MEGAPROJECTS – 50 YEARS, WHAT HAVE WE LEARNED?

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INTRODUCTION

Successful management of megaprojects, meaning delivery within budget, on time and according to expectations, is a fundamental requirement. Many projects have been successful, some have not. This paper reviews megaprojects1, drawn from the author's projects over the last 50 years, with "lessons-learned" and a summary of recommendations that, if implemented, would improve megaproject management and delivery.

Characteristics of these projects are summarized – including outcomes related to key factors such as politics, management, organizational structure, contracting methods, cost estimates, risk and other elements. The projects include the Washington D.C. Metro, Boston Southwest Corridor, LA Metro, Toronto Rapid Transit Expansion Program, BART San Francisco, MARTA Atlanta, London Underground and the Washington State Highway megaprojects – including the SR520 Floating Bridge and the Alaskan Way tunnel.

Other projects that illustrate successful, innovative management and contracting methods include the Madrid Metro (low-cost delivery), the Sydney Northside Storage tunnel (outturn cost, alliancing) and the Lake Mead tunnel (working in partnership, risk management).

KEY ISSUES

A characteristic of megaprojects is that their complexity increases exponentially with size (Reilly 2010, Galloway et al. 2012). These projects are very visible politically, have many stakeholders who must be satisfied and generally span many years and political election cycles. To be successful they must meet expectations, function efficiently, and be delivered under, at or close to budget and schedule.

There is a widely-based perception that large, complex projects are always delivered late, over budget and with problems. Specific examples include projects such as Tren Urbano in Puerto Rico – $1.28 billion over initial budget (+133%), the Silver Line Transitway Project in Boston – $286 million over budget (+90%), the London Jubilee Line Transit Project – 2 years late and £1.4 billion (+67%) over budget, the Channel Tunnel Rail Project – £3.7 billion (+80%) over budget, Denmark's Great Belt Link rail and road link (54% over budget), the 2003 Woodrow Wilson bridge tender in Virginia (72% over estimate) and Boston's Central Artery Project – several billion (and perhaps 100%) over what would have been a realistic initial budget and years late (Reilly 2001c, 2004a; Salvucci 2003).

The cost percentage numbers in the above paragraph are the final cost of the project divided by the budget that was communicated at time of decision to proceed. This is important because it is the "number" that the public remembers and that the media reports. However, it may not include new scope, legitimate changes and other factors. The "number" is often affected by poor initial cost estimates, inadequate estimation of risk, poor management, escalation, the effects of external events and significant political changes.

However, many infrastructure projects, perhaps the majority, have been completed close to or under budget and on time or close to schedule (Reilly 2013b). The initial phase of the Madrid Metro was delivered on schedule at a cost of $52 million/km (IRJ 2003) – compared to $155 million/km for Paris and $375 million/km for London Jubilee (Anderson 2000). Factors for the Madrid project included a lean management structure and a technically knowledgeable and involved owner.

Examples from Boston are given in Table 1. How were these projects able to perform well while other projects under similar circumstances (even in the same city, e.g., the Central Artery project) incurred large cost and schedule over-runs? Some of the answers are implicit in the examples given in this paper.

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[1] Megaprojects are defined as projects costing over $1 billion. Most of the megaprojects herein cost many billions, and others would if costs were adjusted for inflation. For this paper the generic word "projects" will be used.

Table 1 – Boston megaprojects, outturn cost results ($US Millions)

Project	Target Cost	Actual Cost	Schedule	Comments
Southwest Metro	$750	$743 (99%)	+ 6 months	Major political issues
Logan Airport	$4,000	"Within a few %"	Close to schedule	Public-private pressures
Red Line North Metro	$625	$570 (91%)	Close to schedule	Competent management
Boston Harbor	$3,650	$3,800 (104%)	On schedule	Court mandated schedule

Factors relating to successful project management and delivery

An international survey of major infrastructure projects (Reilly & Thompson 2000g) found that specific, relevant cost information was usually unobtainable. Little objective history could be found, including findings that would support recommendations for improvement. Because of the difficulty in obtaining hard data, firm conclusions could not be reliably drawn2, but the following "meta-findings" were reported by the owners:

- There were significant cost and schedule overruns (suggestive of poor management) in at least 30%, and possibly more than 50%, of the projects.
- It appears that the factors that most directly influenced success or failure were:
  - relevant expertise and policies of the owner and
  - Procurement (contracting and delivery) procedures.
- The professional teams engaged in projects were reported, by the owners, to be competent – leading to the conclusion that problems in poorly performing projects may lie primarily with the ability of the owner to lead and manage the complex project delivery process.
- Risk mitigation was not well-understood or applied, even in elemental ways. This was considered to be a promising area for development, in particular as it related to cost over-runs and unforeseen events.
- A conclusion was that reported cost data – especially for "good" results – should be treated very cautiously. Complete, relevant data are very hard to get and almost impossible to validate.

