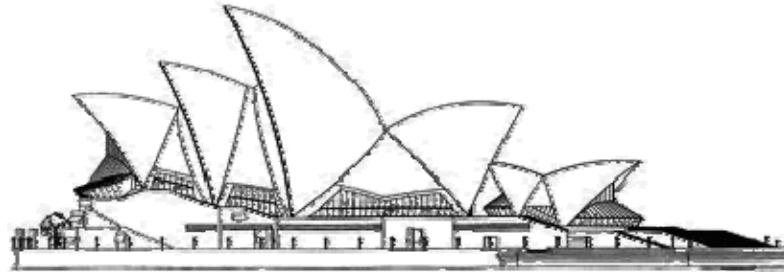


## **PROJECT MANAGEMENT**



### **Sydney Opera House Risk Management case study**

*By KHALED EID*

## 1. Introduction

Risk management is one of the most critical project management practices, to ensure a project be successfully completed. Risk management is thus in direct relation to the successful project completion. Project management literature describes a detailed and widely accepted risk management process, which is constructed from four iterative phases known as risk management plan

- Risk identification
- Risk estimation
- Risk response
- Planning and execution

### Risk Identification

In this stage, we identify and name the risks, there are different sorts of risks and we need to decide on a project by project basis what to do with each type.

### Risk Quantification

Risk needs to be quantified in two dimensions. The impact of the risk needs to be assessed. The probability of the risk occurring needs to be assessed. For simplicity, rate each on a 1 to 4 scale. The larger the number, the larger the impact or probability. By using a matrix, a priority can be established.

		4	Medium	Critical			
Probability		3					
		2	Low	High			
		1					
			1	2	3	4	Impact

Fig 1 quantification scale matrix (Ref. 11)

### Risk Response

There are four actions you can do about a risk. The strategies are:

- Avoid the risk. Do something to remove it. Use another supplier for example.

- Deflect the risk. Make someone else responsible. Perhaps contracting out or insurance against (damage , liability, personnel liability etc)
- Mitigate the risk. Take actions to lessen the impact or chance of the risk occurring. If the risk relates to availability of resources, draw up an agreement and get sign-off for the resource to be available.
- Accept the risk. The risk might be so small the effort to do anything is not worthwhile or a contingency plan may be developed to deal with possible effects.

### Risk Control

The final step is to continually monitor risks to identify any change in the status, or if they turn into an issue. It is best to hold regular risk reviews to identify actions outstanding, risk probability and impact, remove risks that have passed, and identify new risks.

### 1.1 Risk management and construction

The construction industry is subjected to more risk and uncertainty than many other industries. The process of taking a project from initial investment appraisal to completion and into use is complex, generally bespoke, and entails time-consuming design and production processes. It requires a multitude of people with different skills and interests and the co-ordination of a wide range of disparate, yet interrelated, activities. Such complexity is further compounded by many uncontrollable external factors (Flanagan and Norman, 1983). The construction industry has a poor reputation in coping with risks, many projects failing to meet deadlines and cost targets. Clients, contractors, the public and others have suffered as a result (Edwards 1995). This study will focus on applying project risk management strategies on construction of Sydney opera house which is a well-known case for cost overrun.

### 1.2 The aim of the study

The aim of this study is not to reduce the great achievement of construction such a complicated building that changed the face of the city but looking form management point of view to

- Identify and quantify the project risks that been overlooked.
- Highlight the dangers associated with using poor estimate.

### 1.3 About the Sydney Opera House

- The owner :State government of New South Wales
- Architect :Jorn Utzon
- Engineer: Ove Arup & Parteners
- Cost: \$102 million

The Sydney Opera House is the busiest performing arts centre in the world. Since its opening in 1973, it has brought countless hours of entertainment to millions of people and has continued to attract the best in world class talent year after year.

### 1.4 About the Building

There are nearly 1000 rooms in the Opera House including the five main auditoria. There is also a Reception Hall, five rehearsal studios, four restaurants, six theatre bars, extensive foyer and lounge areas, sixty dressing rooms and suites, library, an artists' lounge and canteen known as the "Green Room", administrative offices and extensive plant and machinery areas. The building covers about 1.8 hectares (4.5 acres) of its 2.2 hectare (5.5 acre) site. It has about 4.5 hectares (11 acres) of usable floor space. It is approximately 185 m (611 ft) long and 120m (380 ft) wide at its widest point. The highest roof vault (above the Concert Hall) is 67m (221 ft) above sea level.

