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Managing mega construction projects - learning from two case studies: London Underground's Jubilee Line Extension and BAA's Heathrow Terminal 5

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ABSTRACT

The successful management of mega construction projects is immensely challenging with huge potential risks. These projects often have a significant impact on national economies or the financial stability of private companies.

The aim of this research is to seek to identify project management best practice through the examination of London Underground's Jubilee Line Extension and BAA's Heathrow Terminal 5, using the 22 hypotheses identified in Morris & Hough's book *The Anatomy of Major Projects* as a template.

The research has established that the JLE was beset by problems not helped by the traditional adversarial contracts. In contrast the enlightened project management philosophy adopted by BAA on the Heathrow T5 in which BAA took all the risk and significantly harnessed the "intellectual horsepower" through the use of integrated teams has proved highly significant. Morris & Hough's 22 hypotheses have been found to provide a relevant framework and 4 additional hypotheses have been identified.

KEYWORDS: Project management, mega projects

1. INTRODUCTION

The management of major projects poses special challenges. They are larger, more complex and offer greater risks and rewards, both to society as a whole and to those directly associated with them. Furthermore, major projects are particularly challenging to the participants because they combine complexity with time pressures and often touch on sensitive political and environmental concerns.

It was estimated in 1999 that there were more than 1,500 large engineering projects worldwide (each worth over US$1 billion) at different stages of financing or construction, in sectors such as oil, power, transportation and manufacturing. Furthermore, the number, complexity and scope of the projects have been increasing rapidly over the last few decades (Miller & Lessard, 2000).

Over the years several guides have been produced in order to help participants better understand the project management process on major projects. The National Economic Development Office's *Guidelines for the Management of Major Construction Projects* (NEDC, 1991) identified the importance of the strength, calibre and leadership of the project manager, the requirement for co-operation of all working on the project and the need to freeze designs before proceeding with construction.

The U.K. H.M. Treasury *Guidance No 36: Contract Strategy for Major Projects* noted that the contract strategy has a major impact on the timescale and ultimate cost of major projects (H.M. Treasury, 1992).

The Major Project Association's *Beyond 2000: A Source Book for Major Projects* (MPA, 1994) identified the reduction in the role of the public sector and the move towards new and inventive forms of funding and ownership together with technology advances in IT and growing sophistication in project management techniques. Since publishing the Source Book the MPA have continued to press ahead with an active programme of seminars, investigations and case studies and made summaries of this knowledge available to all via their website (http://www.majorprojects.org/).

In the late 1990s an international team led by research director Roger Miller examined sixty major projects in different industries and parts of the world in order to identify best practices (Miller & Lessard, 2002). The authors emphasised the importance of solid front-end work as a critical success factor identifying that as much as 25% of the total project cost might be spent on exploration of issues pertaining to coalition building, governance, adequacy of institutional framework, the role of the state, population support, and the ecological, social and economic aspects of the project.

2. RESEARCH METHODOLOGY

The aim of this research is to compare and contrast two different large engineering projects: London Underground's public sector £3.5 bn. Jubilee Line Extension which was completed in December 1999 and BAA's private sector £4.3 bn. Heathrow Terminal 5 due for completion in March 2008.

The projects are compared using the 22 hypotheses identified in Morris & Hough's *Anatomy of Major Projects: A Study of the Reality of Project Management* (1987) as a template. In this book Morris and Hough examined in detail nine case studies in a variety of sectors including civil engineering, aerospace, railway, nuclear power, oil, IT and space exploration. The identified hypotheses will be tested based on a thorough review of the relevant published material, in order that lessons can be learned and best practice identified.

3. CASE STUDY 1 – LONDON UNDERGROUND'S JUBILEE LINE EXTENSION

In 1989 London Underground's Jubilee Line Extension, which linked Westminster to the Docklands and beyond to Stratford was reborn after previously being abandoned. This project was initially estimated to cost £1bn with £400m. being provided by Canary Wharf Property developer O&Y. This mega civil engineering project comprised more than 30 major projects embracing 22 km of new running tunnels, four under-river crossings, 11 new stations and complex E&M installations.

The contracts were let based on the JLE Conditions of Contract - a hybrid of the ICE 5th edition and the international FIDIC form, modified by the Hong Kong MTRC and Singapore MRT. The civils contracts including the stations were let on the basis of remeasurement contracts with Interim Payment Schedules (IPS) based on defined milestones within four cost centres. In contrast the E&M contracts, which represented 30% of the total cost, were let on the basis of design and construct contracts based on conceptual designs and performance specifications with schedules of prices.