Research – improvements in megaproject management

Accordingly, research into improvements for megaproject management was initiated by the author in the mid-1990s, leading to a series of papers on this and related topics (www.JohnReilly.us). Following the 1996 WTC/UCA Conference in Washington D.C., this research was focused on complex project management, and included review of articles by authors in related fields (Drucker 1973, Katzenbach et al. 1993, Egan 1998).

Areas addressed included: advanced technical methods; strategies; key person vision and leadership; organization for delivery; re-engineering processes; contracting methods; partnering; owner, designer and constructor capabilities; risk characterization and management; cost estimating (risk-based approach); the use of strategic and technical advisory panels and "alignment" of the project team to key goals and objectives. Basic research was initiated (Reilly & Thompson 2000g), papers and book chapters were written and presented at U.S. and international conferences (Reilly 2014; 2013a,b,c; 2010; 2009; 2008; 2002b, 2000b).

[2] Flyvbjerg subsequently published outturn costs data in 2002 and commented on the costs of megaprojects (Flyvbjerg et al. 2003). The same caution, noted above, should be applied to the cost data in these studies.

CASE STUDIES, PROJECTS, GENERAL LESSONS LEARNED

This paper is intended as a historical overview for the benefit and guidance of owners who may be planning the implementation of a complex megaproject. Consequently, the following project examples are presented in short summary form, with associated “lessons learned” related to, or arising from, each project. The “lessons learned” are of a general nature since specific details would be extensive and therefore too long for this overview paper – details for the more recent projects are planned for subsequent papers. At the end of this paper, recommendations are given, listed by key topic area and specific, more detailed, recommendations can be found in the references cited.

WMATA, Washington D.C. Metro, 1968-72

This monumental project – 118 miles of heavy rail transit (50.5 miles underground) – advanced understanding of successful management, design and construction of underground and transit projects in the U.S.

The author, as project engineer, was responsible for several of the core city projects, including earth and rock tunnels, cut-and-cover stations and Dupont Circle rock station, and was Secretary to the Board of Consultants (BOC), which included Ralph Peck, Don Deere, Al Matthews, Art Chase, Phil Rutledge, Jim Gould and Bill Mueser. Much was learned from these early leaders of the U.S. underground construction industry. They addressed underground construction and tunnel methods, contractual issues and underpinning of structures and introduced methods such as prestressed slurry walls for excavation support and protection of buildings.

Tunnel drives under and adjacent to major buildings were successfully completed. Early TBM shields were improved by use of earth-pressure machines. Rock tunnel support was improved, and the use of NATM was introduced. Al Matthews introduced dispute review boards and escrow bid documents. Partnering was implemented. Leadership and vision, from WMATA’s General Managers, the General Engineering Consultant (GEC) and the BOC, was one key for successful delivery.

Lessons learned:

- Importance of vision, dedication and leadership by WMATA management, GEC + BOC members.
- Alignment of responsibilities for WMATA, GEC, BOC and with design and construction operations.
- Advancing design and construction technologies – for vaulted modular stations, tunnel drives, Dupont Circle Station’s innovative rock support, waterproofing methods, improved underpinning methods.
- The importance of good architecture and urban design, contributing to citizen and political support.
- Early public communications and outreach, public process and adoption of full handicapped access.

MBTA Boston Southwest Corridor, 1978-85

An urban development, high-speed rail, commuter rail and rapid transit project – which diverted highway trust funds for urban development, rail and rapid transit – was completed under budget and close to schedule, even after serious political roadblocks were created. A major disruption to the project’s management occurred after a new governor replaced almost all of the project’s key management with personnel who were not knowledgeable about, or focused on, key objectives and community commitments. The author was one of the few continuous managers during this period.

Lessons learned:

- It is essential to have an understanding of, and strategy for, political transitions and related issues.
- The community can be a strong resource for keeping design commitments and “aligning” politicians.
- Management to budget requires discipline to cost with fidelity to community commitments.
- Market forces are a key determinant of cost and outcomes but are difficult to predict.

LACMTA Los Angeles Metro, 1991-1998

The Los Angeles Metro system advanced complex technical capabilities. Key projects included the Metro Red Line Phases 1-3, Green and Pasadena Light Rail projects. The author's tasks included: project management oversight (PMO) using the FTA process, including "pro-active PMO" (Reilly 1995); program management using integrated offices; team alignment; evaluation of station ventilation effectiveness; recommendations for cost-to-complete; contractual audit findings/recommendations and risk workshops for operational readiness.

