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A Review of Process and Product Systems in Construction

Charles Anthony Mitchell

Technological University Dublin, charles.mitchell@tudublin.ie

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A Review of Process and Product Systems in Construction.



Introduction –

This paper was produced as part of the coursework associated with a Masters in Quantity Surveying (Mechanical and Electrical) undertaken by the Author. The aim of the research was to study and review 1) processes and sub-processes in the pre-construction phase, 2) risk analysis in the project and 3) the use of off-site construction in relation to an iconic structure of the author's choice. In the absence of information the author was permitted to make assumptions about the processes involved as long as these were qualified within the text.

The author chose the Aviva stadium, Dublin 4 as the iconic structure and due to its design and the controversy which surrounded its redevelopment.

Chapter 1 – The Aviva Stadium Dublin; Iconic by its very nature.

The original stadium at Lansdowne road was the brain child of Henry William Dunlop, an outstanding young athlete. Dunlop is credited with organising the first All-Ireland Athletics Championships. The venue was designed as a multi-sport venue catering for athletics, cricket, croquet, archery, tennis and football. The stadium opened in 1872 and the first rugby match was played in 1876. This was an inter-provincial match between Leinster and Ulster.

In 1878 the first of many international rugby matches was held in Lansdowne road. The Irish Rugby Football Union (IRFU) secured a lease on the stadium from the Pembroke estate in the early 1900s.

The first international soccer match took place in 1971 when Ireland played Italy in a friendly. In the early 1980s the Irish football team made the original incarnation of Lansdowne road stadium its home. At this point the stadium was considered the oldest sports stadium in Europe.

The stadium has also played host to many non-sporting distinguished guests such as Frank Sinatra, Sammy Davis Jnr, Celine Dion, Neil Diamond, The Eagles and U2, but to name a few.

As the city of Dublin developed and expanded the stadium became nestled in the heart of a high end suburb which is home to many highflying business people and embassies.

The redevelopment of Lansdowne road was many years in the planning and was plagued with controversy due to its history and location. Locals were concerned about the effects of the proposed redevelopment and as a result the redevelopment was delayed for many years.

The final grant of planning permission was received in early 2007. Works commenced on site in May 2007 and continued until April 2010. The works consisted of the demolition of the existing stadium and construction of a new state of the art stadium and conference centre.

The new development contains 51,700 seats in a continuous curvilinear shaped stand which encloses all four sides of the grounds. The design was developed to provide the maximum amount of daylight to the pitch whilst maintaining daylight to the neighbouring area. The project cost €410 million. The site is 63,802sq.m in area and the development covers nearly all of this area.

The redevelopment included the demolition and recycling of the existing stadium, 5,000 tonnes of structural steel, 8,000 precast concrete units manufactured off-site and 72,000 tonnes of concrete cast in-situ on site, (www.avivastadium.ie).

The stadium was rebranded the Aviva Stadium, Dublin in the latter part of the redevelopment and has continued its iconic status to this date.

The redevelopment has won many awards such as:

British Construction Industry Award (BCIA) for best international project 2011.

Royal Institute of British Architects (RIBA) Award – projects in the European Union Region 2011.

Winner Irish Concrete Society Awards – Building Category and Overall Winner 2010.

Chapter 2 – Task 1 – Describe and map the main processes and sub-processes in the pre-construction stage.

The following series of diagrams seek to map the main processes and sub-processes in the preconstruction stage of the Aviva Stadium, Dublin. It is important to note that many of the points raised regarding the pre-construction stage of the redevelopment of the Aviva Stadium Dublin within this chapter are founded on presumptions made by the author unless otherwise noted.

This iconic project was years in the making and was in the public eye from the moment the idea of the project was conceived.

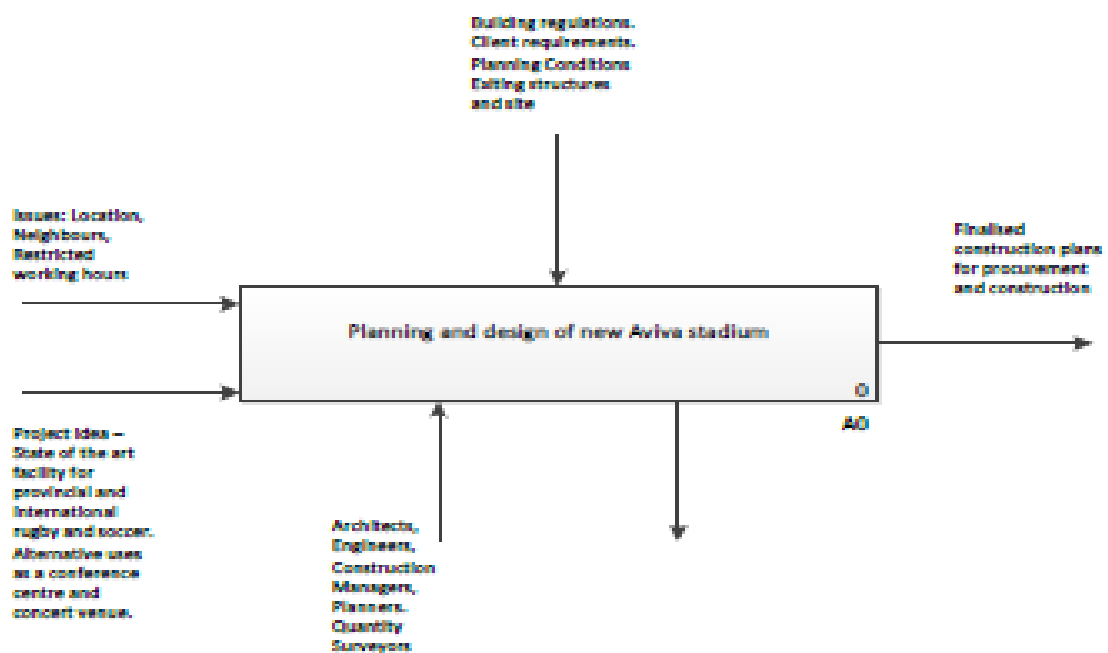


Fig 1. A-0 Aviva Stadium (Context) – Level 0 (Source – Author)

The diagram above, Fig 1, outlines the pre-construction process as a whole. The process in question is the planning and design of the new Aviva Stadium Dublin and this can be described as the function.

On the left of the diagram we see the start point. These are known as inputs. The first input is the client brief, the demolition of the existing stadium and replacement with a new state of the art facility of provincial and international rugby and soccer. The new facility also must provide alternative uses as a conference and concert venue.

The diagram also shows, on the left, the issues which the brief will have. These issues are namely the location, site constraints, neighbours and working hours. These are more inputs into the process.

The arrow leaving on the right shows the output. This is the data or object produced by the function. There may be multiple outputs produced by the function.

At the bottom of the diagram is seen the input of the members of the Design Team. It is noted that the whole project team is assembled as the pre-planning and design team as a whole. This is a client requirement due to the level of co-ordination such a project requires.

Arrows entering from the bottom side of the function box represent the mechanisms. Mechanisms can be described as resources used by the function but not consumed. In this case the mechanism is the whole design team. All the team members bring a magnitude of resources and knowledge, both tacit and explicit. The arrow leaving the bottom of the function box is known as a call and shows the link between the function and other model(s).

The arrows which enter at the top of the function box are known as controls and represent conditions required in order to produce the correct outputs. In this instance the controls relate to building regulations, the client's requirements, planning legislations, the site constraints and site environment.

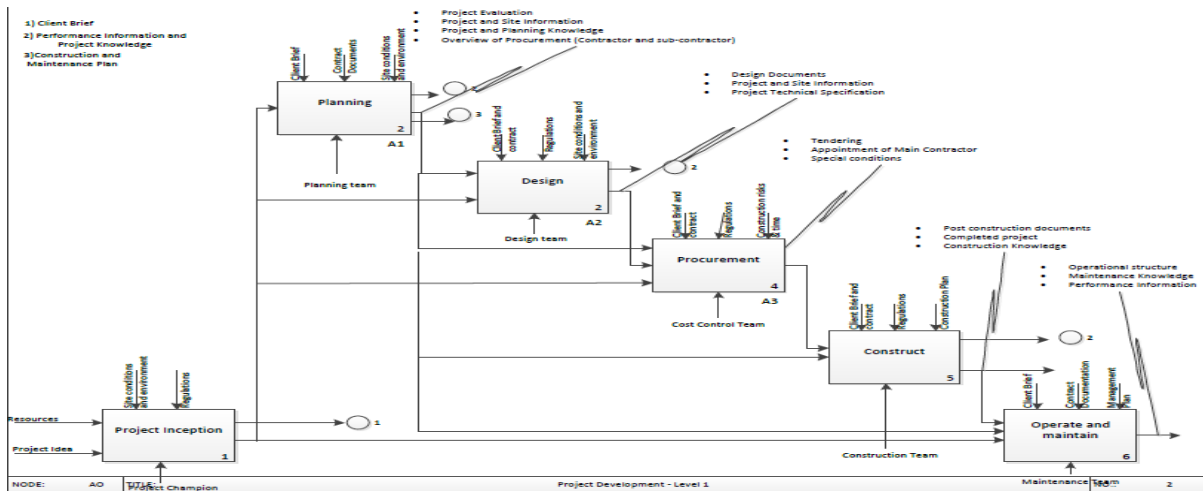


Fig 2. Project Development – Level 1 (Source – Author)

The diagram in Fig.2 is known as a child diagram and follows on from the diagram in Fig.1, the parent diagram. This diagram gives an overview of the project.

Reading from the left we see the project inception and all the processes required to produce the product. In this case a fully functional facility as required by the client brief. The main functions are outlined from point 1 to 6 inclusive.

Each function, as noted, shows its inputs and outputs as well as all associated controls and mechanisms. Each function has a box number outlining that it is the first step in the process. Beneath the box another reference may be found which outlines the major sub-functions to be found in child diagrams.