The roofs are made up of 2,194 pre-cast concrete sections. These sections weigh up to 15.5 tones (15 tons) each. They are held together by 350 km (217 miles) of tensioned steel cable. The roofs weigh 27,230 tones and are covered with exactly 1,056,056 Swedish ceramic tiles arranged in 4,253 pre-cast lids.

The entire building weighs 161,000 tones. It is supported on 580 concrete piers sunk up to 25 m (82 ft) below sea level. The roofs are supported on 32 concrete columns up to 2.5 m (8 ft) square. The exterior and interior walls, stairs and floors are faced with pink aggregate granite which was quarried at Tarana in New South Wales. The two woods used extensively to decorate the interiors are brush box and white birch plywood which were both cut in northern NSW. There are 6,225 sq m (67,000 sq ft) of glass, made in France, in the mouths of the roofs and other areas of the building. It is in two layers - one plain and the other demi-topaz tinted. About 2,000 panes in 700 sizes were installed.

There are 645 km (400 miles) of electrical cable. 120 distribution boards regulate the power supply, equivalent to the needs of a town of 25,000 people. Twenty-six air-conditioning plant rooms move more than 28,500 cubic meters (1,000,000 cubic feet) of air per minute through 19.5 km (12 miles) of ducting.



Fig 2 Sydney opera house (Ref. 6)

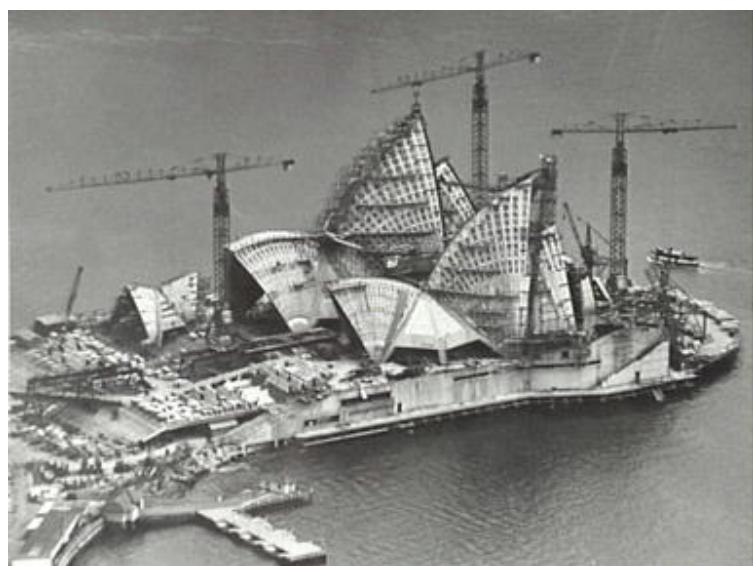


Fig 3 Sydney opera house during construction (Ref. 7)



Fig 4 Sydney opera house shells (Ref. 7)



Fig 4 Sydney opera house shells (Ref. 7)

## 1.5 Design Stage

The original concept for the project was a sketch submitted by Danish architect , Jorn Utzon .Judges selected it from an international open competition that ended with 233 entries from 11 countries. Thought happy to win the competition Utzon was mildly shocked .although his concept had caught the attention of the judges, it consisted only if simple sketches with no plans or even perspective drawings , because the design was so unique , some people presumed it would also be inexpensive to build. No one knew how it would be build , and some experts questioned that it could be built at all.

In spite all uncertainty , the initial project cost estimate was pit at \$7million.The government would use profits from a series of state run lotteries to pay the project. The government was worried that the people scrutinizing the design might raise question about the potential problems hat would stall the project they thus quickly mover ahead and divided the work into three main contracts :the foundation and the building except the roof, the roof, and the interior and equipment.

## 1.6 Construction stage

Many of the world's best-known construction companies were involved in building Sydney Opera House including Arups Structural Engineering, Hornibrook and Rider Hunt, the construction work of S.O.H was divided into three distinct stages as follows (Ref. 19)

- Stage I

Sub structure , concrete structure from the foundation up to the auditoria seating levels excluding any finishes.

- Stage II

Superstructure or shells , concrete roof vaults or major and minor halls an restaurants , including the claddings.

- Stage III

Everything not included in stages I and II , stage towers, all interior finishes, exterior paving and cladding, glass walls , all electrical and mechanical services.

