AN APPLICATION OF THE ANALYTIC NETWORK PROCESS TO ASSESS RISKS IN A MEGA-CONSTRUCTION PROJECT[1]

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ABSTRACT

This paper aims to introduce an Analytic Network Process (ANP) as an innovative tool to support the decision makers or project managers to deal with the potential risks of mega-construction projects. Risks assessment criteria used to accomplish the ANP calculation was based on both a review of the literature and related experience against Social, Technological, Economic, Ecological and Political (STEEP) requirements. A large airport terminal, London Heathrow Terminal 5, was chosen as a case study to demonstrate the effectiveness of the ANP model. The result reveals that ANP is an effective tool to support developers to make decisions based on risks assessment during their feasibility analysis. The ANP model proved its efficiency, and can be adopted by

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construction practitioners to suit the project requirements in order to assess risks in the mega-projects. However, it is recommended additional study is needed to assess risks in mega-projects.

Keywords: Analytic Network Process (ANP), mega-project, risk assessment, STEEP factors

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1. Introduction

Risks and uncertainties always occurred in complicated construction projects that involve many stakeholders and strongly influence the project's progress from feasibility through project handover stage (Flyvbjerg et al., 2003). Clarke and Varma (1999) state the typical risk management process is ongoing and iterative. Even though each mega-project project is different and unique, this process usually contains the following basic steps: risk identification and initial assessment, risk analysis, risk assessment, and risk mitigation (see Figure 1)

Generally speaking, risks have various definitions. However, risk is simplified as a concept that denotes a potential negative impact to an asset, project, or some characteristic of value that may arise from some present process or future event (Crossland, et al, 1992).

Risk is also classified by the "total risk" definition. Baum and Crosby (2008), Brown and Matysiak (2000), and Hargitay and Yu (1993), state "total risk" is associated with several factors, and it is subdivided into two major categories as "Total risk = Systematic risk + Unsystematic risk". Systematic or uncontrollable risk is caused by several external factors that can affect the project, such as the economy or government policy impact on property investment changes. Unsystematic or specific risk is limited or controlled by investors or developers, and relates directly to the company or project's performance and investment decision making.

To clarify the sources of risk in the mega-construction projects, we addressed risks based on Social, Technological, Ecological, Economic and Political (STEEP) factors, which need to be considered while developing a new project (Morrison, 2007). For example, risks in a construction project have been considered in relation to the separation of design from construction, lack of integration and poor communication, uncertainty and changing in environment, economic changes including greater pressure from political issues (Gehner, et al., 2006, He, 1995). STEEP factors risks must be considered and should not be underestimated because of the impact on overall project management progresses, including: project schedule delay, cost overrun and improper project quality which could cause severe loss to project stakeholders and public interest (PMBOK, 2004). STEEP factors were used because it has been used widely in the business context, but in different names, including PEST, TESP, and STEP (Chapman, 2008). The classification of risks in STEEP formation is pragmatic as well as; it is simple and clearly understood by all project participants (Nezhad and Kathawala, 1990).

1.1 Mega-project Definition

Flyvbjerg, et al., (2003) defined "mega-project" as an extremely large-scale investment project. It is typically defined as costing more than $1 billion (approximately £700 million). Examples of mega-project are bridges, tunnels, highways, oil refinery plants, railways and airports (civil and infrastructure works). Large commercial or industrial buildings, information technology systems, and aerospace projects are also included as mega-projects. Mega-projects also draw a lot of public attention because of they have a more substantial impact on communities, the surrounding environment, and budgets. They can also be simplified as "initiatives that are physical, very expensive, and public." It is then accepted that mega-project stakeholders have to pay more extensive concerns during the project development process in order to reduce any possible bias and strategic misrepresentation.

Risks in mega-projects are caused by various sources, both external (inconsistent political situations, lack of local government or community support, community protest, and economic recession) as well as internal factors (lack of communication between project participants, project managers and consultants' experience, improper project fund, and contract development and management) (Choi, et al, 2004; Baccarini and Archer, 1999; Akintoye and MacLeod, 1997 and He, 1995).

The London Heathrow Terminal 5 was classified as "mega-project" due to its size, project budget, construction duration, and the particular impact to surrounding environments and local communities. It also suffered from several sources of risks as well as its complexity. STEEP factors were used as the original sources of risk in this project, and the requirements of STEEP were then associated with the established risk assessment criteria in this paper.

1.2 Current risk assessment methods

Risks assessment methods are continuously developed in construction industry. Bahar and Crandall (1990) introduced a construction risk management system (CRMS) model in the real construction projects that effectively quantifies risks and uncertainties, as well as develops various strategies for dealing with the risks. CRMS consists with four processes: risk identification, risk analysis and evaluation, risk response management, and system administration. These processes were arranged in logical sequential orders, and became more systematic risk assessment method for construction projects. CRMS itself is also counted as a quantitative method rather than subjective one because results could be clarified and potential consequence of risk quantitatively assessed.

Baccarini and Archer (2001) developed the project risk ranking (PRR) method to assess risks to overcome the problem of limited resources to manage equally all risks in many projects. PRR also assesses the relative level of risk of contracting projects in order to estimate an appropriate level of effort to apply to the management of those projects. PRR requires the senior management level to adjust an appropriate score for each risk factor, and then prioritize risk likelihoods and consequences against project time, cost, and quality. Risk is calculated by multiplying the likelihood and consequences of time, cost, and quality. Finally, PRR categorizes the rank of each risk to indicate the highest level of risk affect to overall project progress.

However, Choi, et al (2004) argues that even CRMS model could provide systematic approach to quantify the uncertainties in construction project that this model failed to explicitly quantify subjective judgment data. He accentuates that risks in mega-project are not only caused by objective or quantitative factors, but by subjective factors, such as social risks or political risks. PRR calculation mostly relies on the judgment from the experts or managerial level, so PRR shares the similar disadvantage as risk matrix (see next section), because results derived by both methods are not based on systematic calculation or objective assumptions related to a real project case. Results of this PRR may be varied and biased depending on the panel's perceptions and experience towards risks.

According to the nature of risks in mega-construction projects, risks are mostly caused by both quantitative and qualitative factors (Miller and Lessard, 2008; Morrison, 2007; Choi, et al, 2004). Therefore, Flyvbjerg, et al. (2003) indicated that project managers require the alternative risk assessment methods such as Multi-Criteria Decision Analysis models (MCDM) to assess risks caused by objective or subjective factors. Thus, this paper therefore focuses on the consequences of risks before the project managers conduct the project feasibility analysis, because feasibility analysis is a significant tool to forecast uncertainties as well as to assess the vitality of mega-project construction.