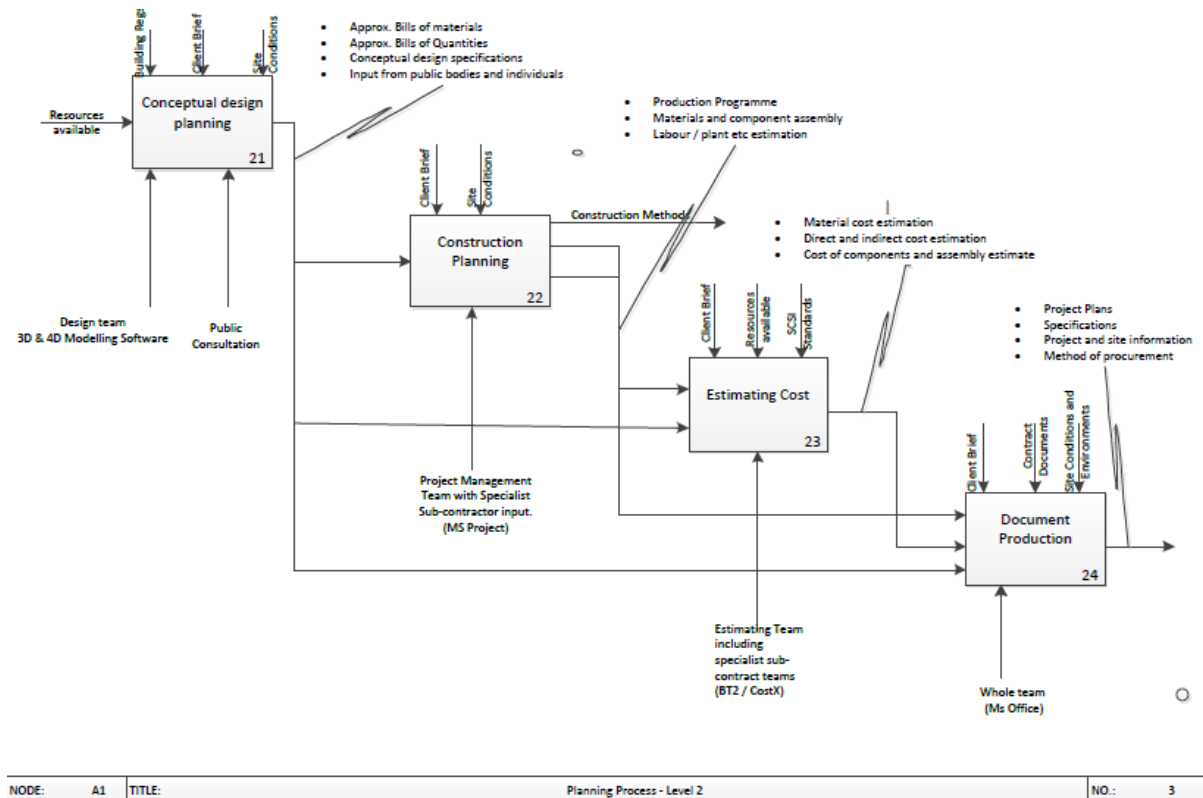


Fig 3. Planning Process – Level 2 (Source – Author)

The planning process diagram, Fig 3, is the first of the level 2 diagrams and is a child of the project development level 1 diagram.

The first function is the *Conceptual Design Planning*; here we investigate the resources available namely. The controls are shown at the top of the function box and include regulation, brief and site conditions. But at this time no conceptual design is available. We see the design team input entering from the bottom of the function box. The author has presumed that both 3 Dimensional and 4 Dimensional software packages are used to create the concept drawings. The initial plan also takes into account the need for public consultation from a very early point in the design process. This issue will be discussed in more detail in later chapters. The main reason for so much early input from so many key players and stakeholders was required to limit exposure to risk and to secure the future of the development.

In the second function, *Construction Planning*, it is envisaged that the whole project management team with input from all specialist sub-contractors will be required. The author has made the presumption that the project management team will use programmes such as MS Project to programme the project. This will be done in conjunction with a review of the construction methods available which may be utilised during the actual construction.

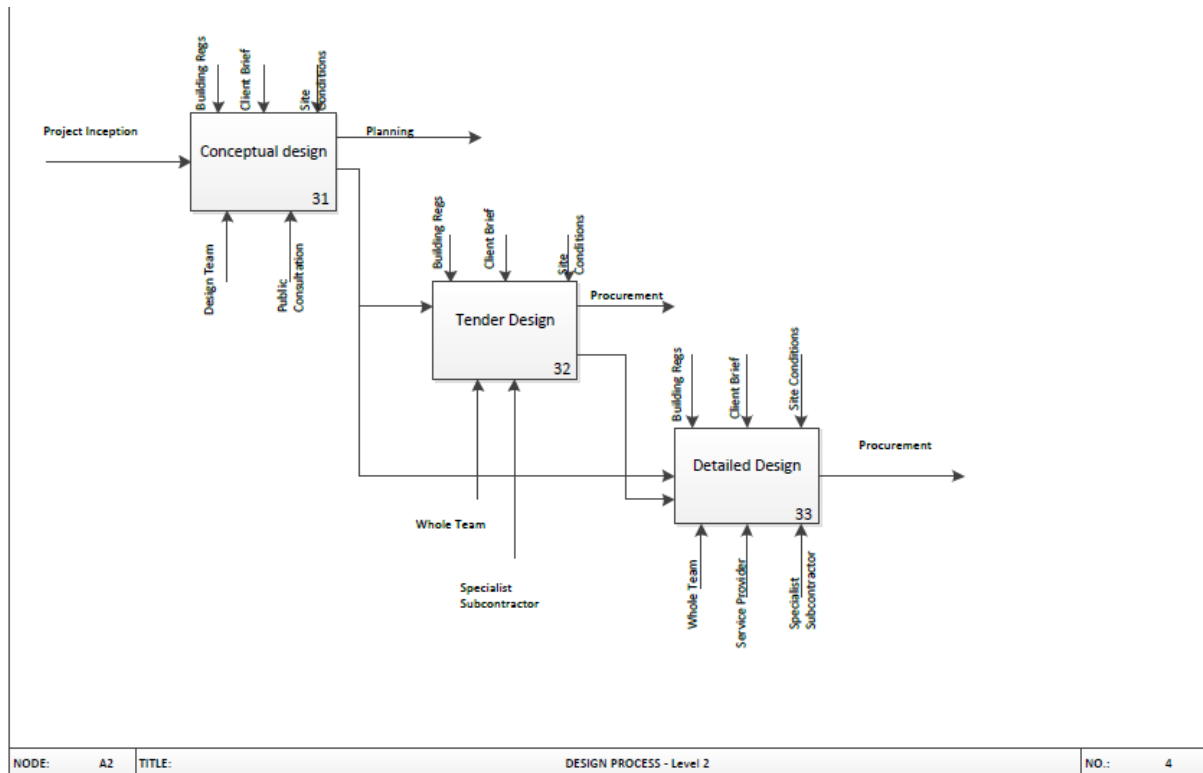


Fig 4. Design Process – Level 2 (Source – Author)

A large portion of the project team’s work and time was involved in the design process, Fig 4. Given the nature of the project and the associated time constraints the client team saw it necessary to get all of the project team involved in the design. It is normal to see the engineers and architects involved at concept stage. However, in this instance the whole team was assembled at the start.

The second part of the diagram, *Tender Design*, has the exact same controls as the *Conceptual Design* process. But now the whole design team are fully involved and working towards a common goal. At this point the goal is a small one, completing the detailed design and moving to procurement and construction.

At this point new players also have entered the process. These are the specialist sub-contractors. It is not unusual to see specialist sub-contractors at this point due to the need to incorporate their tacit knowledge into the design. However, the site conditions and the area surrounding the proposed development necessitated the appointment of these specialist subcontractors prior to receiving a final grant of planning permission for the following reasons, 1) to allow a construction plan to be formulated and 2) to secure resources and allow for a speedy delivery of the project.

It is presumed by the author that the output of this second design stage is two-fold. The first is stage one of the procurement stage. The second is the final detailed design which will involve all the major stakeholders including the future service providers. Now the design is ready to be incorporated into the final procurement package.

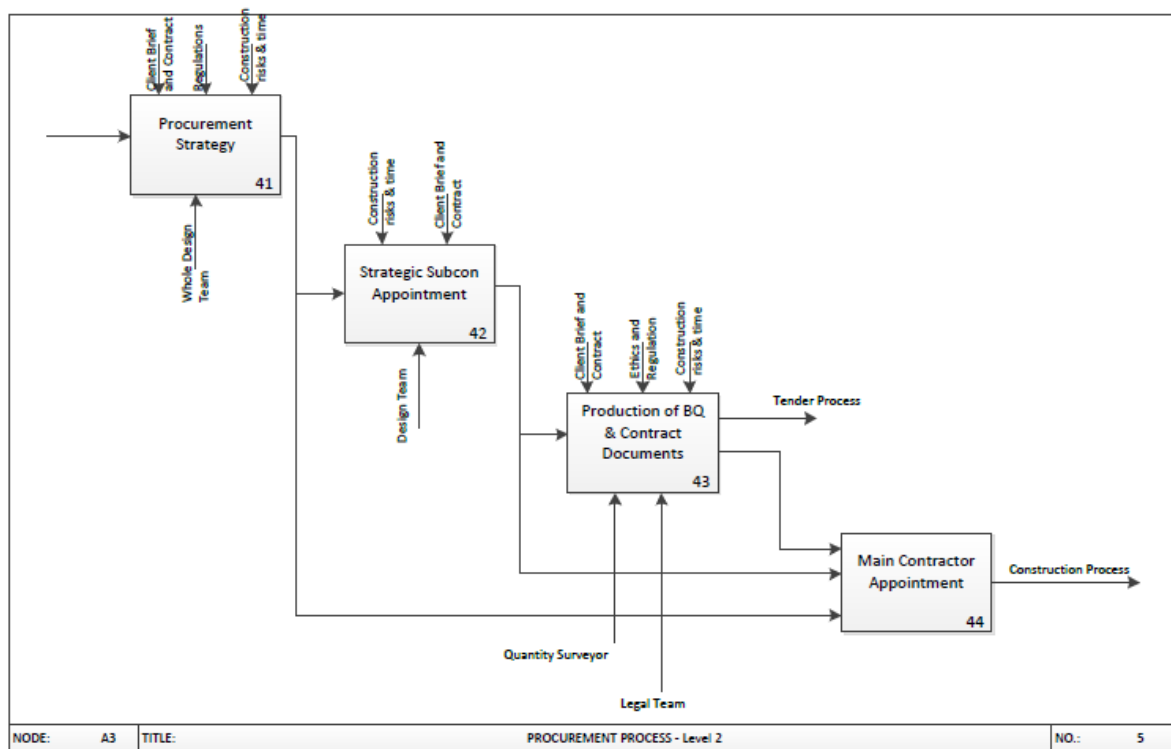


Fig 5. Procurement Process – Level 3 (Source – Author)

The *Procurement Process* diagram shown in Fig 5 is a child of the Project Development diagram Fig 2. It outlines the process in deciding the Procurement Strategy. The whole of the Project Team is required to give their insight and input here.