After he was elected premier of New South Wales in 1965, Askin attempted to force Utzon reduce costs by withholding payments. In 1966 Utzon resigned and returned to his native Denmark. He never even returned to see his masterpiece completed.

The construction of the Sydney Opera House was now handed over to a group or Australian architects. Fortunately, the exterior had already been completed by then so that the impact of the altered design on the overall structure was minimal. The project was finally completed in 1973 after a construction period of 14 years and an expenditure of over \$A100 million, almost 15 times the estimated budget.

## 2. Risk management strategies at S.O.H

### 2.1 Financial

Despite of all cost escalation , taxpayer had little to pay .Virtually all the costs were covered by the proceeds of State Lotteries. The continued need to the subside the running costs of the opera house were financed by the continuation of the Lottery State. The first estimate for the Sydney Opera House was \$7.2 million in Australian dollars. Once started, however, costs kept rising and just to complete the building cost \$102 million.

### 2.2 Political

Political risks are often occur in government project as they often hide information affecting the community's support, which in turn affect the effectiveness of the feasibility study . S.O.H we mostly severely effect by political decisions

#### 2.2.1 Media and public deception

In S.O.H. the original budget of seven million Australian dollars was not a real but a political budget .The labour government of New South Wales the main proponent of the S.O.H, wanted the project started before elections in March 1959-this would reduce the risk of the stopping the project in case Labour lost the elections <sup>(8)</sup>.

#### 2.2.2 Deceptive cost estimate

Kim Utzon explains in lieu of his father "It was a political decision to publicize a low budget for the building, which was expected to gain approval in the political system, but which very quickly was exceeded. So even if the cost overrun turned to be 1400% in relation to the publicized budget, this budget was an eighth of the real budget of the building .So the real overrun is only 100% the rest was politics".

#### 2.2.3 Political construction date

The start of construction for stage I was fixed ., largely for political reasons , as the 2<sup>nd</sup> March 1959.Thus Proceeding with construction before completing the design process which is a great risk .

#### 2.2.4 Political design changes

On 1966 major hall was changed from dual purpose for concert and opera to a single purpose concert hall, the dual purpose was a requirement of the competition .

## 2.3 Structural

### 2.3.1 The Supporting points

Arup and his engineers knew very well that the cross-section shape Utzon chose was far from ideal known structures, however they could not suggest changing to the shape as it will alter the appearance of the roof drastically.

### 2.3.2 The roof

A question should be asked if this design is achievable?. The competition judges choose a complex art design without asking how it will be designed? later on it was a major cause for delaying the roof design if this point was been considered they should either choose a simple shape or a known geometry, at this stage computer program analysis was not yet been introduced that means only manual process can be used to calculate the forces acting on the structure.

### 2.3.3 Lack of suitable boundary condition.

Another technical problem that the engineer had to solve was the lack of boundary condition that leads to some earthwork as sub base for the structure foundation.

## 2.4 Technical

Utzon, ware of possible technical problems since his design required advanced technology not yet available, requested additional time to tackle those challenges Utzon faced the task of converting the concept into a design form which a structure could be built, but he had no prior experience in the design and construction of such a large building. Because of this lack of plans, detailed design drawings, and estimates of materials, little existed from which cost could be determined.

### 2.4.1 Design errors and omissions

- Unfortunately, the roof shells were too heavy for the supporting columns that were already built, so these were demolished and rebuilt. These and several other setbacks led to delays and increasing cost overruns.
- The original design called for two theatres. The government changed its mind and required the building to be altered and that four theatres now be incorporated into the design
- The foundation been demolished to suit the new roof design loads.

### 2.4.2 Fitness for purpose.

- The main design overlooked acoustic requirements which is the main purpose of the building and had to be altered at later stage.
- The Running costs for S.O.H proved expensive , it was a very labour intensive building .In 1974 , it operation cost was \$A6M, of which only \$A2M was covered by

the revenue. Thus costs ruled out small scale opera and the Australian Opera were forced to seek a cheaper venue.

## 2.5 Construction

Engineers who revised the concept noted that the roof shells were much larger and wider than any shells seen so far. Further, because they stuck up so high, they would act like sails in strong winds blowing up the harbour. Thus, the roof would have to be carefully designed and constructed to resist such wind pressure.

The construction was estimated to take about five years at a cost of A\$7 million. Ignoring his request, the government pressured Utzon into starting construction in 1959, two years ahead of the architect's proposed schedule.