Technical improvements included mandatory use of earth-pressure machines after settlement problems in Phase 2 (Eisenstein et al. 1995), value engineering for modular stations, clarifying owner's responsibilities in the selection of TBMs (Reilly 1997) and establishing the technical feasibility of mined stations in earth (subsequently adopted in Washington D.C., Fort Totten Station).

Lessons learned:

- The benefits of team alignment for agency and project personnel to key goals and objectives, proactively dealing with key issues, enhancing internal and external communications (Reilly 2000a).
- Some technical challenges must be addressed using vetted state-of-the-art systems.
- Conventional wisdom may not lead to the best solution for advanced underground structures.
- Early and proactive communication of the agency's plans, goals and objectives, with buy-in from the public and political stakeholders, is necessary. Media engagement is essential.
- Financial interests and status-quo factors can inhibit the use of beneficial technologies and systems.

Toronto – TTC Rapid Transit Expansion Program, 1993-1995

Seven major transit projects in Toronto's core were initiated in the early 1990s to improve urban mobility. Advanced management processes were used, including fully integrated and aligned TTC-Consultant organizational structures and offices. A secondary goal of the program was to build TTC capability in the management and delivery of new infrastructure projects. Areas addressed included strategic management systems, configuration management, value engineering, agency-consultant responsibilities and implementation of the team-alignment/partnering process (Reilly 2007a), building on the Los Angeles example.

Lessons learned:

- Full integration of the owner and consultant teams, aligned with construction partnering, improves communications and adds value to the project delivery process.

BART San Francisco Vehicle Re-Manufacture, 1995-1997

The work included partnering and team-alignment implementation for the re-manufacture of the first fleet of BART transit vehicles with critical in-service requirements. This required adaptation of partnering to a manufacturing environment with an explicit focus on, and definition of, key goals and objectives, operating principles and shared values to improve communications and issue resolution.

Lessons learned:

- Partnering/team alignment was beneficial in focusing the team on key goals and objectives, implementation of more efficient processes, anticipation of critical issues, fostering innovation, adding value and resolving conflicts.

MARTA Atlanta Rapid Transit Re-Organization, 2001-2003

This project included strategic implementation, organizational re-alignment and clarification of roles and responsibilities as the agency design and construction directorate was consolidated with the transit operations directorate to increase organizational efficiencies. The re-organization was implemented using team-alignment principles to clarify roles, responsibilities, key goals and objectives and those key processes necessary to deliver, and maintain, rapid transit design, construction and operations.

Lessons learned:

- A complex re-organization and re-alignment of roles, responsibilities, communications and working relationships in a public agency is necessary for integration of staff from multiple departments. The process requires full buy-in from the agency executive.

London Underground (LU) Signal System Replacement, 2003-2004

A complex project to replace half of London Underground's train-control signal system under traffic was complicated by the structure of an overall PPP organization, previous problems with signals on the Jubilee Line project and the resistance of LU to transfer responsibilities through use of a PPP model. As a result, it was essential to integrate and align the delivery team (four major companies) and then integrate and align that team with LU. A series of "alignment builds" was used, from lower-tier contractors to the PPP prime and LU.

Implementation went better than expected, albeit with resistance to partnering from some personnel. Following the initial implementation, the first workshop led to critical issues being identified but also highlighted a lack of acceptance of responsibility for their resolution by some key personnel. Because of this, the partnering was suspended by the PPP. Subsequently the PPP failed to meet key performance requirements and their contract was terminated by LU, who then assumed responsibility for completion.

Lessons learned:

- A well-tested team-alignment/partnering process can be successful if implemented using key principles but only if top executives fully buy-in to the process and commit to resolution of key issues.

Jumierah Gardens, New City Dubai, 2008

Team-alignment was implemented for this $95 billion new city with a complex mix of local and international staff. The process was developed quickly and implemented successfully with an innovative approach in a mixed cultural environment. The project was halted due to the 2008 international financial difficulties.

Lesson learned:

- It is possible to quickly implement a complex team-alignment process in a mixed cultural environment.

WSDOT Washington State Highway Megaprojects, 2001-2013

In 2001 the Washington State Department of Transportation (WSDOT) was planning several megaprojects, including the $US 3.5 billion Columbia River Crossing between Washington and Oregon, the $US 1.5 billion I-405 Highway program east of Seattle, the $US 4.65 billion State Route (SR) 520 Floating Bridge project across Lake Washington and the $US 3.1 billion Alaskan Way Viaduct replacement tunnel project in Seattle[3].

The Secretary of Transportation realized that "normal" agency procedures would be inadequate and created a special office to manage these megaprojects. The author assisted with procedures and new processes such as the CEVP® probabilistic risk-based cost estimating and budgeting process (Reilly et al. 2004a, 2011a); programmatic team alignment; evaluation of alternative contracting and delivery methods, including design-build, CMGC and alliancing (Reilly 2007b, 2012, Arrigoni 2009); use of strategic/technical advisory panels; clarity of environmental documentation and communication/outreach to public, legislators and media.