Given the major constraints of the site, its location and surrounds coupled with the time constraints of the project the client team decided that it would be a worthwhile risk to enter into contract with specialist subcontractors before having received a final grant of planning permission. Michael Green, project director of the Lansdowne Road Stadium Development Company (LRSDC) stated that the early appointment of the specialist subcontractors *“meant we were ready to start working on site as soon as we had planning permission obtained, it meant we had a real run at the work”*, (Irish Building Magazine, 2011).

This *Strategic Subcontractor Appointment* paved the way for the production of the full suite of tender documents as noted in the Production of BQ & Contract Documents. The constraints have remained the same but at this point the main input comes from the quantity surveying team and the legal team. Both of these parties are versed in the particulars of the project and industry and so are best versed to serve the intentions of the client.

The final stage of this process is to appoint the main contractor who will control the physical construction of the project. Given the size of the project and its associated constraints it will be necessary to select a contractor capable of completing the project. However, there is a limited field of suitable candidates in the Irish market. This is another reason why the whole project team had such input into the procurement strategy.

Conceptual Design - UML

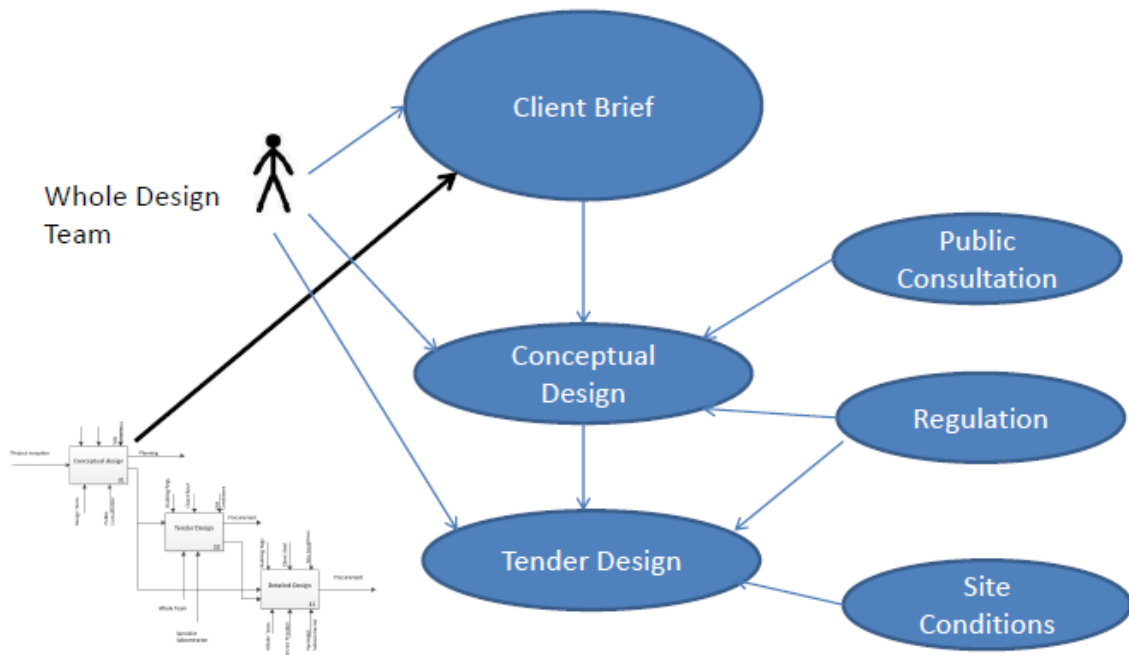


Fig 6. Conceptual Design UML (Source – Author)

Marshall (2000), describes Unified Modelling Language (UML) as a tool for specifying, visualising, constructing and documenting the artefacts of software systems. In this example a Use case diagram is used to show the conceptual design function of the IDEFO model.

The actor on the left hand side plays the whole design team. This takes into account all professional parties and the LRSDC. This actor has input into the brief as it develops and then into concept.

On the right hand side we see some of the controls which will help the concept to develop. These include the public consultation period, building regulations and the site conditions. The site conditions take into account limitations which constrain the design namely, location, existing structure, proximity to a main rail line and environmental risks.

Procurement Strategy - UML

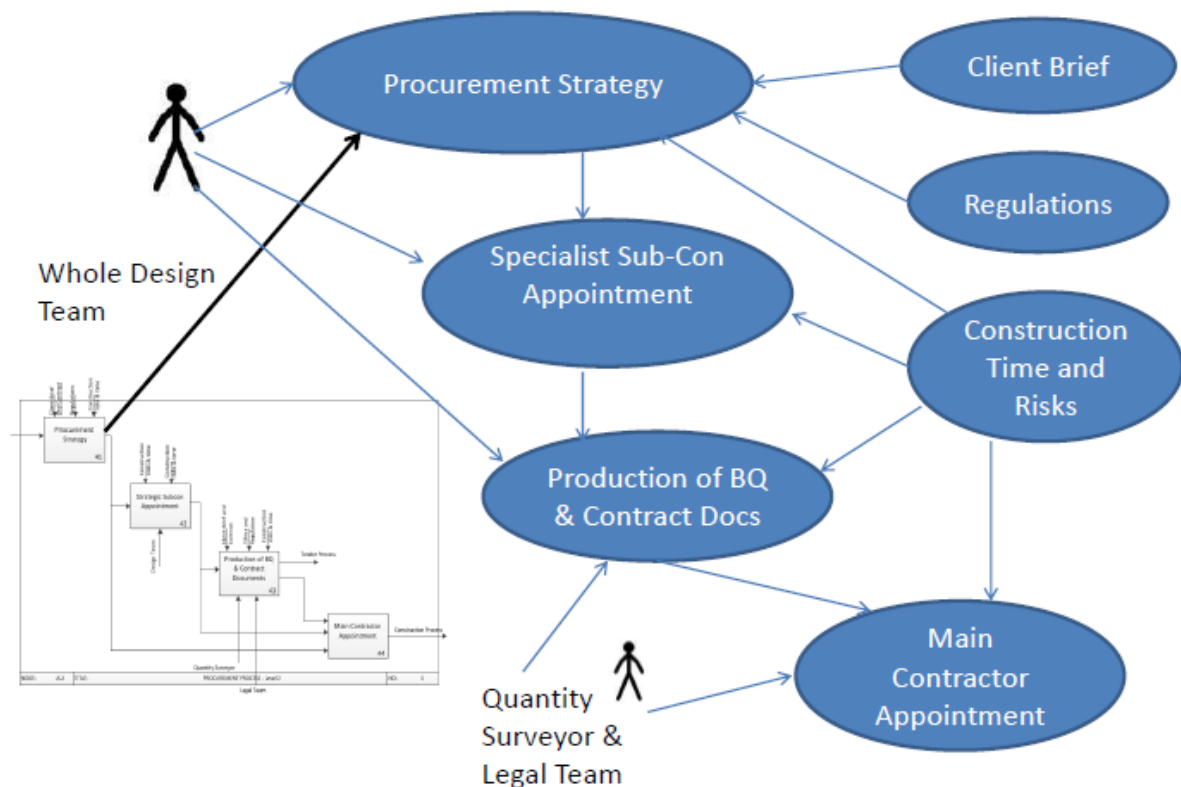


Fig 7. Procurement Strategy UML (Source – Author)

This UML shows how the whole design team, including the LRSDC, design the procurement strategy for the project. Here we have two actors. The second is the combined quantity surveying and legal team. This is a secondary function of the strategy.

One of the main factors which drives the whole design team in designing the procurement strategy is the construction time and risks. These are many and are discussed further in the following chapters.

Chapter 3 – Task 2 – Detailed articulation of the risk analysis of the pre-construction phase of the re-development of the Aviva Stadium, Dublin.

“The purpose of a risk register is to record and manage project risks to enable projects to be delivered successfully” (Corbett and Grigg, 2009).

Every road travelled in life is filled with risk. The same can be said of every venture entered into including construction projects. Many of the risks noted and analysed in this chapter are based on presumptions made by the author.

For the purpose of this exercise the author has made presumptions regarding the site and extent of the risk based on personal knowledge.

In order to rate risk it is advisable to first identify the risks. Some projects have similar risks but the scoring or impact may be different on a project by project basis based on a range of criteria.

In order to assign a level of risk (or risk score) we can use a risk matrix. The one that I have used is an example from Imperial College London.

Risk Scoring Matrix					Probability Categories										
Impact	High/ Critical	3	3	6	9	Description		Prob	Scale Value						
	Medium/ Serious	2	2	4	6	H	Probable	>70%	3						
	Low/ Marginal	1	1	2	3	M	Could happen	30-70%	2						
			1	2	3	L	Improbable	<30%	1						
			Low/ Improbable	Medium/ Could happen	High/ Probable	Impact Categories									
						Description		Guide Scenario		Scale Value					
			Probability			H	Critical	Failure that involves significant rework, modification or reassessment	3						
						M	Serious	Failure or setback that causes additional work and reassessment but containable	2						
						L	Marginal	Impact has some effect causing rework or reassessment but easily handled	1						
Risk Category & Action															
<table border="0"> <tr> <td style="background-color: red; width: 20px;"></td> <td>Key/ Critical Risks - closely monitor, manage & develop fallback plans</td> </tr> <tr> <td style="background-color: orange; width: 20px;"></td> <td>Intermediate Risks - monitor and manage to mitigate/ include specific risk allowances in cost estimate/ programme</td> </tr> <tr> <td style="background-color: green; width: 20px;"></td> <td>Minor Risks - general allowance in base cost estimate & programme</td> </tr> </table>											Key/ Critical Risks - closely monitor, manage & develop fallback plans		Intermediate Risks - monitor and manage to mitigate/ include specific risk allowances in cost estimate/ programme		Minor Risks - general allowance in base cost estimate & programme
	Key/ Critical Risks - closely monitor, manage & develop fallback plans														
	Intermediate Risks - monitor and manage to mitigate/ include specific risk allowances in cost estimate/ programme														
	Minor Risks - general allowance in base cost estimate & programme														

Fig 8 – Risk Matrix (Imperial College, London)

Using a risk register the project team identify project specific risks and assess them using the risk matrix. The register is used to score the probability or likelihood of a risk occurring and also what impact the risk will pose to the success of the project.