To response to these requirements of mega-projects, we adopted Analytic Network Process (ANP). Saaty (2005) defined that ANP is the systematic approaches that can deal with both quantitative and qualitative factors under multiple criteria. ANP approach is then applied to assess risks in a case study against STEEP factors. London Heathrow Terminal 5 project was used as a case study for demonstrating the effectiveness of ANP model to assess risk in the mega- projects. Because ANP is able to deal with a multi-criterion analysis and comparison, and its outcome will be in a mathematic statistics format, ANP could be therefore adopted as a supportive evidence for additional decision making of the risk response and mitigation (Chen and Khumpaisal, 2009).

ANP has been used to assess risk assessment techniques in construction projects. For example, Lu, et al., (2007) implemented ANP to assess risk in an urban-bridge construction project in Taiwan. Their risk assessment criteria covered engineering risks or natural disasters in the construction projects, such as inefficient experience and skill (construction workers), earthquakes, planning, and inadequate design. They found that the risk caused by planning and inadequate design had the highest impact to the case study.

Beltran, et al., (2010) applied both Analytic Hierarchy Process (AHP) and ANP to select the appropriate photovoltaic power plant project to be developed in Spain. The selection criteria were established with the consideration to six type of risks affecting the construction of the project. Their risk criteria consisted of political, technological, economic, time delay, and legal, and social issues. They concluded their study project had been strongly affected by the changes in energy policy, social consequences resulting from land acquisition, and delays in obtaining an environmental study. It was also found that the external factors had the higher impact on the selection and construction of project.

However, our risk assessment criteria were constructed based on the requirements of STEEP factors because STEEP factors cover various sources of risks occurred in the mega-construction project, and their ease of interpretation and explanation for all project participants (Chen and Khumpaisal, 2009).

2. Risk Assessment Criteria

Risks assessment criteria, emphasizing risks and their consequences in mega-project construction was set up and based on extensive literature reviews and the researchers' experience. These assessment criteria were set up based on the STEEP factors' requirements, those shall be concerned when the developers conducting a project feasibility analysis, because of the STEEP factors would cause the variety of risks throughout each project development stage. The assessment criteria and sub-criterion, classified in both quantitative and subjective format, are summarized in Table 1, and adopted as the assessment criteria to assess risks and their consequences in the particular case study. This table includes five major criteria and their 30 sub-criteria (see Table 1).

2.1. Social Risks

Social risks in the mega-projects are mostly caused in the subjective patterns; the practitioners employ qualitative analysis methods to measure and assess consequences of this social risk (Baccarini and Archer, 2001). In addition, the measurement of interdependences inside and outside the social risks cluster requires all social risks to be quantitatively measured. The six social risks consisted in this criterion are:

Community acceptability: evaluated by the degree of benefits to local communities.

Community's participations: evaluated by the degree of discourse of partnership and empowerment to community (Atkinson, 1999).
Cultural compatibility: evaluated by the degree of business and lifestyle harmony within the context of London Metropolitan Area. In this regard, the cultural compatibility could be measured by conducting a marketing survey focusing on the business and lifestyle within the local business context.
Public hygiene: measured by degree of project impact on local public health and safety. The criteria for assessing core standards to establish measurement criteria for public health care and hygiene issued by Commission for Healthcare Audit and Inspection (CHAI, 2006) were modified to assess risks caused by public hygiene issues.
Social needs for new development: this issue is critical to the design and construction of mega-project because of the needs of local community toward the new project must be realized by the project sponsors. Here, risks are measured by the degree of balance between physical development and social needs (Jones and Watkin, 1996).
Workforce availability: measured by the degree of the project sponsor's satisfaction to local workforce market, in terms of quality and amount of workforce. Danter (2007) defined that workforce availability could be measured by consensus methods or observation of workforce targets in the project trade area.

2.2. Technological risks

In this paper, technological risks are defined as the risks typically causing affects or difficulties to project participants from design, project deliveries, construction and execution, through property usage after project handover stage. Risks also included those associated within each project management activities against the basic project requirements of construction, including: project schedule, project cost and quality management are also counted as this risk. (Miller and Lessard, 2008; Smith, et al., 2006; Flyvbjerg, 2003).

There are several more technological risks embedded in this case study due to the project's complexity. However, this paper will focus on the following 10 assessment criteria:

Accessibility and evacuation: evaluated by degree of degree of easy access and quick emergency evacuation in use (Moss et al., 2007).
Amendments: evaluated by possibility of amendments in design and construction.
Constructability: evaluated by degree of technical difficulties in construction.
Duration of development: measured by ratio of total duration between design and construction per 1,000 days.
Durability: measured by probability of refurbishment requirements during a building's lifecycle.

Facilities management: measured by degree of complexities in facilities management and for airport facility management. It could be measured by its performance to handle a large number of passengers (Brown and Pitt, 2001).
Project integration and communication: measured by degree of conflict between project participants, designers, contractors and clients, which will obstruct the construction progress (PMBOK, 2004).
Project Procurement: evaluated by degree of conflict between designers, clients and all contractors (Wolstenholme, et al 2008).
Quality of construction works: measured by degree of project owner's satisfaction toward potential quality standard. Here, it could refer to Greater Toronto Airports Authority's airport construction code (2005).
Transportation's convenience for the passengers: evaluated by the degree of public satisfaction to mass transportation provided to the new project area, including the accessibility to that transportation (Couch and Dennemann, 2000).

2.3. Ecological risks

The development process of any mega-project causes ecological impacts to the surrounding environment or to the local communities due to its site, large number of participants, and length of development duration. The project in this case study produced various sources of pollution, including aircrafts noise, CO_2 or suspense dust, during the development process, and affected the surrounding area (Lister, 2008). The ecological risks assessment plays a key role in the mega-project construction process since the assessment helps the developer to realize the components and environmental issues of the constructed site.

Harrop and Nixon (1999) stated that ecological risk assessment could also help the project sponsors to: identify sources and components of hazards in a facility; analyze the likelihood of hazardous substances in the ecological media through which they are transported; determine the release probabilities, quantities, and rates; identifiy exposure pathways by which substances could reach receptors and the sensitivity characteristics of the receptors at risk; estimate risk of an accepted dose-response relationship; and evaluate the acceptability, or tolerability of the estimated risk.

The four risks included (see Table 1) in this ecological category are:
Adverse environment impact: measured by overall value of the Environment Impact Index developed by Chen, et al., (2005).
Land contamination: evaluated by the fluctuation of the surrounding land plot's price after the completion of the development (Boyd, et al., 1996).
Pollution during the development: measured by CO_2 level (%) or total ecological impact for aeronautical activity (Brown and Pitt, 2001).
Site conditions: measured by the degree of difficulties in site preparation before the project commenced.