Lessons learned:

- Megaprojects are different and require focused management, project-specific procedures and executive commitment.
- Procedures for "normal" projects may be inadequate for megaprojects (Galloway et al. 2012).
- Linkage and coordination between megaproject staff and normal agency staff is difficult – both cultures need to be respectful of one another and must address their specific goals and objectives.

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[3] The Washington State projects will be treated in detail in a subsequent paper.

- "We've always done it that way" is not a valid reason to use existing procedures – often, new methods need to be developed and vetted.
- Commitment to, and focus on, approved budgets is critical, requiring that integrated processes that support management to budget (e.g., VE, CEVP®) be implemented and followed.
- Risk management is an essential day-to-day process for both design and construction phases.

WSDOT Alaskan Way Viaduct Replacement, 2001-2012

Alternatives for replacement of a 50-year-old elevated highway structure, damaged in an earthquake, were developed from 2001 through 2008. Nearly 80 alternatives were debated, and it was not until early 2009 that a deep-bore tunnel project was adopted by the governor, mayor and King County executive based on the recommendation of a citizen advisory board and an international tunnel consultant (one large tunnel was selected for cost reasons – previously two parallel tunnels had been considered). Agency staff were augmented by senior WSDOT managers with megaproject delivery experience and key consultant firms with extensive, international tunnel experience were engaged.

A great deal of work went into preparing for the very large, complex design-build tunnel contract and the north and south approach projects. CEVP® cost estimating was integrated with value engineering (VE) to make significant changes to project scope, plan alignment and methods in order to maintain the projected cost at or less than the legislatively approved 60% probability level of $1.86 billion. Key factors evaluated by WSDOT included the contracting method, alternative technical concepts, best-value determination, risk management, contractual incentives, risk sharing, allowances and contingencies – particularly related to the TBM drive (Neilsen et al. 2011). Confidential meetings with short-listed bidders helped shape the contract documents.

The north and south approach contracts were implemented successfully, and the complex south contract was completed ahead of schedule and under budget. The tunnel contract included several value-added changes, proposed by the contractor, Seattle Tunnel Partners (STP), which included moving the south portal further south to allow a longer TBM start-up/learning curve and the inclusion of safe havens to verify the operation of the TBM before it crossed under the elevated viaduct. However, during the initial drive, major problems with the TBM were found and so the TBM was halted in December 2013 after travelling only 1000 feet. Major modifications were subsequently made to the TBM including major stiffening and reinforcement, a new bearing and seals, plus cutterhead and mixing arm changes. This has delayed the project by some two years and has very substantially increased costs for the contractor, which may lead to litigation.

Lessons learned:

- It was necessary for WSDOT to implement specific management and technical processes as best practices to manage delivery of a major complex tunneling project within the approved budget.
- Management to budget in the preliminary design phase required a constant focus on cost, use of probabilistic cost estimating (CEVP®), aggressive value engineering and cost-reduction efforts.
- It was essential to perform continuous risk management in design – for input to the probabilistic cost estimating, for risk mitigation and for risk input to the bidders (an indicator of construction risks).
- Input from bidders was necessary to shape contract provisions, contingencies and allowances and to maintain a competitive bidding environment.
- Alternative Technical Concepts were beneficial in reducing cost, increasing the safety of the initial drive and to allow time to identify potential problems with the TBM.
- Use of a Strategic Technical Advisory Team was beneficial in forming design and contract documents.
- Political funding constraints, the desired tunnel configuration and demanding schedule requirements drove decisions that limited flexibility and reduced construction contingency.
- The importance of considering low-probability/high-consequence risks has been demonstrated. How such risks should be managed and addressed is not clear – for this and other underground projects.

WSDOT SR520 Floating Bridge, Seattle, 2006-2013

The SR520 floating bridge will replace an existing floating bridge that is at the end of its service life. It will be the longest floating bridge in the world – initially with six lanes of traffic – with provision for two additional lanes or adding light-rail. WSDOT has expertise in the design and construction of floating bridges, having completed the design and construction of several in the state. Megaproject-specific procedures (described above) were implemented by WSDOT for this project including the cost estimate validation process (CEVP®), value engineering, use of expert and strategic advisory panels and an extensive environmental documentation and community/stakeholder outreach program. Team alignment processes, at the SR520 executive and unit levels, were continuous from 2007-2013 (Reilly 2007a). Risk management was continuous during design, linked to the CEVP® process, and a comprehensive risk management specification was included in the construction documents. During construction, WSDOT continued their risk management but with limited risk input from the contractor.