The author has used an amended version of the risk register from the Imperial College London. This risk register shows who is responsible for each risk and allows for notation showing how the risk has been mitigated using corrective actions to date. The author has made assumptions based on his knowledge of the completed project.

RISK IDENTIFICATION & MITIGATION					RISK ASSESSMENT - RESIDUAL RISK				
Ref	Category / Responsibility	Risk	Potential Impact	Completed Mitigation Action (to date)	Probity.	Impact	Risk Score/Category	Cost Impact (Project Costs) [€]	Schedule Impact [weeks]
1	Client	Signing off of brief can lead to design changes	Delay planning and commencement	Public consultation with Client and design team. Early input from all design team members.	2	2	4		
2	External	Objections to planning	Project indefinitely delayed. Cost for redesign. Client in contact with specialist sub-contractors who are aiding with design.	Transparency in development proceedings and public consultations. Planning application delayed to allow all interested parties time to make submissions.	2	3	6		
3	Construction	Limited site area - proposed development will cover most of the site.	No storage or space for on-site manufacture causing delay and additional cost.	Investigation into off-site manufacturing solutions and delivery in a "just-in-time" manner.	3	2	6		
4	Construction	Slow deliveries due to poor infrastructure around the site	Extended construction period and delays	"Just-in-time" method of deliveries. Designated drop zones on site and precise planning.	2	2	4		
5	Construction	Asbestos in existing stands	Asbestos to those involved in demolition and in the vicinity of the works.	Survey carried out. All hazardous materials identified and removed prior to the main demolition works. Air monitoring as required.	3	1	3		
6	Design	Damage to rail network crossing site beneath existing stand.	Main Dublin -Wexford passenger and goods rail line being closed for periods of time.	No works during hours of rail operation in the vicinity of the works. Any closure of the rail line required will be minimum and will be programmed in conjunction with Iarnród Éireann (State Rail Agency). Prefabricated solution for works to this area	2	3	6		
7	External	Injunction due to noise and nuisance	Closure of site and delay	Public consultation and agreement with neighbours as to the extent of the works and preventative measures	2	2	4		
8	External	Extreme weather conditions	Delay and disruption	Extensive site investigation regarding drainage etc. Proposed start date in May 2007.	1	2	2		
9	Design	Pollution to local tidal rivers due to demolitions and construction waste	Remedial clean up operations and cost of same.	Identification of rivers etc adjoining the site. Implementation of waste management system in conjunction with site set up. Use of sustainable materials.	1	2	2		
10	Design	Construction programme over run due to late manufacture and delivery of components manufactured off-site	Delay to programme and increased costs. Delay and disruption.	Key off-site manufacturing contractors appointed by client prior to main tender procurement. Design drawings signed off during planning	2	3	6		
11	Design	Unsustainable construction traffic during the early stages of the project	Injunction, delay and disruption, additional costs	Recycling protocol in place for demolition waste. Original sods etc moved to practice pitches.	2	2	4		

Fig 9 – Risk Register (Imperial College London with Author Amendments)

The risk register does not list the risks in order of priority. As you can see the score allocated to the probability multiplied by the score allocated to the impact gives the risk score / category. The risk score is assigned a numeric value whereas the category is assigned a colour code based on the key provided. A larger version of the risk register shown in Fig 9 is provided in the appendices.

- A. Signing off of the brief - Due to the nature and location of this project the Client did not sign off the brief fully until they were satisfied that the neighbours and public at large were satisfied with the project. The locality and its population were very important factors from conception. Not having the local community onside would have been detrimental to the success of the planning process. This has been proven in other high profile planning applications in the area. The impact and probability

were each awarded a score of 3 which contributed to a risk of 9. This shows that the risk is key / critical. Without this risk being addressed the project may be indefinitely delayed or may not proceed.

- B. Objections to planning – All planning applications stand the risk of objections being lodged. The risk generally can be defined as being intermediate and as such a minor stumbling block. However, this project stood the chance of having objections from private parties and semi state agencies such as Iarnrod Eireann (Rail Agency). As a result of these possibilities the risk or objection was greater and as such required mitigation at the early stage of the pre planning application stage. This was done by the Client team being very transparent in its dealings by using public meetings and by consulting with all relevant parties. This prolonged the preparation of the planning application but mitigated the risk of serious objections.
- C. Limited site area - Proposed development will cover most of the site - The limited site area reduced the space available for onsite fabrication. If not addressed this may lead to a delay in the construction programme, additional preliminaries and supervision costs. It was decided by the design team to investigate various forms of off-site construction coupled with traditional methods of construction. A construction programme using a “just-in-time” delivery method was also investigated to mitigate the risk and its impact.
- D. Slow deliveries due to poor infrastructure around the site – At planning stage the need for “just-in-time” deliveries was noted as a solution to risk 2. However, it was also noted that traditional construction methods on large scale projects generally tend to lead to increased levels of traffic. This concern was intensified by the need for additional deliveries due to the volume of proposed off-site manufacture and associated deliveries. The locality in which the project is situated is a well-developed residential and high profile area with no room for the widening of roads and no provision for off street parking of lorries or trailers. This risk is in the intermediate category and can be mitigated using good construction and logistics planning.
- E. Asbestos in existing stands - The construction of the existing stands visibly contained asbestos and as a result also posed a risk. The author has determined this to be a medium risk as the materials used contained minimal amounts of asbestos to constitute a high risk. The risk is still present but as the materials were not damaged,

the author has determined this to be an intermediate risk. In order to mitigate this risk a survey will be carried out in order to identify the extent of the issue and categorise the various risks so as to allow for the safe removal and disposal of same prior to the completion of the demolition works.

- F. Damage to rail network crossing beneath existing stand – The main Dublin to Wexford rail line runs at the base of one of the stands and crosses the site. This adds further limitations to the actual working area of the site as noted in earlier risks. However the proposed structure will actually be partially built over the rail line. The realignment of the rail line is not an option. It is also not an option to divert rail traffic from the area as the Irish rail network is limited compared to other European countries. The author has assumed a medium probability of the risk occurring due to the author's experience of working in proximity to rail networks. The level of training, regulation and safety precautions in place for working on or next to rail lines is defined in Railways Safety Act 2005 and guidelines for third parties are provided by Irish Rail, (www.irishrail.ie). Also the rail line in question does not operate on a 24 hour basis and so work can be scheduled around these periods. However in the event of an incident occurring, it would be detrimental to the project and so the risk is critical to the success of the project. This risk was mitigated by scheduling the works in the area outside of peak rail usage times and by minimising the amount of rail closures required. The use of offsite prefabrication was of huge importance here. The rail line was protected by a pre-cast concrete tunnel which was designed as part of the planning process in conjunction with the rail agency. This was only possible by the involvement of the whole design team and the early involvement of the specialist subcontractors, in this case. This is further confirmed by comments made by Mr. Green of the LRSDC in the Irish Building Magazine's article on the Aviva in 2011.

Fig 10 (Below) Precast tunnel in place above rail network. The new stand is built around this structure.



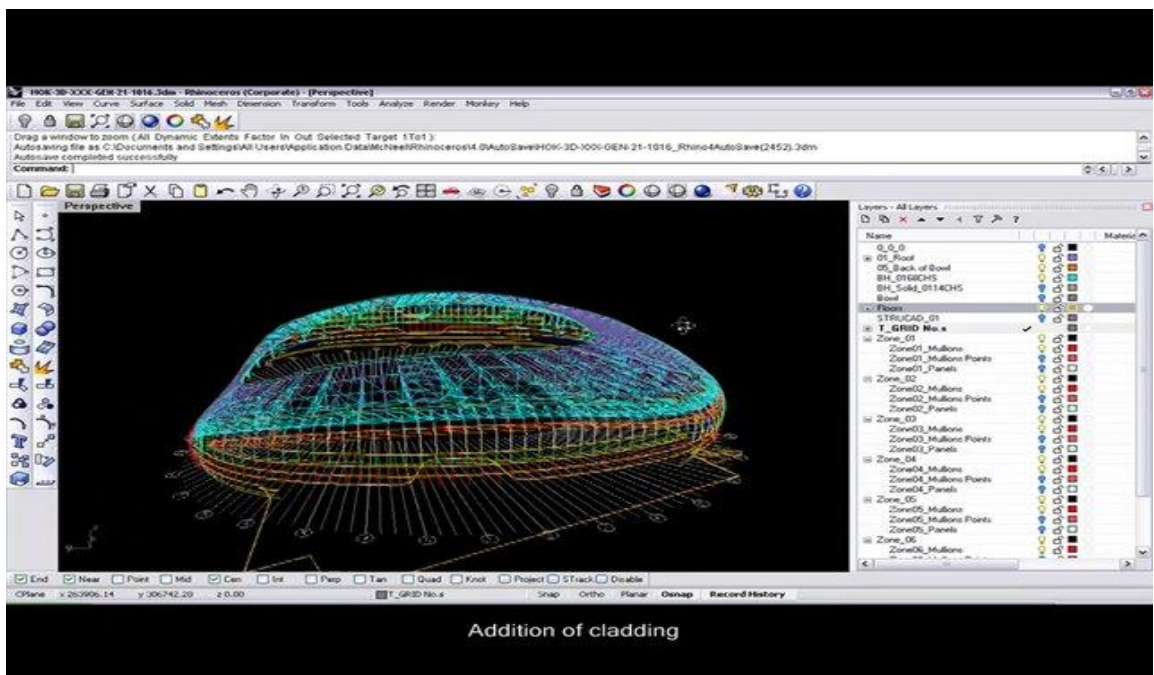
- G. Injunction due to noise and nuisance – The local residents and community groups had previously campaigned vigorously against the redevelopment of the stadium and its facilities. The stadium is situated in a very affluent suburb of the city and so the funding of any opposition was not to be an issue. Any such injunction or threat thereof would have had an adverse effect on the project. It would have caused both time delay and cost issues. The LRSDC made the whole team aware of this at the early stages and it was decided to conduct public consultation and meet with the representative of the groups concerned. Whilst noise and dust are inevitable in all construction projects it must be taken into account that some projects are more sensitive than others. The threat of injunction on this project would not have been a one off occurrence and so it was necessary to mitigate the risk as early as possible. The author presumes that the appointment of a project / community liaison representative or team was key to reducing the risk. This would have allowed a clear line of communication between the all parties concerned.
- H. Extreme weather conditions – This is viewed as a low risk due to the way in which the design developed and the construction methods used. The project still contained factors which needed to be addressed under this heading such as the demolition and

ground works packages. Excessive rain and wind here would have caused delay which would have had a time and cost implications. The site is situated with a few miles of the coast and so was susceptible to intermittent high winds, but no more than other sites in the capital. The author believes that in order to mitigate this risk extensive site investigation works are required to expose area which may be prone to delay due to rain or a rise in the ground water levels. The main mitigating factor is the scheduling of work which can be affected by seasonal weather changes to be scheduled for commencement during periods of relative calm. This information can be accessed through meteorological data.