2.4. Economic risks

The uncertainties of economic and financial situations strongly impact a mega-project's development process and its vitality. Normally, project sponsors require the highest return of investment, and thus they have to bear the high economic and financial risk, as well. Typical economic risks in construction projects are caused by the variation of interest rates, loan and developer credit, sources of development funding, and project debt and equity ratio (Sagalyn, 1990; Case, et al., 1995; Nabarro and Key, 2005; Strischeck 2007). In addition, project sponsors require the highest life cycle value of the properties, which could be measured by Net Present Value (NPV) achieved from the investment (Smith, et al., 2006; Adair and Hutchison, 2005). Marketing managerial factors, such as demand and supply forecasting for the mega-project, can also cause economic risks (Miller and Lessard, 2008; Adair and Hutchison, 2005). According to the characteristics of a studied project, the competitors of Terminal 5 are comparable to other UK International airports, such as Manchester, London Gatwick (BAA, 2009). Economic risks also cover the number of jobs created and loss during the project life cycle. In fact, this project injected more than 15,000 posts into the British aviation job market, but it affects the existing workers in this constructed area as well (BAA, 2009). Thus, the following criteria are established to assess this project's economic risks:

Capital exposure: evaluated by estimated rate of lifecycle cost per £1 billion.
Demand and supply: measured by degree of regional (UK) competitiveness.
Development fund: measured by the amount of fund injected to the mega-project, as well as number of funding sources availability to project investors.
Interest rate: measured by degree of impacts to project investment in regard to an increment of loan interest rate.
Investment return: measured by the percentage of internal rate of return (IRR) and capitalization rate required by the project sponsors.
Job creation: measured by number of jobs created and loss for the project's life cycle.
Lifecycle value: measured by depreciation percentage of 5-years of use after the project's opening.

2.5. Political risks

For this paper, political risks are defined as risks caused by the long duration in approval process from the related authorities and public inquiries activities. A long duration consumed by these approval activities will apparently affect the vitality of the project.

According to the specific characters of a studied project, there are the risks criteria categorized in this criteria, which are:

Political activists/group: measured by degree of protest by the urban or local communities affected by the new project (Arthurson, 2001).

Council or local administration approval: evaluated by total days of construction, design approval process by planning committee. The level of risk is dependent upon the number of days consumed by approval process, which would affect the project's schedule and income stream (Flyvbjerg, et al.,2003).

Public inquiries: evaluated by the total days of public inquiry affecting operating time. Case study itself suffered from a long period of public inquiry, 46 months, from May 1995 until March 1999, which also affected the operation of new terminal and project budgets (Pellman, 2008).

Table 1
Risks Assessment Criteria for the mega-projects

Criteria	No.	Sub-Criteria	Valuation methods	References
1. Social risks	1.1	Community acceptability	Degree of benefits for local communities (%)	Danter, 2007
	1.2	Community's participations	Degree of discourse of partnership and empowerment to community	Atkinson, 1999
	1.3	Cultural compatibility	Degree of business & lifestyle harmony with the context of London Metropolitan Area (%)	Danter, 2007
	1.4	Public hygiene	Degree of impacts to local public health & safety (%)	CHAI, 2006
	1.5	Social needs for new development	Degree of balancing between physical development and social need (%)	Jones and Watkins, 1996
	1.6	Workforce availability	Degree of the project sponsor's satisfaction to local workforce market (%)	Danter, 2007
2 Tech-nological risks	2.1	Accessibility & evacuation	Degree of easy access and quick emergency evacuation in use (%)	Moss, *et al*, 2007
	2.2	Amendments	Possibility of amendments in design and construction (%)	Flyvbjerg, *et al*, 2003
	2.3	Constructability	Degree of technical difficulties in construction (%)	Khalafallah, *et al*, 2005
	2.4	Duration of development	Total duration of design and construction per 1,000 days (%)	Khalafallah, *et al*, 2005
	2.5	Durability	Probability of refurbishment requirements during buildings lifecycle (%)	Chen, 2007
	2.6	Facilities management	Degree of complexities in facilities management (%)	Brown & Pitt, 2001; Moss, *et al*, 2007
	2.7	Project integration & communication	Degree of conflict between designers, clients and contractors (%)	PMBOK, 2004
	2.8	Project procurement	Degree of conflict between project sponsors and vendors (%)	Wolstenholme, *et al*, 2008
	2.9	Quality of construction works	Degree of performance of construction works toward potential quality standard (%)	GTAA, 2005
	2.10	Transportation's convenience	Degree of public satisfaction to transportation services after new development (%)	Couch & Dennemann, 2000
3. Eco-logical risks	3.1	Adverse environment impacts	Overall value of the Environmental Impacts Index (EII)	Chen, *et al*, 2005
	3.2	Land contamination	Price of the contaminated land plot	Boyd, et al, 1996
	3.3	Pollution during development	Degree of pollution measured by CO_2 level (%)	Harrop & Nixon, 1999, Lister 2008, Brown & Pitt, 2001
	3.4	Site conditions	Degree of difficulties in site preparation for each specific plan (%)	Danter, 2007, Khalafallah, *et al*, 2005
	4.1	Capital exposure	Rate of estimated lifecycle cost per 1 billion pound (%)	Smith, et al, 2006; Adair & Hutchison, 2005