In 2010 the program was running at budget and it was possible to increase the available balance by $189m following receipt of lower construction bids in 2009 for the pontoon construction4, related to the 2008 recession. This, plus flexibility provided by 2010 legislation allowing WSDOT to use the remaining $400 million in available toll-backed bond proceeds for any project within the SR 520 Program provided a path, in May 2011, to proceed with the West Approach, Floating Bridge and Landings and the Eastside Approach.

However, in early 2012, unanticipated cracking was found in one of the bridge pontoons, caused by unbalanced prestressing forces. The author chaired an expert panel to report on the cause of, and remediation for, the cracking. Additional prestressing stress cracks in the end walls, top and base slabs near the end of each pontoon were found. The pontoons require a 75-year life, so these cracks had to be remediated by the addition of transverse prestressing and other measures including epoxy injection and carbon-fiber waterproofing. Pontoons in the early production cycles were retrofitted, and fixes for subsequent cycles were designed in. This issue caused a delay to the project and over $200 million extra cost. Even so, the project will be completed to the previously approved budget. The project (except for the future west-side connection to I-5 which is now funded) will be completed and opened to traffic in April 2016.

Lessons learned:

- Team alignment with management and project units, supported by agency executives, is a key process to clarify key goals and objectives (linked to strategic agency goals), roles and responsibilities; identify key issues; enhance communications and improve working relationships.
- The probabilistic cost estimate validation process (CEVP®) reasonably projected final outturn costs.
- Best-practices risk management was used in design, but was not integrated well with construction.
- Agency management did not appreciate the need to fully link the needs of the SR520 program office with the operations of the internal WSDOT bridge design unit. Divergent internal agency vs. SR520 program goals led to a form of contract which included design-bid-build within a design-build contract, thus responsibility for the concrete cracking fell to the agency instead of the design-build contractor.
- Recommendations specific to megaproject needs can be difficult to communicate within traditional agency organizations. Agency executives need to be aware of this, intervene and resolve problems.
- Use of expert and strategic advisory panels benefited executive decisions, the transition from design to construction, timely resolution of technical issues and development of remedial measures.
- Continuity of executive and program management is essential to meet project goals and objectives.

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[4] A lower pontoon bid increased the available balance by $189 million (Budget $1,988m, Estimate $1,799m)

WSDOT-ODOT Columbia River Crossing, 2009

The Columbia River Bridge is a critical north-south link for U.S. West Coast transportation. It was built in 1919, expanded in 1958 and is deficient in standards, capacity and earthquake resistance. A replacement was planned as a safer bridge, with greater capacity and including light rail. Management of the planned replacement involved both Washington and Oregon, the cities of Portland OR and Vancouver WA, WSDOT and ODOT and Tri-Met light rail. However, agreement on management, organization, funding, policies, and inclusion of light-rail was contentious. Accordingly, both state Secretaries of Transportation asked for assistance with organization and team alignment of key staff. This was done in 2009 and resulted in key issues being highlighted but not fully resolved – in part because of significant political differences between the cities and states. Subsequently the project was cancelled because one agency was unable to fund their cost.

Lessons learned:

- Team alignment can accelerate identification of key issues to be resolved.
- Team alignment is an essential megaproject management process, but, for complicated megaprojects with multiple political entities, success depends on the support and understanding of top executives and politicians and their ability to resolve complex political issues.

SNWA Lake Mead Tunnel, Intake #3, 2008-2015

This project created a new, 300' deep water intake in Lake Mead, Nevada, to ensure a reliable water supply for Las Vegas. It involves a 600' deep shaft, a 3-mile-long tunnel, and used a 23.6' diameter closed/open mode TBM with 14" thick bolted and gasketed precast concrete segments. The tunnel drive was completed in December 2014 after successfully mining up to 16 bar pressure with long drives and difficult rock conditions (Nickerson et al. 2015). It mated successfully with the sunken intake structure under 9.3 bar pressure. A major contractual change was resolved successfully after the starter tunnel collapsed, however the schedule was extensively affected.

Early in the project the Southern Nevada Water Authority and contractor S.A. Healy Co./Salini-Impregilo S.p.A. agreed that success would require "working in partnership." Accordingly, they established such a working relationship (Jensen et al. 2016) and engaged assistance by the author, as a risk management oversight consultant. Risk management was implemented in accordance with contract requirements, best practice and the 2006 ITIG "Code of Practice for Risk Management." Open, cooperative risk workshops were held regularly, with the owner, contractor and consultants, using an open risk register, updated often with input from the individual "risk-owners." Alignment and clarity of responsibilities was verified continuously and risk oversight and compliance reports were written annually. The project used best practices for risk management working in an open and collaborative environment (Grayson et al. 2015).