- I. Pollution to local tidal rivers due to construction and demolition waste – Most of Dublin city and its suburbs is built on reclaimed land. This reclamation started during the Vikings time in Ireland as noted by Simms (1979). As a result there are numerous rivers and underground streams running through the city to the sea at Dublin Bay. One such river, The Dodder, flows close to the site of the Aviva stadium and has many underground tributaries which cross the site. It is necessary to form culverts around these waterways in order to protect both them and prevent flooding to the development. The waterways beneath the development were encased using precast concrete culverts early in the development. This use of precast culverts reduced the risk of construction waste for this process entering the waterways. The fact that the waterways were encased early in the project reduced the risk of any contamination either intentional or unintentional. These measures were decided on in the design and procurement stages.
- J. Construction programme overrun due to late manufacture and delivery of components manufactured off-site - As noted in the Chapter 2 diagrams, the whole design team reviewed the planning from first principles in line with the Client brief and in conjunction with public consultation. This approach led to the need for early and strategic appointment of specialist subcontractors. These sub-contractors had a dramatic input into the design of major elements of the structure. The sub-contractors needed to be chosen based on their ability to design, manufacture and deliver. The main contractor also had a large part in the programming of the works in this regard. A failure on either party's part would have led to delays. These delays would have had significant time and cost delays, not to mention the risk of dispute.

The early appointment and involvement of these subcontractors allowed for designs to be completed and signed off by the Client team before the main contractor was appointed. Site investigations were concluded well in advance and when the project had received planning permission the specialist subcontractors were in a position to organise their production lines as well as their construction teams. This was invaluable. Now the construction team needed to incorporate this information into the construction programme and ensure that the logistical issues noted earlier were resolved.

Fig 11 – (Below) Specialist Subcontractor screenshot showing steel frame at preconstruction stage. (Source – Populous)



- K. Unsustainable construction traffic at the early stages of the project – At the early stages of this project it will be necessary to demolish the existing stand, establish the site and complete the ground works as noted earlier. Traditionally this would mean a line of trucks being loaded and disposing of materials. Traffic is constant around the site due to its location and given that the construction of the project commenced towards the end of Ireland’s last property boom the construction traffic in the city was already a concern. This could have led to injunctions and delays to programme

and cost implications. In order to mitigate the risk recycling protocols were put in place which reduced the traffic and also aided in the sustainable construction of elements of the building. However this did add to the restriction of the working area of the site and was another factor which helped to define which components to the structure needed to be manufactured offsite.

Fig 12 (Below) Demolition of the East stand at the original Lansdowne road stadium.
(Source – www.Flickr.com)



Chapter 4 – Task 3

Offsite Construction

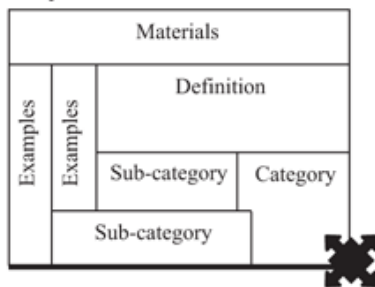
Due to the time constraints mentioned in earlier chapters it is easy to understand how elements of offsite construction were necessary in order to complete the project to the client's requirements and within the required time frame.

Studies in the United Kingdom have noted that the use of offsite construction methods in large housing developments is low. The current usage looks set to increase due to the need *"to improve quality, cost, time, productivity and health & safety"* (Pan, Gibb & Dainty, 2008).

With regard to general construction projects, Alvanchi et al (2012), note that the planning of offsite production of construction components can provide more challenges than solutions to the construction manager. The authors further discuss the use of discrete event simulation to reduce the challenges. During the design and construction of Aviva Stadium elements of 3 dimensional (3D) designs was used to help to ease the planning process.

Early in the planning and design elements of this project the all design team members realised the need for working to the main constraints of the project namely, time and onsite manufacturing facilities. Another issue which was realised is that components manufactured in factory settings provide higher and more consistent levels of quality than those manufactured onsite. However, more planning is required with offsite manufacturing than with onsite construction. Offsite manufacture requires more forward planning than other methods of construction due to the many different types of off-site construction options available.

Key:



Various materials		Steel, pre-cast concrete, timber, aluminium, advanced composites, hybrids	
Door furniture, windows, etc. Bricks, Tiles, etc.	Items always made in a factory and never considered for on-site production		Pre-assembled units which do not create usable space
	Factory-made components	Component manufacture & sub-assembly	Non-volumetric pre-assembly
	Sub-assemblies		
Skeletal		Structural frames	
Planar			
Complex		Cladding, wall panels	
Edge of town retail units, motels, prison blocks, medium rise residential	Factory clad	Modular building	Volumetric pre-assembly
	Clad on site		
	Pre-assembled volumetric units which form the actual structure and fabric of the building		
Steel frames, stressed skin plywood, pre-cast concrete, various cladding, materials		Dry-lined lightweight steel frames, pre-cast concrete, advanced composites	On to another building
		Plant rooms, etc.	Toilet pods, shower rooms

Source: Gibb and Isack (2003)

Fig 13 – Types of Off-site construction.

As shown in Fig 13 there are 3 main classifications of off-site construction and these are

- Non-volumetric pre-assembly – This comprises of units which do not create a usable space in their own rights but are connected to the building frame irrespective of the construction. An example of this is a prefinished wall panel.
- Volumetric pre-assembly – Here a pre-assembled factory finished unit is produced which creates a usable space. An example of this is toilet pod.
- Modular building – Here the preassembled volumetric units referred to above actually form the building as a whole. The main assembly of each of the units to form the structure is completed onsite.

The redevelopment of the Aviva Stadium in Dublin had many constraints in relation to its construction. As noted in earlier chapters these constraints were overcome by appointing the specialist subcontractors at the planning stage. This enabled the whole design team to evaluate the use of different methods of construction prior to the planning stage let alone at tender and pre-appointment of the main contractor.

Precast concrete solutions were used for forming culverts for naturally occurring waterways within the site and a protective tunnel for the rail network running through the site. These were prefinished units which could be defined as being within the volumetric pre-assembly

category as they provided a usable space. It is the opinion of the author that the definition of the usable space is dependant of the function which the structure will fulfil. This function will change from project to project and differs between building and civils projects.

These solutions mitigated risks as noted in the risk register which may have caused delay and cost implications. The use of the precast solution around the rail network saved time and cost as well as disruption to the rail network. The precast solution was designed, manufactured and brought to site on a just-in-time manner. The use of this solution reduced disruption of the rail network to a minimum. It was only necessary to close the rail line for a 72 hour period in order to complete the main installation. This was carried out over a bank holiday weekend with bus transfers in place to provide alternative travel arrangements.

Other precast concrete solutions were also incorporated into the structure. These include elements of the structural frame, floor slabs and stairs. These items on their own do not provide a volumetric solution but would be considered to be part of the non-volumetric pre-assembly. The use of the these forms of construction allowed the building to progress at a more progressive rate than if only traditional in-situ methods had been used.



Fig 14 - Precast Concrete frame construction (source: www.patkirwan.ie)

PM Group's Pat Molloy is quoted as saying "The extensive use of precast concrete elements had the additional benefit of providing a cleaner, whiter finish", (Irish Building Magazine, 2011).



Fig 15 – Roof steel on the Aviva Stadium (Source: www.flickr.com)

The steel frame for the external wall and roof cladding is another example of modular construction on this project. Again Pat Molly refers to off-site manufacture as being a key issue in this regard. Apart from the early design and off-site manufacture the installation of the roof steel work in particular benefited from the use of bolted rather than welded joints. This is a key feature of this well designed off-site manufactured solution. It saved cost and time in construction as well as allowing for a just-in-time delivery process.

Quality Management

It is quite usual in the Irish construction industry for contractors to be asked to provide evidence of quality management certification or evidence of systems they have in place when completing pre-qualification questionnaires. Generally an answer in the affirmative signifies that the contractor has some form of document management systems in place. But is this enough to guarantee quality?

In real terms the short answer is no, not entirely. However, a document management system does provide a paper trail which can be used as part of a quality control system in the construction process.

A paper trail system such as ISO: 9001 can be used to link many functions within an organisation, make processes more streamlined and prevent duplication of work. If we look at the process of the manufacture of a precast floor slab we can look at how a paper based quality management system work.

- Design – Slab engineered and designed to meet client brief. The initial design and specification is reviewed and once correct signed off for issue for construction.
- Tender – The drawings and specification for the slab is now issued for pricing.
- Manufacture – The appointed contractor now has a specification and drawings which specify how the slab is to be made, the materials required, the finish required and all tolerances. And special requirements. This specification allows the manufacturing team to examine the slab and determine if it meets the specification.
- Delivery to site – Once the slab is delivered it will be check for defects by the construction team prior to installation.

The stages noted above are just overviews and do not look deeper at the review and examination of the many components of each stage.

In relation to the Aviva Stadium project it was very important to have a quality management system in place. Given the size and complexity of the project the system required would need to have many tiers and be adaptable to all processes within the project.

In relation to this project I believe the pre-planning process used was a variant of Business Process Reengineering (BRP). Harmon (2003, chp. 9) describes a comprehensive generic methodology consisting of five phases as outlined below:

1. Planning a process design effort
2. Analysis of an existing process
3. Design of a new or improved process
4. Development of resources for an improved process
5. Managing the implementation of the process

With regard to the Aviva Stadium project the first phase consisted of the formation of the project team and its key players. The second was a review of the traditional pre-planning and procurement mechanisms. The third was the design of the new strategy which incorporated early engagement of the many design team members and specialist subcontractors and the decision to engage new construction techniques and mechanisms. The fourth was the review of resources required for the process. These resources include mechanisms for design, manufacture, delivery and installation. The fifth, the author assumes, was the formulation of management structures for the control of quality management.

The author believes that the BRP methodology can be used in many different sectors on many industries with success.

Chapter 5 – Conclusions and Recommendations

Every construction project is different. The Aviva Stadium redevelopment is a very unique structure and had many different issues which required meticulous planning and execution. The client was well aware of the many problems which could arise in relation to the planning of the project but was willing to acknowledge that the only way to proceed in an efficient manner was to employ a team of expert construction professionals from the earliest point possible.