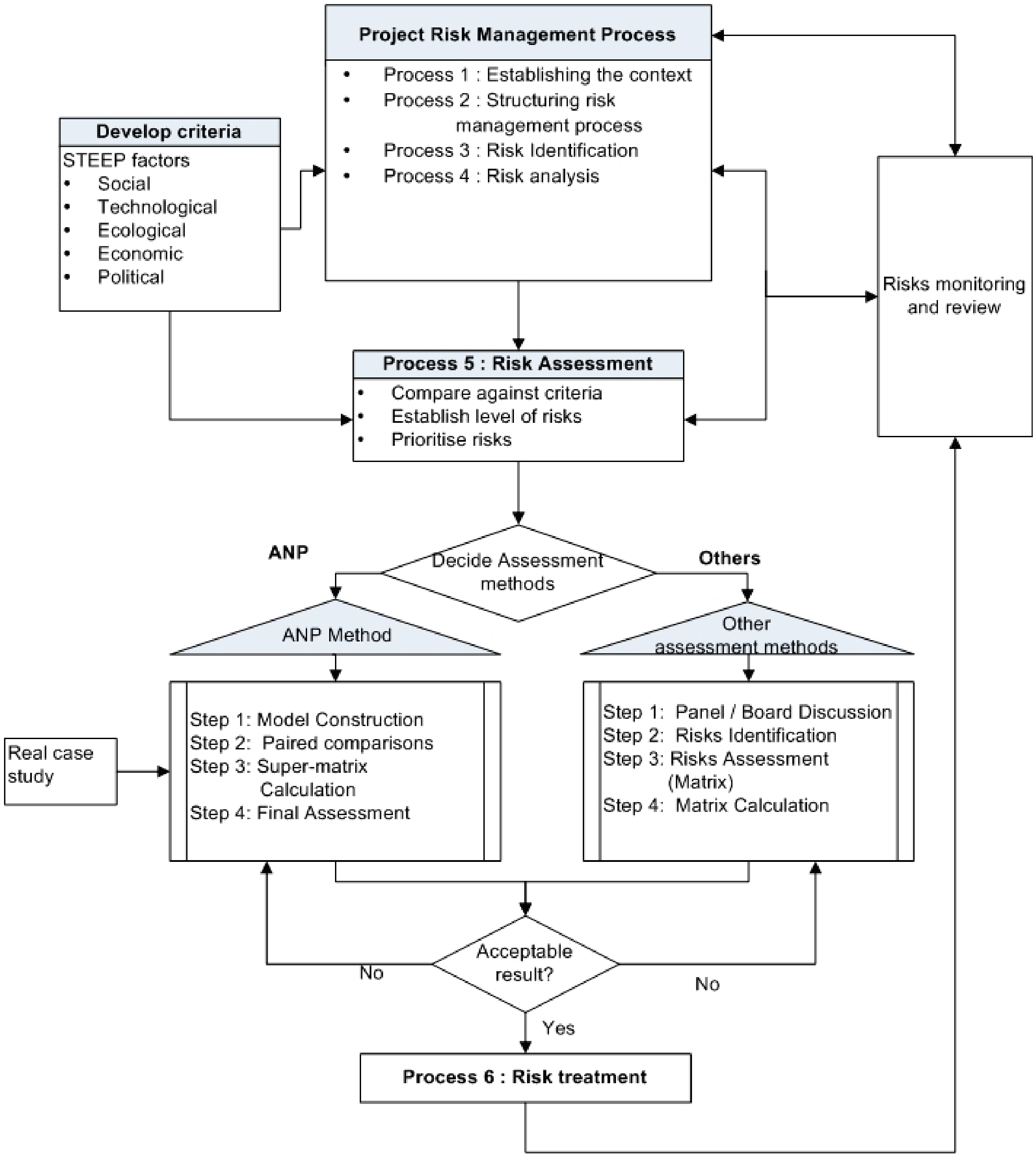
4. Economic risks	4.2	Demand and Supply	Degree of competitiveness with other airports in UK (%)	Adair & Hutchison, 2005
	4.3	Development fund	Amount and sources of funding injected to mega project construction	Adair, *et al*, 2000
	4.4	Interest rate	Degree of impacts of the increment of loan rate (%)	Sagalyn, 1990; FSA, 2005; Nabarro & Key, 2005
	4.5	Investment return	Expected Internal rate of return & Capitalization rate (%)	Sagalyn, 1990; Watkins, et al, 2004
	4.6	Job creation	Numbers of Jobs created and loss for entirely project lifecycle (%)	Jones & Watkins, 1996
	4.7	Lifecycle value	Degree of Net Present Value achieve from the investment (%)	Smith, *et al*, 2006; Adair & Hutchison, 2005
5. Political Risks	5.1	Political groups/activist	Degree of protest by the urban communities (%)	Arthurson, 2001
	5.2	Council approval	Total Days of construction, design approval process by Planning committee	Crown, 2008
	5.3	Public inquiry	Total Days of public inquiry and affect to operating time	Pellman, 2008

3. Methodology

Methodology adopted in this research consists of literature review, and interview with a practitioner to gather information of the current risks assessment approaches used in mega-projects, following by data analysis to support ANP model. Finally, a case study of mega-project has been used to test ANP model's effectiveness. The research methodology could be extended by the content in Figure 1; the typical risk management process also compares a selection of risk assessment methods, between ANP and traditional method (Risk Assessment Matrix).

The risk management process normally started with establishing the contexts (Process 1), whether strategic, organizational and additional risk management contexts, depending on the characteristics of a specific project and the preference of decision-makers. The project managers set up the project risk management structure (Process 2); in this case, it is associated with STEEP factors. Risks identification (Process 3) is conducted to clarify the effect of each risk and to identify risk sources. Risk analysis (Process 4) is undertaken to determine the likelihood and the consequence of each risk impact on the project, consequently.

Risk assessment (Process 5) is then used to compare risks against the established criteria, and adjust the consequences and prioritize the significant of each risk. In this process, the project managers could decide whether to use the existing risk assessment methods (in this regard, the existing are Risk Matrix or PRR method) or Analytic Network Process (ANP). In the case of using the traditional method, the decision makers have to conduct a panel/board discussion to identify the affect of risks to the project, each participants use their experiences to classify predictable risk events. Following by the assessment method set up, in the current practice, it is most likely to create a risk assessment matrix (RAM). RAM describes the likelihood and consequence of each risk in a tabular format, the panel



Source: AS/NZS 4360: 2004 risk management standard (ACT 2004)

Figure 1 Risk management process with the alternatives of risk assessment method can also level overall risk events. This method is simple to use, and it is also easy for laypersons to understand (Rafele et al, 2005; ioMosaic, 2002; Kindinger, 2002). However, the results derived by matrix assessment method are not based on either non-linear mathematic calculation or objective assumptions related to a real project case, as well as it does not allow the comparisons amongst each criteria (see Figure 2). The results calculated by matrix are normally subjective, providing less detail of data to help the decision makers to structure their decision-making process. The risk factors are numerous and complicated, particularly in large mega-project projects, while humans are limited in assessing many risks at the same time (He, 1995).

Alternatively, when decision makers select the ANP technique to deal with risks, they first have to create an ANP model, followed by pairwise comparison process to form a super-matrix in order to quantify the interdependences between paired criteria and the alternatives of development plan. The results calculated by super-matrix calculation can suit the project team in order to get a numerical suggestion regarding to the most appropriate development plan. The result from ANP is useful to support the decision making process toward the project risk mitigation. In addition, a project knowledgebase is required to be integrated into the process for using either traditional method or ANP method in order to complete decision making tasks. The knowledgebase provides adequate and accurate information to achieve reliable results, and the knowledge can be collected from existing or new projects. To pursue this ANP requirement, an experimental case study of ongoing mega-project will be employed to demonstrate and test the effectiveness of the ANP model, which established the risks assessment tool in this paper (Chen and Khumpaisal, 2009).

In addition, accepted results, whether calculated by ANP or the existing method, lead to the final stage of risk mitigation or risk treatment actions. Risk treatment options shall be identified by the project participants, and evaluated for the probabilities of use in the real project. Each stage in project risks management process will be frequently monitored and reviewed by the responsible persons in order to set up the process effectively, and the mitigation or treatment plan could be implemented.