Construction work commenced in December 1993 with an intended completion date of June 1997, in the event the line was opened in December 1999. The project was delayed throughout its life cycle by four major events: an 18 month moratorium while private sector funding was secured; the collapse of the Heathrow Express tunnels using the NATM system which impacted on three of the most complex JLE contracts, failure of the Moving Block Signalling system and the decision to site the Millennium Dome at Greenwich.

The projects were tendered in a period of industry recession and the bids were relatively low ("bid low – claim high"); critically the working drawings at tender award were incomplete. The project was plague with changes to the programme, which caused delay and disruption, with extensions of time and acceleration resulting in substantial claims. Additionally there were considerable co-ordination problems at contract interfaces. In the event the IPS payment system, which had worked well in Hong Kong, became difficult to operate and discouraged collaborative working.

The project was opened in time to provide an underground transport link to the Millennium Dome and despite facing considerable space constraints the architects rose to the challenge to provide memorable station architecture, viz. Foster Associates' Canary Wharf Station.

The project cost nearly 70% more than the approved budget (£2.1 bn. to £3.5 bn.) and overran by 20 months (53 months to 73 months) (Mitchell, 2003).

4. CASE STUDY 2 - BAA's HEATHROW TERMINAL 5

The BAA Heathrow Terminal 5 is currently one of Europe's largest and most complex construction projects. The Secretary of State approved terminal 5 on 20 November 2001 after the longest public inquiry in British history (46 months) and when completed in March 2008 it will add 50% to the capacity of Heathrow and provide a spectacular gateway into London.

The £4.3bn project includes not only a vast new terminal and satellite building but nine new tunnels, two river diversions and a spur road connecting to the M25; it is a multi-disciplinary project embracing civil, mechanical, electrical systems, communications and technology contractors with a peak monthly spend over £80 million employing up to 8,000 workers on site. The construction of T5 consists of 16 main projects divided into 140 sub-projects and 1,500 "work packages" on a 260 ha site.

The project management approach on Terminal 5 was developed based on the principles specified in the *Constructing the Team* (Latham, 1994) and *Rethinking Construction* (Egan, 1998) but went further than any other major project. The history of the UK construction industry on large scale projects suggested that had BAA followed a traditional approach T5 would end up opening 2 years late, cost 40% over budget with 6 fatalities; this was not an option for BAA.

Significantly BAA expected a high degree of design evolution throughout the project in order to embrace new technological solutions and changes in security, space requirements or facilities functionality. On such a complex project early freezing of the design solution was not realistic.

BAA realised that they had to rethink the client's role and therefore decided to take the total risk of all contracts on the project. BAA introduced a system under which they actively managed the cause (the activities)

through the use of integrated teams who display the behaviours and values akin to partnering.

This strategy was implemented through the use of the T5 agreement under which the client takes on legal responsibility for the project's risk. In effect, BAA envisaged that all suppliers working on the project should operate as a virtual company. Executives were asked to lose their company allegiances and share their information and knowledge with colleagues in other professions. BAA's aim was to create one team, comprising BAA personnel and different partner businesses, working to a common set of objectives.

The T5 agreement is a unique legal contract in the construction industry – in essence it is a cost reimbursable form of contract in which suppliers' profits are ring-fenced and the client retains the risk. It focuses in non-adversarial style on the causes of risk and on risk management through integrated team approaches. The reimbursable form of contract means that there have been no claims for additional payments and no payment disputes so far on the project (NAO, 2005a).

This approach created an environment in which all team members are equal and problem solving and innovation are encouraged in order to drive out all unnecessary costs, including claims and litigation, and drive up productivity levels (Douglas, 2005).

BAA uses cost information from other projects, validated independently, to set cost targets. If the out-turn cost is lower than the target, the savings are shared with the relevant partners. This incentivises the teams to work together and innovate. It is the only way to improve profitability; all other costs, including the profit margin, are on a transparent open-book basis (NAO, 2005b). BAA takes precautions against risk of the target being too high through a detailed "bottom up" analysis by independent consultants.