The project process as outlined in the Irish Building Magazine (2011) shows how a multi-disciplinary team, including specialist subcontractors, working together could re-engineer the planning and construction process in a manner which saved more than a year from programme. Whilst the design of the building could have been achieved using traditional construction methods the consistency of the quality of the finishes may not have been achieved.

The main recommendations that the author would make are:

1. The clients should take council from there professional team and plan their projects correctly and in a timely manner.
2. The whole project team should define the processes to be used in the construction and evaluate the benefit of alternative methods of construction and the possible benefits which may be derived from their use.

The author was impressed by the manner in which the planning stage was approached by the client and the design team. The use of strategic subcontractors early in the design and procurement process was ingenious.

Chapter 6 – References

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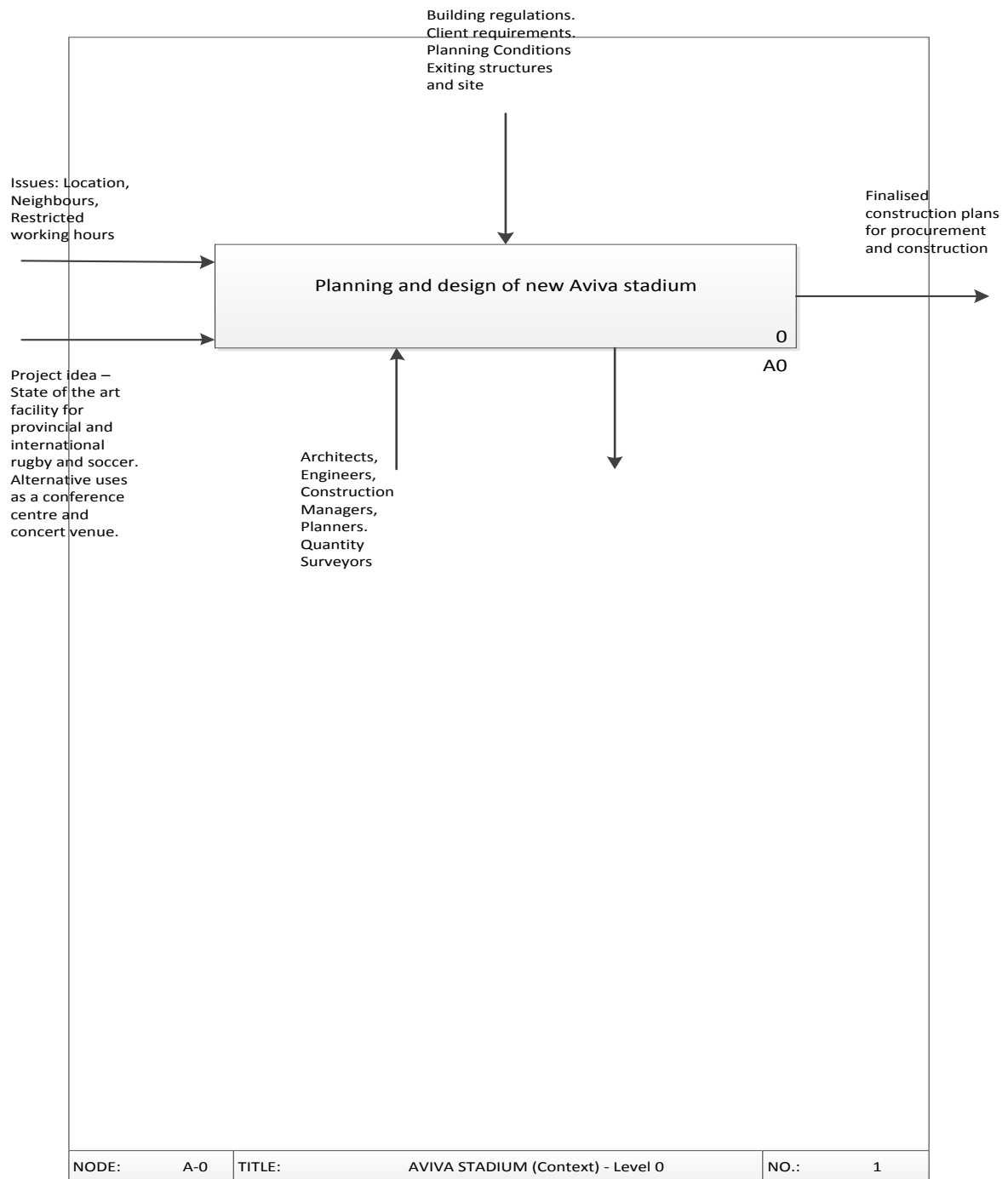
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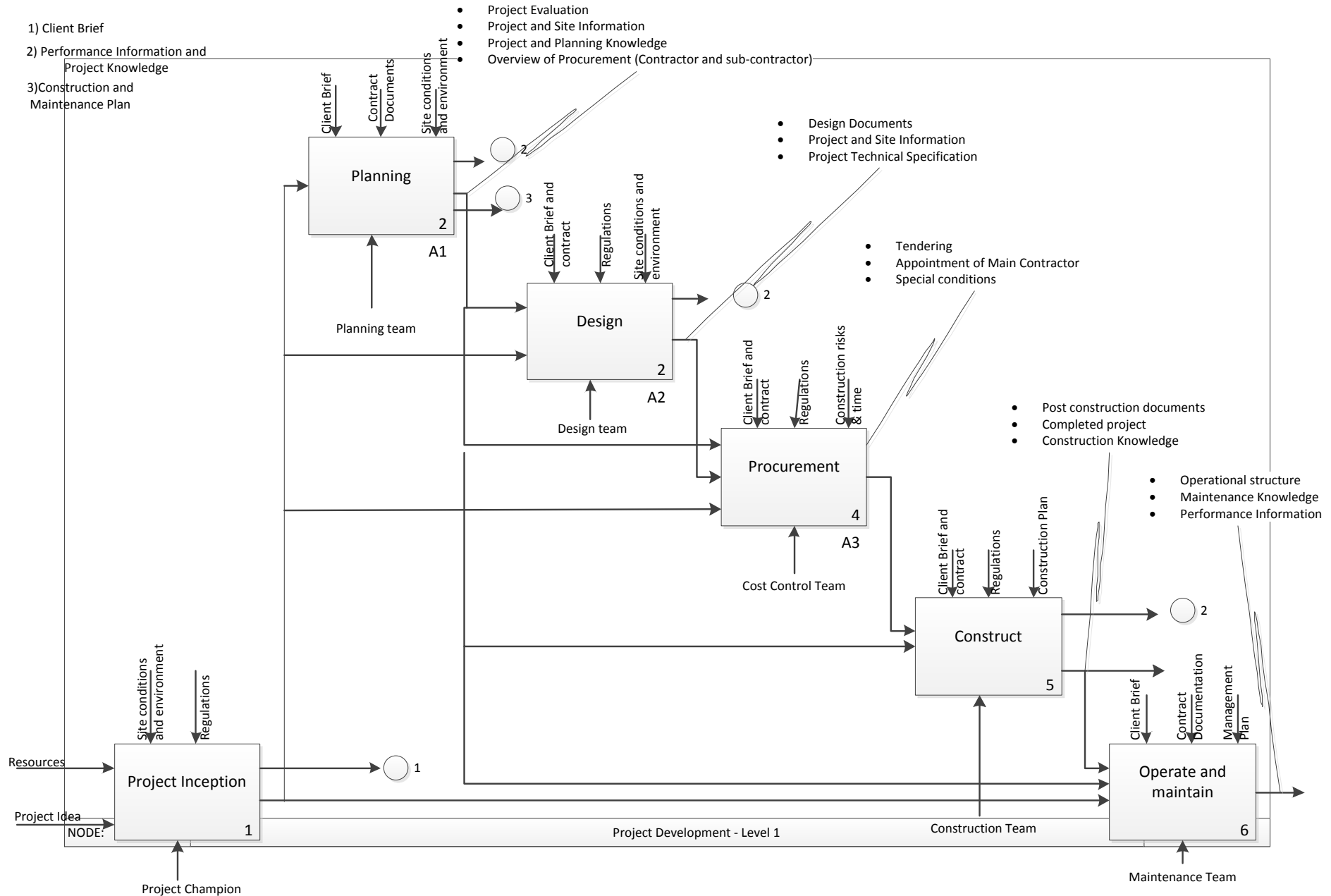
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Chapter 7 – Appendices

IDEFO Diagrams





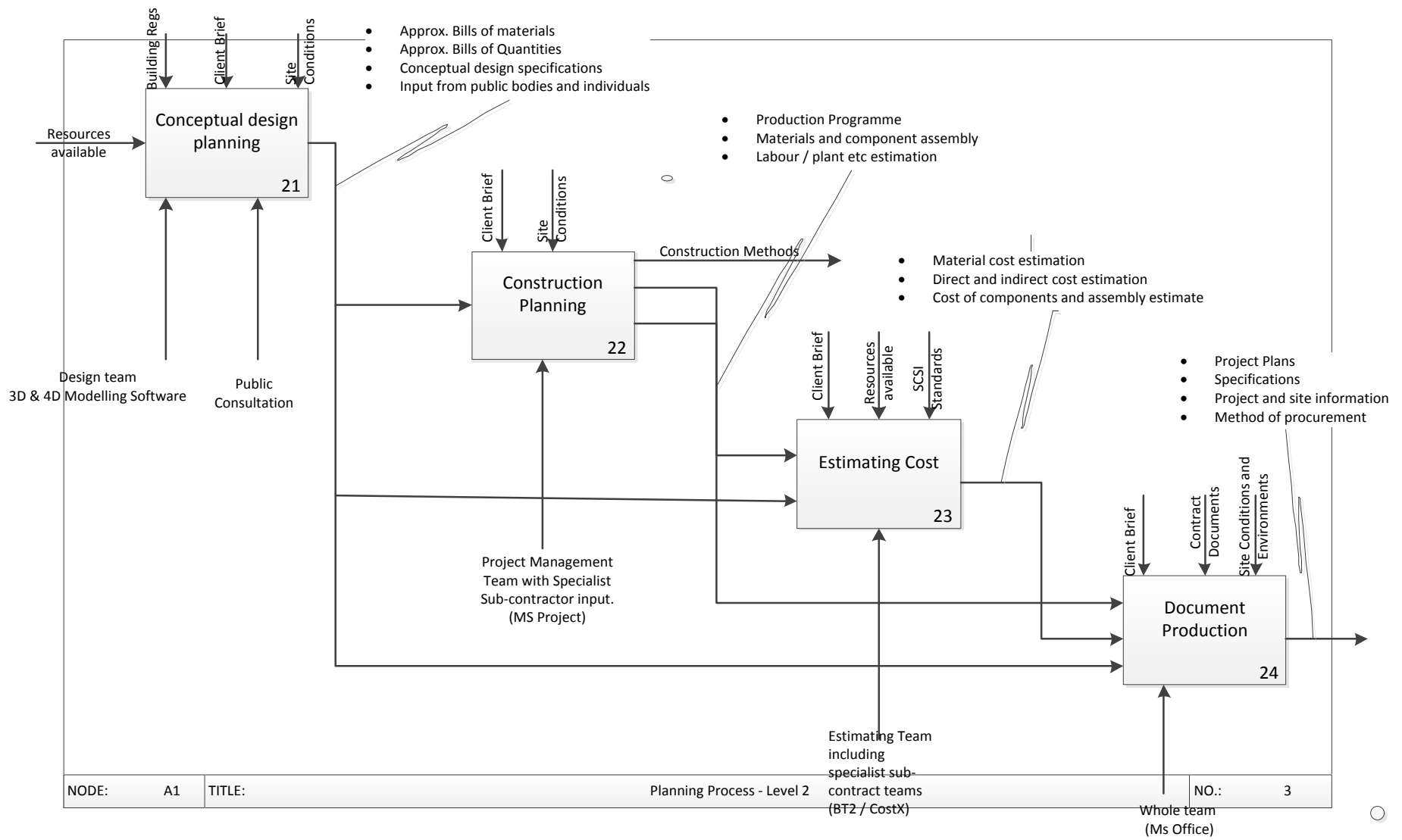
- 1) Client Brief
- 2) Performance Information and Project Knowledge
- 3) Construction and Maintenance Plan