In order to complete the requirement of this research methodology, we interviewed a construction expert (“the practitioner”) who had involved in this case study. He was a construction project manager on contractor site of the Heathrow Terminal 5 project. He had 20 years of experience in construction management working on various infrastructure projects. However, in according to his business confidentiality and research etiquette, we were asked to conceal his name and organization. He gave his judgment regarding the consequences of each risk in the established criteria and the impacts to the existing project (Plan A) and the assumed alternative project (Plan B).

Risk assessment criteria specifically created for this case study are presented in the next section.

Risk No.	Requirements	In-charge Team	Risk(s)	Likeli-hood (%)	Rank	Rate	Mitigation Method
1	Installation of A/C sets in guestrooms	M&E –A	A/C accessories might be not matched with the requirements of customers	30%	2	L	PM, designers, M&E and clients set a meeting to solve this problem
2	Installation of lifts in atrium	M&E –B	Some equipment cannot be delivered to site due to custom regulations	70%	4	M	Procurement manager to contact custom immediately

Source: Khumpaisal

Figure 2 Example of a Risk Assessment Matrix

4. ANP modeling

An ANP model was developed for assessing risks when the decision maker conducts a construction project feasibility analysis. According to Table 1, the ANP model herein established 30 defined criteria. The SuperDecisions software for decision making was employed to calculate and model the ANP model. The ANP model comprises six clusters and 32 nodes based on the criteria and sub-criteria defined in Table 1. Alternative development plans cluster represent development plans to be evaluated against all assessment criteria consisting of two nodes, representing two alternative plans for a case study. Those plans are assumed regarding the ANP method requirements that need to quantitatively evaluate interrelations between either paired criteria or paired sub-criteria. This enables the practitioners to use their judgments to assess all defined risks.

The illustrated ANP model (Figure 3), consists of six clusters: alternatives development, social risks, ecological risks, economic risks, technological risks, and political risks. There are 32 nodes in this ANP model; among them, there are two nodes inside the alternatives cluster, Plan A, and Plan B, to represent alternative plans for a specific Terminal 5 project for project sponsors to select the most appropriate plan. The other 30 nodes are located in five different clusters, in accordance to those clusters as described in Table 1. Two-way and looped arrow lines in Figure 3 describe the interdependences and relationship amongst paired clusters as well as nodes (Chen and Khumpaisal, 2009; Saaty, 2005). In addition, there are fixed interrelations between paired clusters, while there are fixed interrelations between paired nodes inside one cluster, as well as from two different clusters.

As discussed, in order to quantitatively measure all interrelations inside this ANP model, an interview with the practitioner gathered information, opinions, and judgments to compare the relative importance between paired clusters and nodes. These knowledge and information were then collected and concentrated into an ANP model.

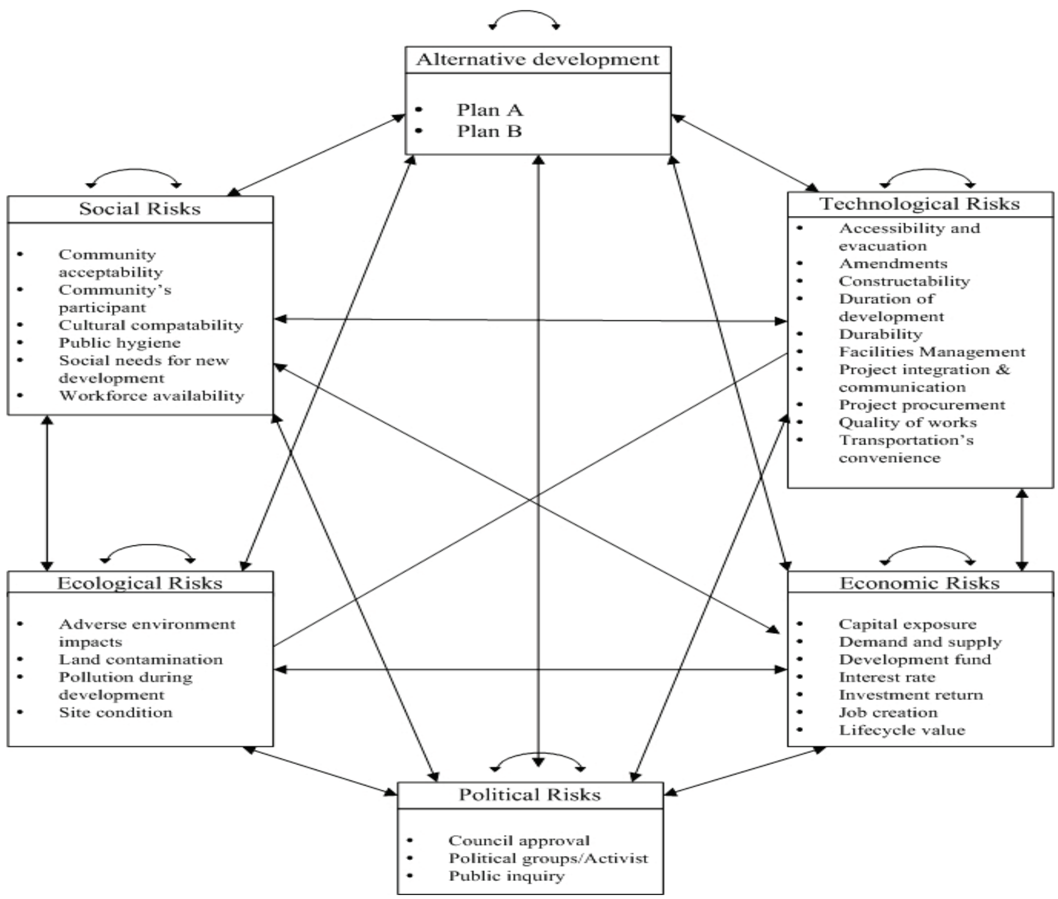


Figure 3 ANP Model for mega-project development risk assessment

As shown in Figure 3, the ANP model structures and quantifies all possible interdependent relations inside the model. Pairwise comparisons are made using subjective judgments in accordance with the fundamental scale of pairwise judgments (Saaty, 2005) (see Table 2). Table 2 generally describes how to conduct pairwise comparison between paired clusters, as well as nodes regarding their interdependences as defined in the ANP model (see Figure 1) and relative importance based on their specific characteristics and experts' knowledge. The ANP model is based on the risks assessment criteria to make judgments to quantify interdependences for 30 risk assessment criteria inside clusters 2 to 6 (see Figure 3), and specific characteristics of alternative plans, which are used to make judgments in quantifying interdependences for alternatives in the experimental case study.