- The lack of preparation soon backfired. After the completion of the grand podium with an enormous, 86 meter (282ft) wide stair, several years were spent reworking the design of the roof.
- Three tower cranes imported from France for this job costing \$100,000 each and it was the first building constructed in Australia using tower cranes.
- Unfortunately the roof shells were too heavy for the supporting columns that were already built, so these were demolished and rebuilt.

## 2.6 What goes wrong *Consequences?*

- Cost overrun 1300% (Ref. 18)

As feared many experts the project became an engineering financial debacle, lasting 15 years and costing \$107 million (\$100 million over the initial estimate).

- Schedule overrun 250% (Ref. 18)
- Media and public scandal

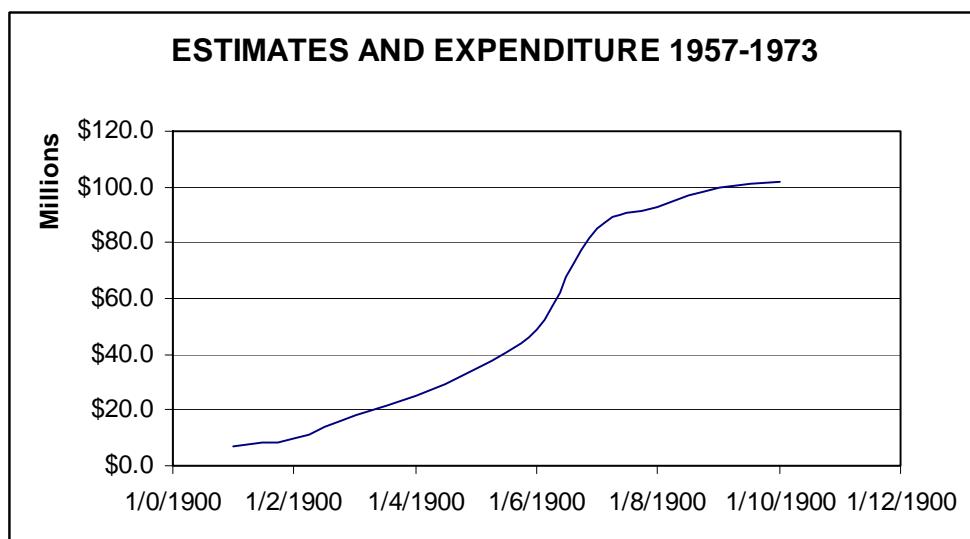


Fig 5 Time /cost Escalation

- Management conflict occur between the client and the architect that cause him to resign before the end of stage III .

### 3. Risk identification quantification

#### 3.1 Identification

By looking at the project there are some risks appear not used have the most adverse effect on the project

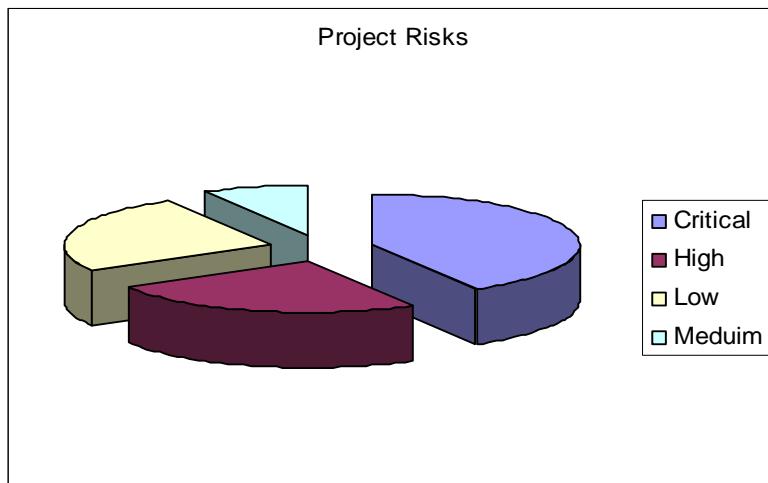
1. Poor Cost Estimate.
2. Incomplete design.
3. Failure to keep within the cost estimate
4. Failure to achieve the required completion date.
5. Changes in project scope and requirements.
6. Design changes.
7. Pressure to deliver project on an accelerated schedule.
8. Inaccurate contract time estimate
9. Lack of communication between project participants.
10. Inadequately defined roles and responsibilities.
11. Insufficient skilled staff.
12. Political risks.