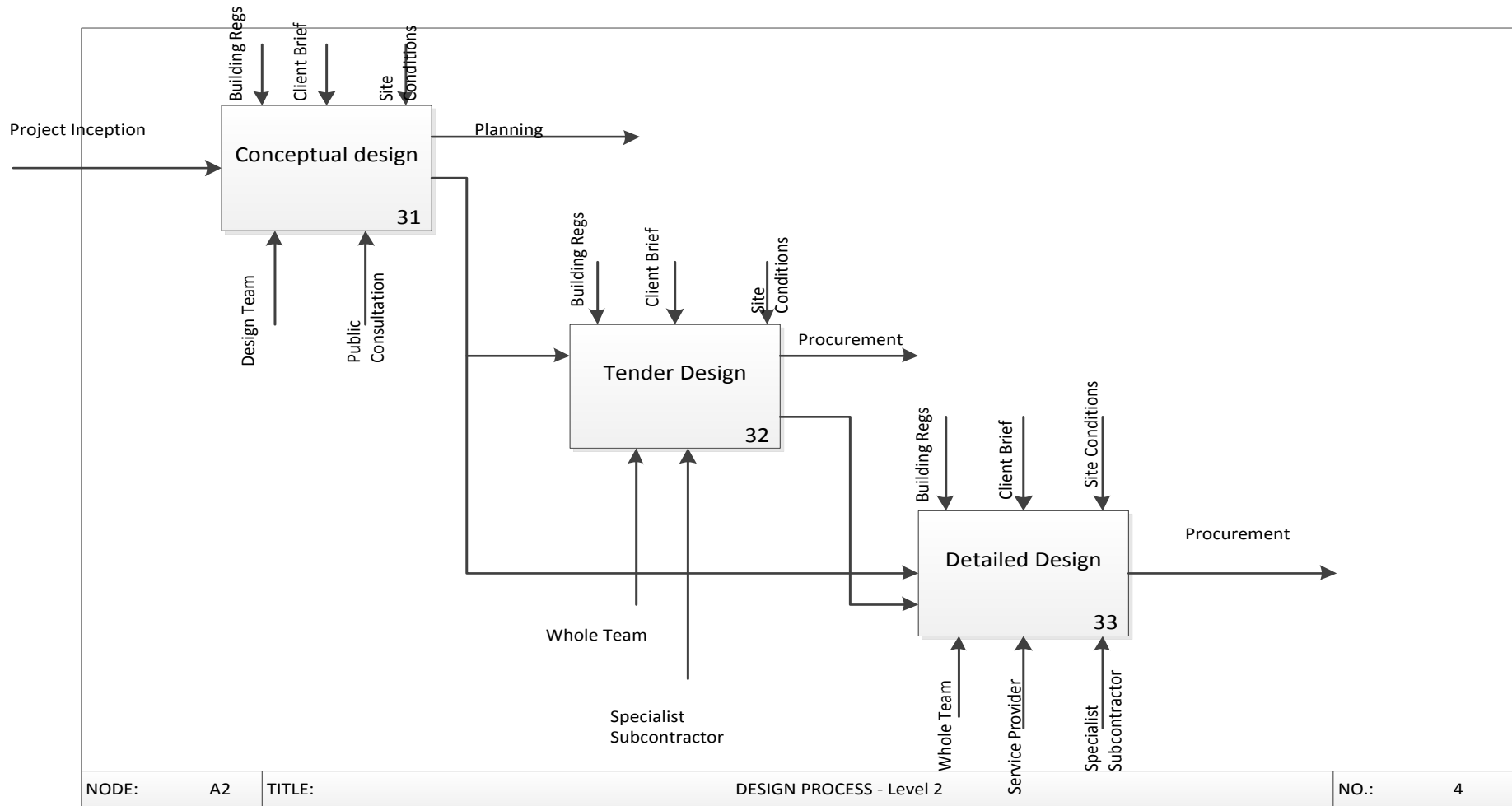
- Design Documents
- Project and Site Information
- Project Technical Specification

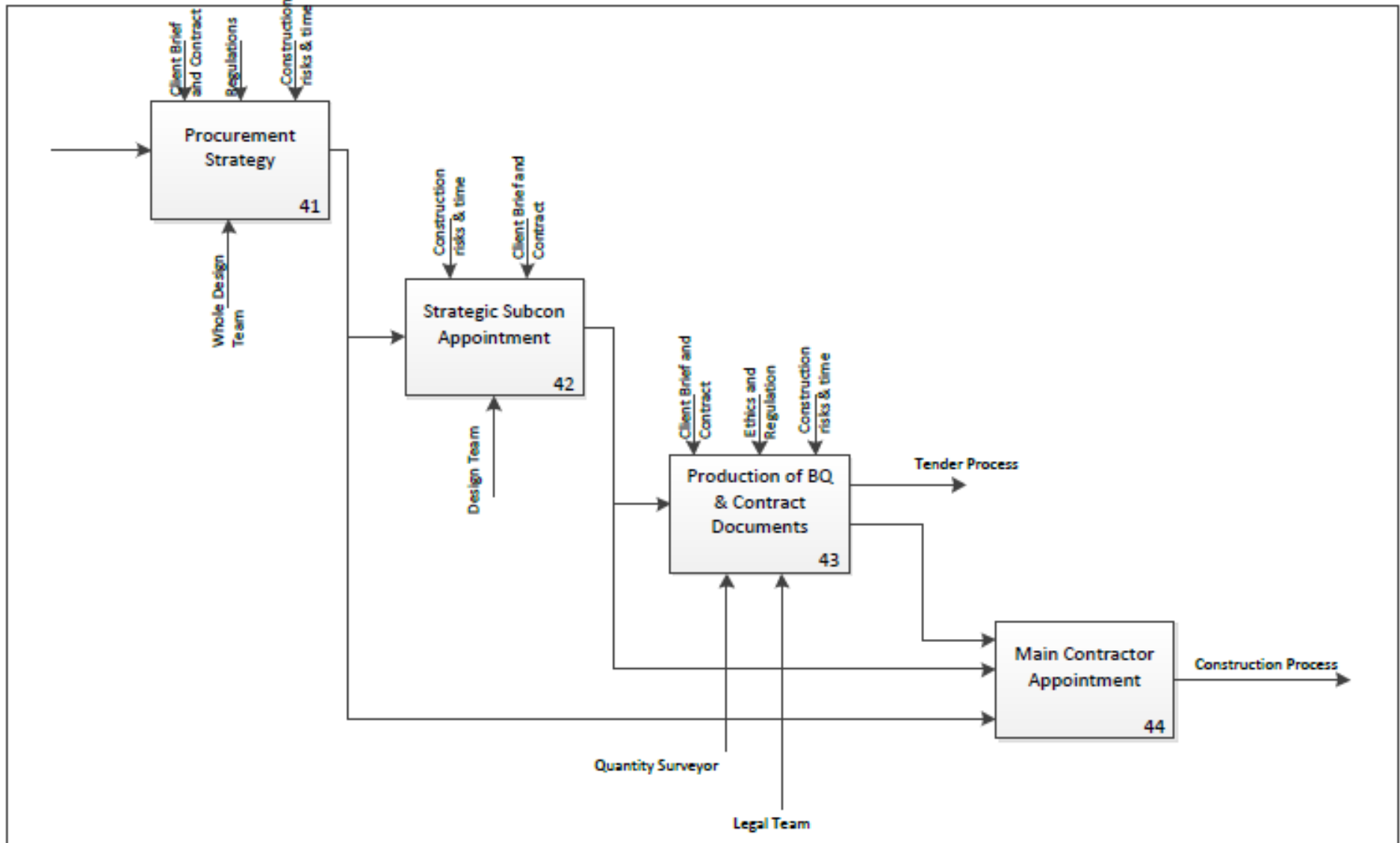
- Tendering
- Appointment of Main Contractor
- Special conditions