Table 2
NP Judgments between paired clusters/nodes

Clusters/Nodes		**Scale of pair-wise comparisons**								
		±1	±2	±3	±4	±5	±6	±7	±8	±9
Cluster I	Cluster J	×	×	×	×	×	✓	×	×	×
Node I_i	Node J_j	×	×	×	×	×	✓	×	×	×

Note:

1. The fundamental scale of pair-wise judgments: 1= Not important, 2= not to moderately important, 3= Moderately important, 4= Moderately to strongly important, 5= Strongly important, 6= Strongly to very strongly important, 7= Very strongly important, 8= Very strongly to extremely important, 9= Extremely important.
2. The symbol × denotes item under selection for pair-wise judgment, and the symbol ✓ denotes selected pair-wise judgment.
3. I and J denote the number of Clusters, whilst i and j denote the total number of Nodes.
4. The symbol ± denotes importance initiative between compared Nodes or Clusters.

Sources: Chen and Khumpaisal (2009)

The other outcomes provided by an ANP calculation were the supermatrix, these matrices were combined with unweighted supermatrix and weighted supermatrix. These results indicated the priority and comparison of STEEP factors in order to give the final synthesized priority weight (see appendices).

5. Case Study

A case of Terminal 5 of London Heathrow is chosen to demonstrate the effectiveness of the ANP model to select the most appropriate plan for this specific mega-project. A study was conducted based on information collected from an ongoing Terminal 5 project. The alternative plans assumptions are assumed into two alternative plans (Plan A and B). This project is constructed as a part of London Heathrow International Airport with the approximately area of 260 hectares, located on the western side of the airport, between the western ends of the northern and southern runways, and on the eastern side the M25 motorway. There are two artificial watercourses, Longford River and the Duke of Northumberland's river, that run through the middle of the site.

Terminal 5 project consists of 16 major projects and 147 subprojects, including three terminal buildings, and a railway station. Terminal 5 comprises a main building (Terminal 5A), and two satellite buildings (Terminal 5B and 5C). Terminal 5A and 5B were completely constructed and opened, while 5C was under construction and planned to open in May 2010. Terminal 5A is the largest free-standing buildings in the United Kingdom, with four levels of approximately 3 million square feet (ft^2). This building attached with retail space of 200,000 ft^2, which comprise 150 retail units and 25 restaurants, and duty free shops. The passenger capacity is approximately 27 million per year. BA is the major user of this terminal, which delivers passengers to 102 destinations, domestically and internationally. The layout of Terminal 5 is shown in Figure 4.

(Image courtesy of: BAA)

Figure 4 Terminal 5 Layouts

The construction process started in September 2002. Phase 1 was completed in April 2008, and Phase 2 will be completed in 2011. Total construction cost of £4.2 billion was sponsored by British Airports Authority (BAA), British Airways (BA) and HM Government. This project involved with more than 60 subcontractors. This project faced the problems of a long public inquiry duration (from 1995 through 1999), and the difficulties of many building services systems or specialty systems, such as baggage handling system., air-traffic control system, and miscellaneous information technology (IT) issues. As seen by the chaos in the grand opening day on 27 March, 2008, BA cancelled 34 flights. Over the next 10 days, 28,000 bags failed to travel with their owners, and 500 flights were cancelled. The significant sources of those problems stemmed from a lack of proper IT systems and as well as insufficient system testing and staff training (BAA, 2009; SGP, 2009).

Because of the complicated characteristics of this project, risk assessment criteria, including the alternative plans, were established in order to perform the ANP calculation effectively. The ANP model requires a comparison among each criterion with the alternative solutions. In order to respond to this requirement, the comparison of Plan A and Plan B attributions were established in order to understand the differences between each alternative. Plan A is based on the current development plan, while Plan B is assumed as the purposed plan by minimizing gross building area, dimensions, and functions (see Table 3 in the Appendix).

The practitioner provided his judgments and perceptions to the consequential degree of risks affected to this project. Consequences of each risk are ranked in percentage (%) format, which the higher percentage (%) equal to higher risk that affect to each criteria and alternative plans. Those raw results are summarized and indicated in Table 4.

Table 4
Results of questionnaire survey

Criteria	**No.**	**Sub-Criteria**	**Unit**	**Alternative Development Plans**	
				Plan A	**Plan B**
1 Social Risks	1.1	Community acceptability	%	60	**60**
	1.2	Community's participations	%	70	**50**
	1.3	Cultural compatibility	%	80	**50**
	1.4	Public hygiene	%	60	**60**
	1.5	Social needs for new development	%	50	**30**
	1.6	Workforce availability	No.	50	**30**
2. Technological Risks	2.1	Accessibility & evacuation	%	50	**30**
	2.2	Amendments	%	30	**60**
	2.3	Constructability	%	40	**60**
	2.4	Duration of development	months	70	**50**
	2.5	Durability	%	70	**50**
	2.6	Facilities management	%	70	**55**
	2.7	Project integration & communication	%	65	**45**
	2.8	Project procurement	%	55	**40**
	2.9	Quality of construction works	%	65	**45**
	2.10	Transportation's convenience	%	50	**65**
3. Ecological Risks	3.1	Adverse environment impacts	%	50	**50**
	3.2	Land contamination	%	40	**40**
	3.3	Pollution during development	%	60	**60**
	3.4	Site conditions	%	60	**60**
4. Economic Risks	4.1	Capital exposure	%	30	**50**
	4.2	Demand and Supply	%	40	**60**
	4.3	Development fund	%	60	**75**
	4.4	Interest rate	%	50	**70**
	4.5	Investment return	%	70	**50**
	4.6	Job creation	%	70	**50**
	4.7	Lifecycle value	%	70	**50**
5. Political Risks	5.1	Political groups/activist	%	55	**40**
	5.2	Council approval	months	65	**40**
	5.3	Public inquiry	months	70	**45**

Notes: Plan A: The current Terminal 5 development plan; Plan B: The purposed plan for Terminal 5 construction.

Although interdependences among 30 risk assessment criteria can be measured based on experts' knowledge, the ANP model should include all specific characteristics of each alternative plan, which are given in Table 4. According to the fundamental scale of pairwise judgments (see Table 2), all possible interdependences between each alternative plan and each risk assessment criterion, and between paired risk assessment criteria in regard to each alternative plan are evaluated; Table 2 also provides the result of all these pairwise comparisons used to form a two-dimensional supermatrix for further calculation. The calculation of the limit supermatrix aims to form a synthesized supermatrix to allow for resolution of the effects of the interdependences that exist between the nodes and the clusters of the ANP model (Saaty, 2005 as cited in Chen and Khumpaisal, 2009).

According to the practitioner's opinions, it could be concluded that political risks and economic risks had strongly impacted the studied project due to the nature of this project, which was impacted by the delay in approving of the construction plan, and the reconciliation processes during the project planning and design stages. Furthermore, the technological risks also affected Terminal 5, as seen by the confusion of the airport staff and non-harmonious coordination of IT system at the grand opening day.

