reduced temporal discounting (Joshi and Fast, 2013). Related concepts include; expectation of staying in the same job (Liebermann, Wegge and Muller, 2012), and the collective futures framework, reflecting on potential social changes (Bain et al., 2013).

Understanding and recognising self continuity traits may therefore be important to the selection of project management professionals and the make-up of project teams.

Conclusion

It is clear from the literature reviewed in this paper that there is a gap in research relating to decision-making in a mega-project environment and the role that education can play in improving the quality of decision-making, prior to entering, and once established in industry.

Whilst we can retrospectively address the issue of poor decisions made on mega projects, an evaluation of what can be done in education would be less processual and focus more on the impact of individual and situational factors affecting decision-making. As cohorts increase in size and the quantity of information students are expected to retain during their engineering programs increases in line with new technologies and practices, are we forgetting to address the fundamental issue of values, identity and choice, and in turn inhibiting the development of critical decision-making skills?

By evaluating current education delivery and identifying the factors affecting personal development and social identity, timely intervention in the Civil Engineering curriculum could provide an opportunity to develop ethical decision-making skills and ultimately lead to delivery of superior mega project performance outcomes.

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