- Post construction documents
- Completed project
- Construction Knowledge

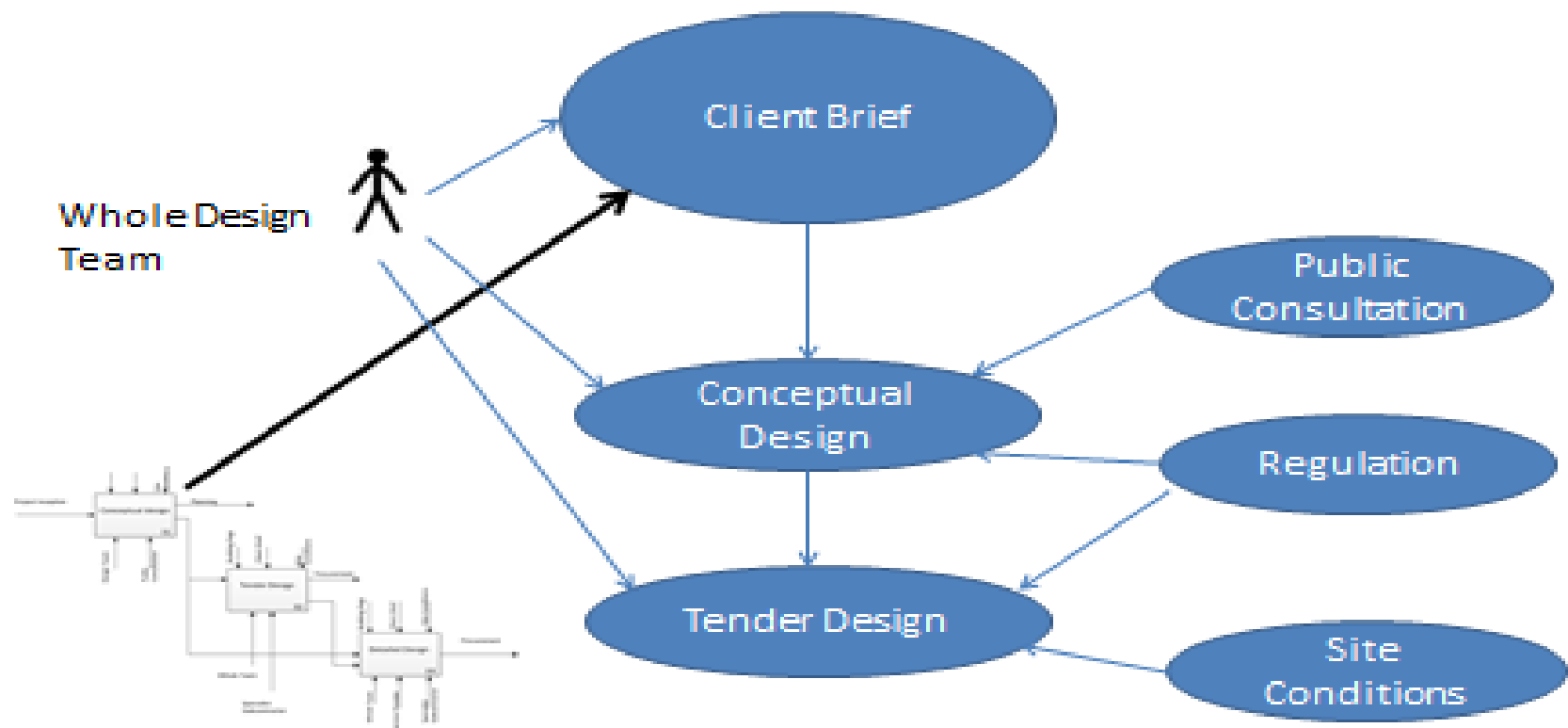
- Operational structure
- Maintenance Knowledge
- Performance Information



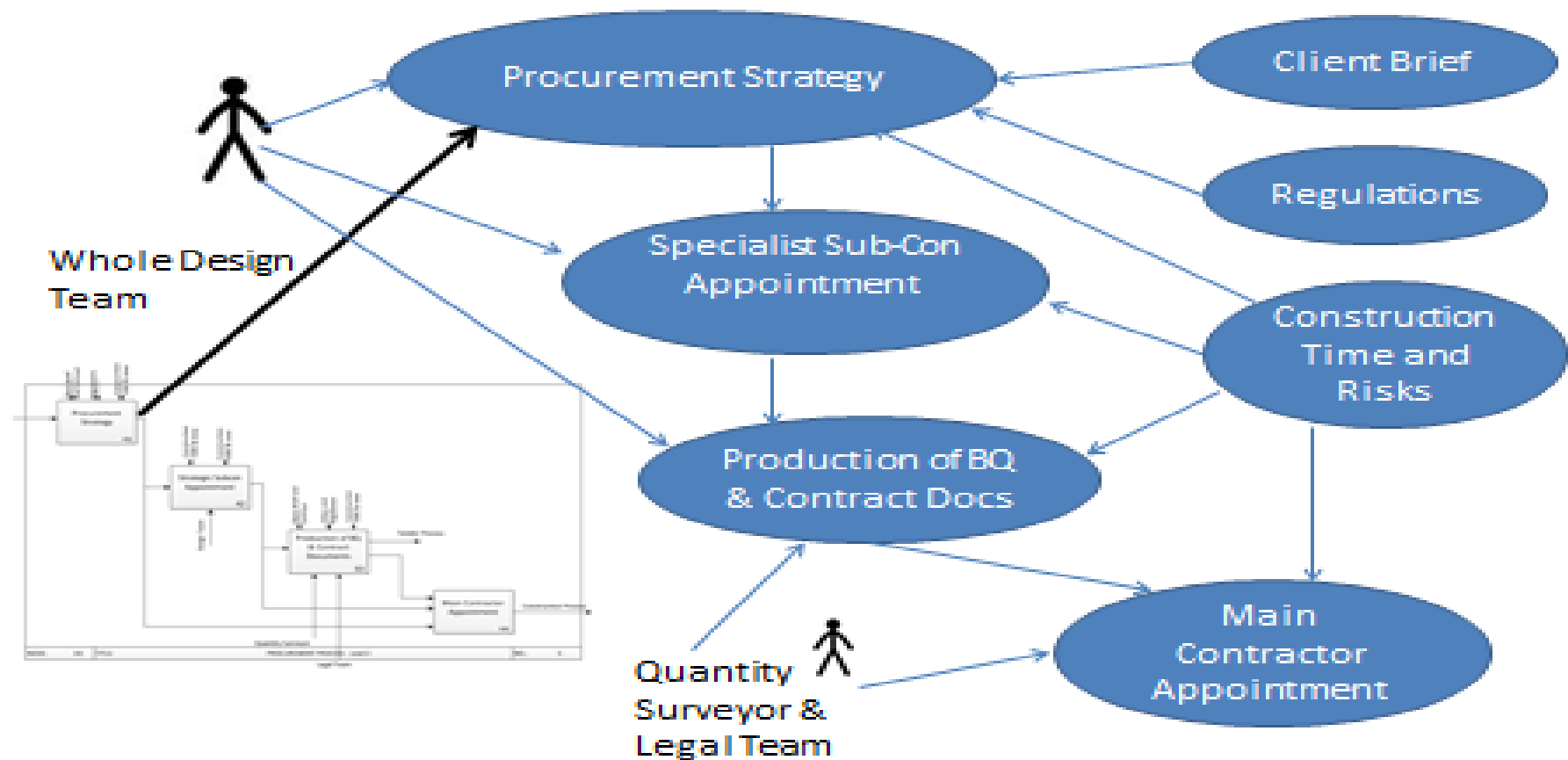




Conceptual Design - UML



Procurement Strategy - UML



Risk Scoring Matrix

Impact	High/ Critical	3	3	6	9
	Medium/ Serious	2	2	4	6
	Low/ Marginal	1	1	2	3

1	2	3
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Low/ Improbable	Medium/ Could happen	High/ Probable
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Probability




Probability Categories

Description		Prob	Scale Value
H	Probable	>70%	3
M	Could happen	30-70%	2
L	Improbable	<30%	1

Impact Categories

Description		Guide Scenario	Scale Value
H	Critical	Failure that involves significant rework, modification or reassessment	3
M	Serious	Failure or setback that causes additional work and reassessment but containable	2
L	Marginal	Impact has some effect causing rework or reassessment but easily handled	1

Risk Category & Action

	Key/ Critical Risks - closely monitor, manage & develop fallback plans
	Intermediate Risks - monitor and manage to mitigate/ include specific risk allowances in cost estimate/ programme
	Minor Risks - general allowance in base cost estimate & programme

RISK SCORING MATRIX (Imperial College London)

RISK IDENTIFICATION & MITIGATION					RISK ASSESSMENT - RESIDUAL RISK				
Ref	Category / Responsibility	Risk	Potential Impact	Completed Mitigation Action (to date)	Prob. Impact	Risk Score/ Category	Cost Impact (Project Costs) [€]	Schedule Impact [weeks]	
1	Client	Signing off of brief can lead to design changes	Delay planning and commencement	Public consultation with Client and design team. Early input from all design team members.	2	2	4		
2	External	Objections to planning	Project indefinitely delayed. Cost for redesign. Client in contract with specialist sub-contractors who are aiding with design.	Transparency in development proceedings and public consultations. Planning application delayed to allow all interested parties time to make submissions.	2	3	6		
3	Construction	Limited site area - proposed development will cover most of the site.	No storage or space for on-site manufacture causing delay and additional cost.	Investigation into off-site manufacturing solutions and delivery in a "just-in-time" manner.	3	2	6		
4	Construction	Slow deliveries due to poor infrastructure around the site	Extended construction period and delays	"just-in-time" method of deliveries. Designated drop zones on site and precise planning.	2	2	4		
5	Construction	Asbestos in existing stands	Asbestosis to those involved in demolition and in the vicinity of the works.	Survey carried out. All hazardous materials identified and removed prior to the main demolition works. Air monitoring as required.	3	1	3		
6	Design	Damage to rail network crossing site beneath existing stand.	Main Dublin -Wexford passenger and goods rail line being closed for periods of time.	No works during hours of rail operation in the vicinity of the works. Any closure of the rail line required will be minimum and will be programmed in conjunction with lamrod Eireann (State Rail Agency). Prefabricated solution for works to this area	2	3	6		
7	External	Injunction due to noise and nuisance	Closure of site and delay	Public consultation and agreement with neighbours as to the extent of the works and preventative measures	2	2	4		
8	External	Extreme weather conditions	Delay and disruption	Extensive site investigation regarding drainage etc. Proposed start date in May 2007.	1	2	2		
9	Design	Pollution to local tidal rivers due to demolition and construction waste	Remedial clean up operations and cost of same.	Identification of rivers etc adjoining the site. Implementation of waste management system in conjunction with site set up. Use of sustainable materials.	1	2	2		
10	Design	Construction programme over run due to late manufacture and delivery of components manufactured off-site	Delay to programme and increased costs. Delay and disruption.	Key off-site manufacturing contractors appointed by client prior to main tender procurement. Design drawings signed off during planning	2	3	6		
11	Design	Unsustainable construction traffic during the early stages of the project	Injunction, delay and disruption, additional costs	Recycling protocol in place for demolition waste. Original sods etc moved to practice pitches.	2	2	4		

RISK REGISTER – Imperial College London (– Amended)