In order to obtain useful information for development plan selection, the calculation of a super-matrix is conducted in the following three steps, which transform an initial super-matrix or un-weighted one based on pairwise comparisons to a weighted super-matrix, and then to a synthesized super-matrix. Results from the synthesized super-matrix are given in Table 5.

Table 5
Comparison of Alternative Development Plan results

Results	**Alternative Development Plans**	
	Plan A	**Plan B**
Synthesized priority weights	0.5747	0.4253
Ranking	1	2

According to the results shown in Table 5, Alternative plan A is identified as the risky plan for the specific development because it has the highest synthesized priority weight than another alternative. The difference between Plan A and B results indicates the likelihood of the practitioner to select the most appropriate development plan based on results by the ANP calculation. By the results above, it is suggested that the developer should select Plan B as the project development plan of the studied project.

6. Conclusions

The Analytic Network Process model, established to assess risks in mega-projects, was introduced in this paper. In order to make this ANP model more pragmatic, the risk assessment criteria and alternative development plans have been settled. They were constructed based on the information gained by the extensive literature review. The said risk assessment criteria were developed against the requirements of the STEEP factors, which were considered by the project managers when conducting the project feasibility analysis.

The ANP model was correlated with the defined risks criteria associated with STEEP factors; there were 30 risks under five clusters and two alternative plans. An assumption has been made that one of two alternative plans would be selected as the appropriate development plan for the case study. To ensure a comprehensive coverage of possible risks occurred in mega-project, practitioners were interviewed. They gave their judgments and opinions toward risks in the specific case study. According to the results, it was found that the Alternative B (or the alternative development plan) was the appropriate plan. The results of each development plan are not significant distinct, because the purposed development plan is assumed improperly as well as the opinions obtained by the practitioners are quite similar in several criteria, those strongly affected the calculation of ANP model.

It could be concluded that the ANP model is an effective tool to support the practitioners to provide some precise data to support decision making towards risks. However, due the limitation of time, experience of the researchers, including the aim of this paper is to introduce innovative risk assessment model to the industrial only, but this paper do not deeply investigated into the construction projects' details. Therefore, the additional research is needed to collect large-scale information from construction practitioners to improve the consistency and reliability of the risk assessment criteria.

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APPENDIX I

Unweighted Supermatrix

Unweighted Supermatrix

		Alternative Development Plans		Ecological Risks				Economic Risks							Political Risks		
		Plan A	Plan B	Adverse environment impacts	Land contamination	Pollution during development	Site conditions	Capital Exposure	Demand and Supply	Development fund	Interest rate	Investment return	Job creation	Lifecycle Value	Council approval	Political groups/activist	Public inquiry
Alternative Development Plans	Plan A	0.8889	0.1111	0.7500	0.8000	0.7500	0.5000	0.2500	0.5000	0.1667	0.2500	0.5000	0.2000	0.8000	0.3333	0.3333	0.8571
	Plan B	0.1111	0.8889	0.2500	0.2000	0.2500	0.5000	0.7500	0.5000	0.8333	0.7500	0.5000	0.8000	0.2000	0.6667	0.6667	0.1429
Ecological Risks	Adverse environment impacts	0.2500	0.3750	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.6207
	Land contamination	0.2500	0.3750	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2140
	Pollution during development	0.2500	0.1250	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.1080
	Site conditions	0.2500	0.1250	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.0573
Economic Risks	Capital Exposure	0.0308	0.1488	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.3340
	Demand and Supply	0.0500	0.0861	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.2574
	Development fund	0.1205	0.0521	0.1205	0.1205	0.1205	0.1205	0.1205	0.1205	0.1205	0.1205	0.1205	0.1205	0.1205	0.1205	0.1205	0.1168
	Interest rate	0.0766	0.0521	0.0766	0.0766	0.0766	0.0766	0.0766	0.0766	0.0766	0.0766	0.0766	0.0766	0.0766	0.0766	0.0766	0.1140
	Investment return	0.1998	0.1488	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.0630
	Job creation	0.1998	0.1488	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.0666
	Lifecycle Value	0.3225	0.3632	0.3225	0.3225	0.3225	0.3225	0.3225	0.3225	0.3225	0.3225	0.3225	0.3225	0.3225	0.3225	0.3225	0.0482
Political Risks	Council approval	0.1634	0.2500	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.5750
	Political groups/activist	0.2970	0.2500	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.3043
	Public inquiry	0.5396	0.5000	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.1207
Social Risks	Community Acceptability	0.1446	0.2792	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.3530
	Community's participation	0.2206	0.1598	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.1469
	Cultural Compatibility	0.3752	0.1598	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.2429
	Public Hygiene	0.1263	0.2792	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1312
	Social Needs for new development	0.0773	0.0610	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0760
	Workforce Availability	0.0560	0.0610	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0500
Technological Risks	Accessibility & evacuation	0.0501	0.0332	0.0501	0.0483	0.0501	0.0501	0.0501	0.0501	0.0501	0.0501	0.0501	0.0501	0.0501	0.0501	0.0501	0.0905
	Amendments	0.0257	0.2351	0.0257	0.0253	0.0257	0.0257	0.0257	0.0257	0.0257	0.0257	0.0257	0.0257	0.0257	0.0257	0.0257	0.1242
	Constructability	0.0360	0.1809	0.0360	0.0350	0.0360	0.0360	0.0360	0.0360	0.0360	0.0360	0.0360	0.0360	0.0360	0.0360	0.0360	0.1103
	Durability	0.1703	0.0992	0.1703	0.1676	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1337
	Duration of development	0.1703	0.0992	0.1703	0.1676	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1337
	Facilities management	0.1752	0.0992	0.1752	0.1574	0.1752	0.1752	0.1752	0.1752	0.1752	0.1752	0.1752	0.1752	0.1752	0.1752	0.1752	0.0986
	Project integration & communication	0.1081	0.0565	0.1081	0.1006	0.1081	0.1081	0.1081	0.1081	0.1081	0.1081	0.1081	0.1081	0.1081	0.1081	0.1081	0.0684
	Project procurement	0.0601	0.0380	0.0601	0.0623	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0535
	Quality of construction works	0.0955	0.0565	0.0955	0.0938	0.0955	0.0955	0.0955	0.0955	0.0955	0.0955	0.0955	0.0955	0.0955	0.0955	0.0955	0.0883
	Transportation's convenience	0.1086	0.1024	0.1086	0.1421	0.1086	0.1086	0.1086	0.1086	0.1086	0.1086	0.1086	0.1086	0.1086	0.1086	0.1086	0.0986