Lessons learned:

- Owner and contractor, working in partnership, can efficiently resolve difficult construction and contractual issues, address risks proactively and recover costs successfully.
- Use of best practices for risk, including compliance with the ITIG Code of Practice, led to better visibility of potential risks, improved risk mitigation and consideration of linked/dependent risk scenarios.
- Best practices in risk management were improved during the project by the partnership approach.

OTHER PROJECTS WITH DEMONSTRATED RESULTS

Madrid Metro, 1999-2003

From 1999-2003 the Madrid Metro expanded its network at costs substantially below levels of other Metros – $52 million/km (IRJ 2003) vs. $155 million for Paris and $375 million for London Jubilee (Anderson 2000). They built 36 miles of 31' diameter tunnels, 39 stations and 8 interchange stations plus rolling stock (IRJ 2003).

Lessons learned/management structure – articulated by Project Director Manuel Melis:

- Managed by three chief engineers with six assistant engineers.
- Owner's management technically knowledgeable about details such as TBM machine specifications.
- Need for early, pro-active work to anticipate problems and resolve potential disputes – including change orders for contractors – before problems "became unmanageable."
- No large firm hired as general project/engineering manager.
- Selection of contractors "undertaken with greatest care."
- Tunnel safety the most important overall factor.
- Soil mechanics most important technical factor with no financial restrictions on soil investigations.
- No lump sum contracts – fixed price with bill of quantities, additional work resolved quickly.

Sydney Water – Alliancing, Northside Storage Project, 1998-2000

Alliancing (Henderson 1999, Ross 2003, Reilly 2004b) requires that the owner, designers, contractors and suppliers work together as a single team, with contractually defined risk-reward (pain-gain) provisions to meet, or better, a defined target cost. The owner and the service providers (engineers, contractors) collectively assume responsibility for delivering the project against pre-agreed target and performance outcomes. The first Alliance projects were the North Sea British Petroleum Hyde and Andrew Projects – oil and gas platforms constructed in the early 1990s with the following outturn results.

Off-shore Project	**Target Cost £M**	**Actual Cost £M**	**Cost Saving £M**	**Percent Saved**
Britinnia	1,500	1,200	300	20%
BE ETAP	926	742	85	9%
BP Andrew	373	287.5	85.5	23%
Interconnector	316.5	240	76.5	24%

Table 2 – Cost savings from early allianced North Sea projects

Results have been impressive for allianced projects in the U.K. (e.g., CTRL project), New Zealand (Spies et al. 2015) and Australia (Henderson 1999). The Sydney Northside Storage Project, a complex tunneling project under Sydney harbour, which had to be completed before the Sydney Olympics, was judged only possible if the alliance delivery process was used. After completion, a retrospective value-for-money report (Evans & Peck 2004) concluded that the cost results were: Target outturn cost – A$451 million; Final cost – A$466 million (+3.3%); Normal design-build cost estimate – A$483-$507 million (20% & 80% ranges); and Estimated design-build cost at completion – A$567-A$573 million (20% & 80% ranges). That is, an actual cost of A$466 million for the alliance and a probable cost (50% range) of A$571 million if using Design & Construct – a difference of A$105 million saved by alliancing (22%). This analysis is retrospective – however, even if the assumptions are overly optimistic for alliancing and pessimistic for design-build, the fundamental conclusion is that the alliance delivered significant value in these circumstances.

RECOMMENDATIONS

The "lessons learned" associated with the projects described above are generalized considerations, related to the specific issues which arose on those projects. Following are more specific recommendations, grouped by key area, as an initial listing and guide for owners responsible for implementation of a complex megaproject. For specifics regarding processes and detailed recommendations, see references cited at the end of this paper.

A. Key areas, questions that should be asked

1. Product – what is to be delivered, what are the key goals, what are the measures, how do we know?
2. Processes – definition of appropriate processes, procedures, methods and systems.
3. Resources – funding, key personnel, communications, community and political support.
4. Personnel – key personnel with necessary capabilities, experience and attitudes.
5. Leadership and teamwork are essential for success, focused on key goals and issue resolution.

B. Specific elements and processes

Leadership: Managers administer a "normal" process but leaders seek a better way – they create a new paradigm for success and added value. Project leaders should create teams that are inclusive, fair and technically capable, with clear vision and purpose and that operate with high ethical standards (Katzenbach et al. 1993). These attributes are central to partnering and team-alignment principles (Wageman et al. 2008).

Management & organization: The structure of the organization should be related directly to the products and use processes which can most efficiently deliver the results under the specific circumstances of the agency and commitments which have been made to the public and legislative bodies. In practice this means a more "flat" organization, with clarity of procedures and responsibilities, delegated authority and good communications.