#### 3.2 Qualitative risk analysis

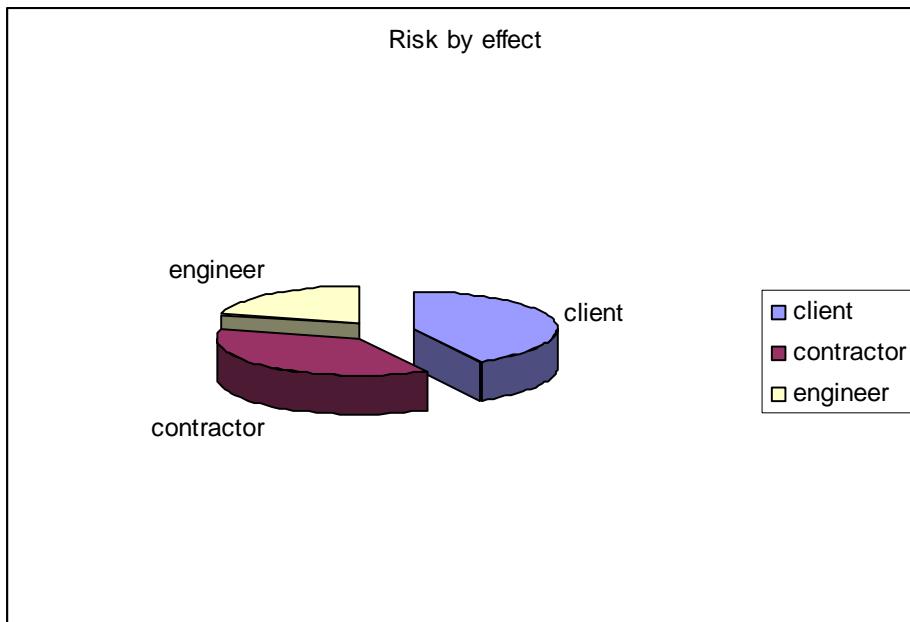
Qualitative risk analysis assesses the importance of the identified risks and develops the prioritized lists ,using the 1 to 4 scale matrix discussed above to quantify identified risks

Risk	Probability	Impact	Risk Importance
1. Poor Cost Estimate.	3	3	Critical
2. Incomplete design.	1	3	High
3. Failure to keep within the cost estimate	3	4	Critical
4. Failure to achieve the required completion date.	4	3	Critical
5. Changes in project scope and requirements.	1	3	High
6. Design changes.	2	2	Low
7. Pressure to deliver project on an accelerated schedule.	2	2	Low
8. Inaccurate contract time estimate	3	4	Critical
9. Lack of communication between project participants.	3	4	Critical
10. Inadequately defined roles and responsibilities.	1	4	High
11. Insufficient skilled staff.	1	2	Low
12. Political risks.	4	2	Medium

Three risks were selected for detailed qualitative risk assessment (refer to sheet 1 , 2 and 3)



Risk	Risk Control
1. Poor Cost Estimate.	Client, Contractor
2. Incomplete design.	Client , Contractor
3. Failure to keep within the cost estimate	Client
4. Failure to achieve the required completion date.	Client, Contractor
5. Changes in project scope and requirements.	Engineers
6. Design changes.	Contractor
7. Pressure to deliver project on an accelerated schedule.	Engineers
8. Inaccurate contract time estimate	Contractor, Client
9. Lack of communication between project participants.	Engineers, Contractor, Client
10. Inadequately defined roles and responsibilities.	Engineers, Client
11. Insufficient skilled staff.	Client
12. Political risks.	Contractor



### 3.2 Risk response

#### 3.2.1 Risk Avoidance

As discussed most of the risk could be avoided by only

- Completed design .
- Estimating at a very detailed level.
- Not selecting untested design .
- Using local Architecture office will reduce many and more communication and experienced architecture designer

#### 3.2.2 Risk transfer

- Using a fixed price contract will transfer construction risk to the contractor.
- Obtaining Insurance to cover costly risks.

#### 3.2.3 Mitigate the risk

Risk analysis shows that no clear management process for controlling the project however using an experienced project manager would effectively reduce probability or impact of risks to an acceptable level.