The T5 Agreement creates a considerable incentive for performance. If the work is done on time, a third goes to the contractor, a third goes back to BAA and a third goes into the project-wide pot that will only be paid at the end (Douglas, 2005). Suppliers also benefit from ring-fenced profit and an incentive scheme that rewards both early problem solving and exceptional performance.

The final strand to the T5 Agreement is the insurance policy. BAA has paid a single premium for the multi-billion project for the benefit of all suppliers, providing one insurance plan for the main risk. The project-wide policy covers construction all risk and professional Indemnity.

The T5 agreement allows the project to adopt a more radical approach to the management of risk including early risk mitigation. Key messages include: "working on T5 means everyone anticipating, managing and reducing the risks associated with what we're doing".

5. SUMMARY OF FINDINGS BASED ON MORRIS & HOUGH'S HYPOTHESES

Hypotheses	**Jubilee Line Extension**	**Heathrow T5**
1. Evaluation of the project viability should be objective and realistic from the participants view.	DoT study (1988) showed that the project was viable in cost-benefit terms.	BAA identified its requirement for more space in world class facility.
2. Unclear objectives mean an unsatisfactory project.	Clear broad objectives to provide a modern mass transit railway to Docklands and beyond; however design modifications throughout.	Clear objectives; early change made to roof shape and column configuration.
3. Changes in the specification can lead to management or performance problems.	Lack of fit on day one on construction between tender drawings and working drawings.	Changes controlled and managed.
4. Technical uncertainty/innovation increases chances of difficulties.	Suspension of NATM (sprayed concrete tunnel lining) following Heathrow tunnel collapse.	Template for future U.K. construction; off-site trials for roof erection; use of common 3D computer model.

Hypotheses	**JLE**	**Heathrow T5**
5. Interface co-ordination can create difficulties.	Significant co-ordination problems civil/E&M led to substantial re-work.	Use of 3D computer generated prototype of the whole project – eliminated errors and omissions before work starts on site.
6. Design management difficulties can cause problems.	Large number of civil & architectural designers used; civil & architecture designers looking to freeze design, E&M elements still at conceptual definition stage.	RRP had to obtain design approval from 43 stakeholders; RRP works closely with other design practices and specialist contractors.
7. Amount of finance required may cause difficulties.	Increase in finance from initial £1.2bn to £3.5 bn.; £1.3 bn. diverted from LUL's investment programme.	Fixed budget £4.3bn.
8. Mixed public/private funding can create difficulties.	Canary Wharf developer O&Y caused 18 months delay.	N/A Private funding.
9. Financial risk/difficulty of forecasting final costs, etc indicative of problems.	Generally low civils tenders led to high level of claims; tenders kept alive during 18 months moratorium.	BAA holds all the risk on time, cost and quality.
10. Geophysical challenges increase chance of overruns.	£6m. site investigation minimised problems.	Intensive design and planning throughout on existing contaminated site.

Hypotheses	**JLE**	**Heathrow T5**
11. Political, social, community and other "external factors" affect success chances.	Huge political and environmental pressure on project; completion of JLE. linked to Millennium Dome.	Longest public inquiry in UK; close liaison with local community; terrorist effect uncertain.
12. Schedule phasing chosen so as to minimise risks of political, financial, etc., changes.	Four major interventions: 18 month moratorium; Heathrow NATM failure; failure to implement MBS (signalling system); transport link to Millennium Dome.	Controlled planning throughout with five overlapping key stages.
13. Urgent schedules can create problems.	Hugely ambitious initial schedule; 53 months planned became 73 months actual.	Controlled high level expenditure with realistic fixed completion date.
14. Inadequate planning increases the likelihood of failure.	Rigorous programming throughout; little float; parallel critical paths on many major projects.	Single virtual project model; smart logistics; 2 logistic centres; off-site manufacture.
15. Legal agreements and contract strategy and conditions influence structure and roles.	30 major civil contracts based on BofQ with payment liked to milestones: E&M based on D&C with performance spec; contracts perceived as adversarial.	Bespoke T5 Agreement manages cause not effect – based on commitment, trust and teamwork; applies to all key suppliers; long-term relationships.
16. Organization structure should fit project needs and be dynamic.	Structure of project team subject to considerable metamorphosis.	Matrix management organisation; ten core processes; sixteen integrated design and construction teams.