Team alignment: This process, using partnering principles, identifies key goals and objectives of the agency and project for participants consistent with overall strategic plans. It aligns goals, performance measures, roles and responsibilities, communications and working relationships for project personnel, management and executives.

Definition and adoption of efficient processes: For the majority of complex megaprojects, specific and new processes will need to be developed or adapted from existing protocols. "Business as usual" will be inadequate (see Hatem et al. 2010, Galloway et al. 2012).

Discipline to process: Communication of procedures and implementation requirements needs to be clear, processes must be understood, respected and implemented. Their implementation needs to be supported by the executive and changes, or improvements, need to be introduced carefully. Also relates to team alignment.

Contracting and delivery: Much is written on contracting and delivery methods, which are key processes to manage to cost and schedule (Reilly 2013c, 2012). Processes for the selection of a contracting method are available from several sources (e.g., TCRP 2009, Procedure 131). Use of innovative, more collaborative contracting methods, such as alliancing, have the potential to deliver better value and lower outturn cost for owners of complex projects, but their implementation must consider legislation and cultures (Reilly 2009).

Cost estimating: Outturn cost is the value that the public tracks related to successful delivery – therefore a viable cost estimate is essential, as are effective processes to manage to budget. An example of such a process is WSDOT's Cost Estimate Validation Process (CEVP®) developed by the author with WSDOT in 2002 (Reilly 2004a), which combines cost estimate validation with probabilistic risk and opportunity costs.

Risk and opportunity: If risk is not identified and managed, it is impossible to deliver to budget or schedule. Risk processes have been well documented (ITA 2004, Reilly 2008, ITIG 2012, Sander 2012, Moergeli et al. 2015, RIAAT 2014, Grasso et al. 2016) and their implementation is not unduly complicated. Risk processes need to be a key priority for management, enforced in both design and construction. Risk management processes and their implementation should be considered a higher priority than "normal" management processes.

REFERENCES

Anderson, J. 2000 “Costs of Metro projects” presented by Reilly at the AUA regional conference Seattle.

Arrigoni, J 2009 “Contract and Construction Aspects“ Annex, in”Mechanized tunnelling in urban areas: design methodology and construction control”, Gugliemetti, V, Grasso, P, Mahtab, A. & Shulin, X, Taylor & Francis

Drucker 1973 “Management – Tasks, Responsibilities, Practices”, Harper Row, New York

Egan, J 1998, ‘Rethinking Construction’, Report of the Construction Task Force to the Deputy Prime Minister on improving the Quality and Efficiency of UK Construction.

Eisenstein, Z, Martin, G & Parker, H 1995, ‘Los Angeles Country Metro Rail Project, Report on Tunneling Feasibility and Performance’ November.

Evans & Peck, 2004, “Northside Storage Tunnel Project, Post Implementation Cost Review, Final Report” 15 November

Flyvbjerg, B; Bruzelius, N & Rothengatter, W; ‘Megaprojects and Risk: An Anatomy of Ambition’ Cambridge University Press, March 2003, 208 pages. ISBN: 0815701284

Galloway, P, Nielsen, K & Dignum, J. “Managing GIGA Projects”, ASCE Press, 2012.

Grasso, P., Pescara, M. & Soldo, L. 2016 “Risk Management in Tunnelling- a Review of Current Practices” Proc WTC2016 Conference San Francisco.

Grayson, J., Nickerson, J. & Moonin, E. 2015 “Partnering through Risk Management: Lake Mead Intake No. 3. Risk Management Approach”, RETC June.

Hatem, D J et. al. “Megaprojects and Recommended Practices”, ACEC Press, 2010

Henderson, A 1999 (2) ‘Northside Storage Project’, Proc 10th Australian Tunneling Conference, Melbourne March, p 57.

IRJ 2003, International Railroad Journal, ‘Madrid Confirmed its Low-Cost Approach’ May

ITA 2004 “Guidelines for Tunnelling Risk Management”, International Tunnelling Association, Working Group 2, Eskensen, S, TUST Vol. 19, No. 3, pp 217-237

ITIG “Code of Practice for Risk Management of Tunneling Works” ITIG, January 2006 & May 2012 (2nd Ed.)

Jensen, M., Moonin, E. & Nickerson, J. “Avoiding Disputes on Challenging Ground Conditions in the Lake Mead Intake No. 3 TBM Starter Tunnel”, Proc. WTC2016, International Tunneling Association Conference

Katzenbach, J R and Smith, D K 1993, ‘The Discipline of Teams’, HBR March-April 1993, pp 111-120, extracted from ‘The Wisdom of Teams: Creating the High-Performance Organization’ (Harvard Business School Press 1993)

Moergli, A., Sander, P., & Reilly J. 2015 “Risk-Based, Probabilistic Cost Estimating Methods” International Tunneling Association, World Tunnel Congress, Dubrovnik May

Nickerson, J, Bono, R, Cimiotti C & Moonin, E, 2015 “Lake Mead Intake No. 3 – TBM Tunneling at High Pressures”, Proc. RETC June.