### 4. Assessment forms

Following a three assessment forms for 3 of the significant risks

Performa for a Qualitative Risk Assessment (sheet 1)			
<b>Reference No:</b> 6	<b>Date:</b> 25/06/2007		
<b>Potential risk:</b>	<b>Importance of Risk:</b> <i>Low</i>		
<i>Design changes</i>	<b>Probability</b>	<i>Medium</i>	
	<b>Consequence</b>	<i>Medium</i>	
<b>Stage of the project affected by this risk:</b>			
<i>Construction stage</i>			
<b>Statement of risk:</b>			
<i>Cost and schedule overrun</i>			
(The factor that could cause it to occur) <i>Political business interest</i> <i>Site problems</i>			
(any relationship or dependency on other risks) <i>Incomplete design</i>			
(the likelihood of occurring) <i>Medium</i>			
(how it could be affected) <i>Design checking prior leaving the design office</i>			
<b>Project:</b> <i>Sydney opera house</i>	<b>Client:</b> <i>New South Wales government</i>	<b>Risk Analyzed by:</b> <i>Khaled</i>	

<b>Performa for a Qualitative Risk Assessment (sheet 2)</b>			
<b>Reference No:</b> 1	<b>Date:</b> 25/06/2007		
<b>Potential risk:</b>	<b>Importance of Risk:</b> Critical		
<i>Poor Cost Estimate</i>	<b>Probability</b>	<i>High</i>	
	<b>Consequence</b>	<i>High</i>	
<b>Stage of the project affected by this risk:</b>			
<i>Design stage</i> <i>Construction stage</i>			
<b>Statement of risk:</b>			
<i>major source of complaint</i> <i>time consuming</i>			
(the factor that could cause it to occur)			
<i>Changes in project scope and requirements</i>			
(any relationship or dependency on other risks) <i>Inadequately defined roles and responsibilities.</i>			
(the likelihood of occurring)			
<i>Height</i>			
(how it could be affected) Effective project management Clearly defined roles			
<b>Project:</b> <i>Sydney opera house</i>	<b>Client:</b> <i>New South Wales government</i>	<b>Risk Analyzed by:</b> <i>Khaled</i>	

Performa for a Qualitative Risk Assessment (sheet 3)		
<b>Reference No:</b> 9	<b>Date:</b> 25/06/2007	
<b>Potential risk:</b>	<b>Importance of Risk:</b> <i>Critical</i>	
<i>Lack of communication between project participants.</i>	<b>Probability</b>	high
	<b>Consequence</b>	high
<b>Stage of the project affected by this risk:</b>		
<i>Construction stage</i> <i>Design stage</i>		
<b>Statement of risk:</b>		
<i>Insufficient working drawing details</i> <i>Late and in adequate information</i> <i>Major costly errors.</i>		
(the factor that could cause it to occur)		
<i>Lack of management</i> <i>Interest conflict between project participation</i>		
(any relationship or dependency on other risks)		
<i>Incomplete design</i>		
(the likelihood of occurring)		
<i>Height</i>		
(how it could be affected)		
<i>Proper project management</i>		
<b>Project:</b> Sydney opera house	<b>Client:</b> New South Wales government	<b>Risk Analyzed by:</b> Khaled

## 5. Lessons learned

- Risk must be identified to be managed
- A poorly defined risk structure will breed more risks.
- A proper risk management strategy would planning.
- All designs and calculations should be checked before they leave the design office further check calculation should be made by the authority , many errors that escape are picked up and corrected during construction .This often cause a delay to the project and might effect the cost.
- The goal is to prevent political and business interests from interfering with design and thus to arrive at an outcome as close as possible to the original design drawings.
- Continually monitor risks to identify any change in the status, or if they turn into an issue. It is best to hold regular risk reviews to identify actions outstanding, risk probability and impact, remove risks that have passed, and identify new risks.
- Risk management is not one off activity instead, it should be applied continuously through the project life.
- The best way to control budget is not to proceed with the building until you have all the drawings complete.

## 6. Conclusion

Study clearly identifies the great importance of risk management on construction projects, negligence will lead to an expensive cost effecting the project successes.

A risk analysis project shows a large number qualitatively ranked as 1 , those risks have a high probability of occurrence and height consequence shared between the client 42% , the contractor 36% and the engineer 21% .

This indicates that it was a very risky project nevertheless risks were either downplayed or ignored , and not much was done to keep them under control, the project management strategies was only focused on keeping the project going no matter how it is going .

Finally although the opera house put Sydney on the world map, both architecturally and culturally but from project management perspective it was a spectacular failure as a consequence of ignoring risk management.

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