Hypotheses	**JLE**	**Heathrow T5**
17. Absence of effective project controls increases chances of overruns and poor performance.	Milestone system became ineffective due to substantial changes and revised programmes; many changes approved retrospectively.	Effective use of team targets; 70 key milestones; high level of transparency; use of ARTEMIS PM software (Schedule and Cost Performance Indices generated at all levels and for each package).
18. Leadership has a strong influence on chances of success.	Three different client Project Managers (Russell Black/Hugh Docherty/Bechtel) all provided significant leadership.	Professional expert client; BAA chose industry experts to head integrated teams and key roles (forty total).
19. Team work is important to success.	Teams not created early; team charters only implemented late in project; creation of “family” environment.	Use of integrated teams; contractors work in partnerships; collaboration centres.
20. Labour relations can disrupt project implementation.	Generally good on civils: later industrial dispute with electricians caused some delay.	T5 pay agreement; unprecedented standards for pay, welfare, safety and training (80 modern apprenticeships per year); local labour strategy; occupational health centre.
21. Poor communications reduce the chances of success.	Monthly progress review meetings; regular meetings with the Government.	Regular meetings with 42 stakeholders.

Hypotheses	JLE	Heathrow T5
22. Error incompetence, incapacity or incapability can jeopardize the project. success	Failure to deliver state of the art signalling system (untried technology).	High performance levels and benchmarking standards.

6. SUGGESTED NEW HYPOTHESES

Hypotheses	JLE	Heathrow Terminal 5
23. Requirement for identification of the roles and responsibilities of the parties.	Contracts based on ICE/FIDIC – some problems with role of the Engineer (impartiality v representing client).	Clear identification of roles within an integrated team.
24. Correct use of PM tools and techniques: RM/VM/WLC/KPIs etc should improve efficiency of process.	Traditional approach on civils contracts; little contractor involvement in design or constructability though contractors could offer alternative designs; risk analysis used throughout project.	Use of Artemis PM software - produces Schedule Performance Index and Cost Performance Index for all levels for each package; significant use of VE particularly on roof/columns design/erection; use of “Project Flow” web-based based on Pull logistics (J.I.T. delivery); productivity raised from typical 55-60% to 80-85%.

Hypotheses	**JLE**	**Heathrow T5**
25. Project culture team-based partnership approach improves likelihood of project success.	Projects managed through Project Director/Project Managers and large project team; became inflexible and adversarial.	BAA created positive culture and commercial environment through use of T5 Agreement; BAA provided one insurance plan for construction all risk and professional indemnity.
26. Claims represent inefficiency; adjudication represents failure.	Two years after completion significant commercial claims still to be settled; lawyers involved in claims evaluation and settlement; legal action taken against some contractors.	No claims or litigation to date.

A review of the fundamental project management issues cost/time/quality shows that the JLE failed on both cost and time whilst achieving a resounding success with quality. In contrast the enlightened approach taken by BAA on Heathrow T5 indicates that the project will be completed within budget, opened on time with a world-class quality.

7. CONCLUSIONS

The hypotheses identified in the Morris and Hough book *Anatomy of Major Projects* has proved a sound framework for comparing London Underground's Jubilee Line Extension with BAA's Heathrow Terminal 5.

Four new hypotheses have been identified; firstly, requirement for clear identification of the roles and responsibilities of the parties; secondly, correct use of PM tools and techniques (RM/VM/WLC/KPIs etc) should improve the efficiency of the process; thirdly, the issue of project culture – a team based partnership approach improves the likelihood of project success and lastly, claims represent inefficiency, adjudication/litigation represent failure.

London Underground's Jubilee Line Extension was tendered in a period of recession based on a modified traditional civil engineering form of contract, which had worked well in Hong Kong and Singapore. However the design was not complete at tender and following four major delaying events the project quickly became adversarial. It was completed late and massively over budget.

In contrast, BAA on their Heathrow Terminal 5 project has taken an enlightened approach creating a virtual company in which all team members are equal. Under this approach BAA have taken all the risk and harnessed the "intellectual horsepower" through the use of a partnering approach with integrated teams. Innovation and problem solving is encouraged in order to drive out unnecessary cost and improve productivity levels. Heathrow Terminal 5 has proved to a watershed in embracing the principles of lean construction allowing the implementation of industry best practices and the achievement of world-class performance.

This paper has contributed to the general subject of development by critically examining the management of two mega construction projects in the U.K. and identifying a significant improved procurement strategy for experienced and knowledgeable clients like BAA.

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