Nielsen, B, McCormick, P, Abbott, E & Bambridge, C, 2011. Contracting for the SR 99 Bored Tunnel, Seattle, Washington, Proc RETC 2011

RIAAT 2014 http://riaat.riskcon.at/

Reilly, J.J. 2014 “Megaprojects Management and Delivery”, Paper and presentation to the Italian Tunneling Society conference, Bologna, October.

Reilly, J.J. 2013a, "Megaprojects, Successes Learned" keynote presentation for the UCA Fox Conference, New York, January.

Reilly, J.J. 2013b Author of the Foreword, co-author of the Chapters on Risk, Cost and Schedule management in "Managing Gigaprojects", ASCE press 2013, Edited by Galloway, Nielsen and Dignum.

Reilly, J.J. 2013c "Alternative Contracting and Procurement for Megaprojects", UCA/Tunneling Journal Cutting Edge Megaprojects Conference, Seattle, November.

Reilly, J. J. 2012 "Review and Report, Contracting & Delivery Methods" Westside Subway Extension Project, LACMTA, Los Angeles.

Reilly, J.J., Laird, L., Sangrey, D. & Gabel, M. 2011a "Use of Probalistic Cost Estimating CEVP® in the management of Complex Projects to Defined Budgets" International Tunnelling Association Conference, Helsinki, May.

Reilly, J.J., 2010, "Cost and Schedule Control", Chapter 5 "Megaprojects: Challenges and Recommended Practices" Spring.

Reilly, J.J. 2009, 'Alternative Contracting and Delivery methods – Update', Proc. International Tunneling Association, World Tunnel Conference, Budapest May

Reilly, J.J 2008, "Chapter 4, Risk Management" in "Recommended Contract Practices for Underground Construction", Society for Mining, Metallurgy, and Exploration, Inc. Denver.

Reilly, J J 2007a 'The Team Alignment Process - Implementation Work Sessions', John Reilly Associates, internal guidelines re the team alignment processes, applied to the SR520 Floating Bridge replacement project, WSDOT Seattle, February.

Reilly, J.J 2007b, "Alternative Contracting and Innovative Project Management", Proc. Rapid Excavation & Tunneling Conference, Toronto, June.

Reilly, J.J 2004a w. McBride, M., Sangrey, D., MacDonald, D. & Brown, J. "The development OF CEVP® - WSDOT's Cost-Risk Estimating Process," Proceedings, Boston Society of Civil Engineers

Reilly, J.J 2004b "Alliancing for Underground Construction Projects", TBM Magazine, June.

Reilly, J J 2002b 'New Project Management Processes and Supporting Systems' Keynote address, DownUnder 2002, International Tunneling Association Conference, Sydney, March

Reilly, J J 2001c 'Managing the Costs of Complex, Underground and Infrastructure Projects', American Underground Construction Conference, Regional Conference, Seattle, March.

Reilly, J J 2000a 'The Management Process for Complex Underground and Tunneling Projects', Journal of Tunnelling and Underground Space Technology, Vol. 15, No. 1, pp 31-44

Reilly, J J 2000b 'Tying it together – Policy, Management, Contracting and Risk – an Overview, Proc. North American Tunneling Conference 2000, Boston, June, pp 159-168

Reilly, J J & Thompson, R, 2000g 'International survey, 1400 projects', confidential report.

Reilly, J J 1997, 'Owner responsibilities in the selection of tunnel boring machines with reference to contractual requirements and construction conditions' Tunnels for People Vienna April Proc pp 749-756 AA Balkema

Reilly, J J 1995 'Project Management Oversight - Consideration of a Proactive Approach', Proc American Rapid Transit Association, Rapid Transit Conference, June.

Ross, J 2003, 'Introduction to Project Alliancing', April 2003 Update, Alliance Contracting Conference, Sydney, Australia, 30 April.

Salvucci, F.P. 2003 "The 'Big Dig' of Boston, Massachusetts: Lessons to Learn", Tunnels & Tunnelling, North America, May and Proc. International Tunnelling Association Conference, Amsterdam, April.

Spies, P, Eratne, S & Ireland, T 2015 "The $1.4B Waterview Connection Motorway Tunnels – Outcomes and Progress from a Client's Perspective" Proc. RETC New Orleans pp 798-809.

TCRP Report 131 2009 "A Guidebook for the Evaluation of Project Delivery Methods", TCRP Transportation Research Board, Washington DC,

Wageman, R., Nuines, D., Burruss, J. & Hackman, J 2008 "Senior Leadership Teams" Harvard Business School Press.