		Social Risks						Technological Risks									
		Community Acceptability	Community's participation	Cultural Compatibility	Public Hygiene	Social Needs for new development	Workforce Availability	Accessibility & evacuation	Amendments	Constructability	Durability	Duration of development	Facilities management	Project integration & communication	Project procurement	Quality of construction works	Transportation's convenience
Alternative Development Plans	Plan A	0.7500	0.7500	0.8000	0.7500	0.3333	0.1667	0.5000	0.7500	0.1429	0.3333	0.2000	0.8333	0.8000	0.5000	0.5000	0.8000
	Plan B	0.2500	0.2500	0.2000	0.2500	0.6667	0.8333	0.5000	0.2500	0.8571	0.6667	0.8000	0.1667	0.2000	0.5000	0.5000	0.2000
Ecological Risks	Adverse environment impacts	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.5488	0.2500	0.2500	0.2500
	Land contamination	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.1930	0.2500	0.2500	0.2500
	Pollution during development	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.1818	0.2500	0.2500	0.2500
	Site conditions	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.0763	0.2500	0.2500	0.2500
Economic Risks	Capital Exposure	0.0308	0.0357	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.1213	0.0308	0.0308	0.0327
	Demand and Supply	0.0500	0.0596	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0622	0.0500	0.0500	0.0504
	Development fund	0.1205	0.0000	0.1205	0.1205	0.1205	0.1205	0.1205	0.1205	0.1205	0.1205	0.1205	0.1205	0.1468	0.1205	0.1205	0.1208
	Interest rate	0.0766	0.0921	0.0766	0.0766	0.0766	0.0766	0.0766	0.0766	0.0766	0.0766	0.0766	0.0766	0.0968	0.0766	0.0766	0.0725
	Investment return	0.1998	0.2240	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1639	0.1998	0.1998	0.2003
	Job creation	0.1998	0.2240	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1998	0.1639	0.1998	0.1998	0.2003
	Lifecycle Value	0.3225	0.3646	0.3225	0.3225	0.3225	0.3225	0.3225	0.3225	0.3225	0.3225	0.3225	0.3225	0.2451	0.3225	0.3225	0.3232
Political Risks	Council approval	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634
	Political groups/activist	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970	0.2970
	Public inquiry	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396	0.5396
Social Risks	Community Acceptability	0.1446	0.1446	0.1551	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446	0.1446
	Community's participation	0.2206	0.2206	0.2161	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206	0.2206
	Cultural Compatibility	0.3752	0.3752	0.3684	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752	0.3752
	Public Hygiene	0.1263	0.1263	0.0860	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263	0.1263
	Social Needs for new development	0.0773	0.0773	0.0804	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773	0.0773
	Workforce Availability	0.0560	0.0560	0.0940	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560	0.0560
Technological Risks	Accessibility & evacuation	0.0501	0.0501	0.0501	0.0501	0.0501	0.0501	0.0501	0.0501	0.0501	0.0512	0.0501	0.0501	0.2382	0.2771	0.3349	0.0488
	Amendments	0.0257	0.0257	0.0257	0.0257	0.0257	0.0257	0.0257	0.0257	0.0257	0.0246	0.0257	0.0257	0.0850	0.2004	0.1934	0.0240
	Constructability	0.0360	0.0360	0.0360	0.0360	0.0360	0.0360	0.0360	0.0360	0.0360	0.0738	0.0360	0.0360	0.1964	0.1642	0.1491	0.0354
	Durability	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1642	0.1703	0.1703	0.1210	0.0728	0.0963	0.1199
	Duration of development	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1703	0.1798	0.1703	0.1703	0.1009	0.0842	0.0536	0.1946
	Facilities management	0.1752	0.1752	0.1752	0.1752	0.1752	0.1752	0.1752	0.1752	0.1752	0.1620	0.1752	0.1752	0.0881	0.0740	0.0573	0.1859
	Project integration & communication	0.1081	0.1081	0.1081	0.1081	0.1081	0.1081	0.1081	0.1081	0.1081	0.1003	0.1081	0.1081	0.0661	0.0489	0.0416	0.1294
	Project procurement	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0646	0.0601	0.0601	0.0469	0.0276	0.0313	0.1050
	Quality of construction works	0.0955	0.0955	0.0955	0.0955	0.0955	0.0955	0.0955	0.0955	0.0955	0.0891	0.0955	0.0955	0.0241	0.0261	0.0247	0.0807
	Transportation's convenience	0.1086	0.1086	0.1086	0.1086	0.1086	0.1086	0.1086	0.1086	0.1086	0.0903	0.1086	0.1086	0.0333	0.0246	0.0177	0.0762

APPENDIX II

Weighted Supermatrix

Weighted Supermatrix

		Alternative Development Plans		Ecological Risks				Economic Risks							Political Risks		
		Plan A	Plan B	Adverse environment impacts	Land contamination	Pollution during development	Site conditions	Capital Exposure	Demand and Supply	Development fund	Interest rate	Investment return	Job creation	Lifecycle Value	Council approval	Political groups/ activist	Public inquiry
Alternative Development Plans	Plan A	0.0274	0.0034	0.0245	0.0261	0.0245	0.0163	0.0071	0.0142	0.0047	0.0071	0.0142	0.0057	0.0227	0.0115	0.0115	0.0296
	Plan B	0.0034	0.0274	0.0082	0.0065	0.0082	0.0163	0.0212	0.0142	0.0236	0.0212	0.0142	0.0227	0.0057	0.0230	0.0230	0.0049
Ecological Risks	Adverse environment impacts	0.0499	0.0749	0.0177	0.0177	0.0177	0.0177	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0204	0.0204	0.0507
	Land contamination	0.0499	0.0749	0.0177	0.0177	0.0177	0.0177	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0204	0.0204	0.0175
	Pollution during development	0.0499	0.0250	0.0177	0.0177	0.0177	0.0177	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0204	0.0204	0.0088
	Site conditions	0.0499	0.0250	0.0177	0.0177	0.0177	0.0177	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0204	0.0204	0.0047
Economic Risks	Capital Exposure	0.0085	0.0409	0.0126	0.0126	0.0126	0.0126	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0109	0.0109	0.1181
	Demand and Supply	0.0137	0.0237	0.0205	0.0205	0.0205	0.0205	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0177	0.0177	0.0910
	Development fund	0.0331	0.0143	0.0494	0.0494	0.0494	0.0494	0.0439	0.0439	0.0439	0.0439	0.0439	0.0439	0.0439	0.0426	0.0426	0.0413
	Interest rate	0.0211	0.0143	0.0314	0.0314	0.0314	0.0314	0.0279	0.0279	0.0279	0.0279	0.0279	0.0279	0.0279	0.0271	0.0271	0.0403
	Investment return	0.0549	0.0409	0.0819	0.0819	0.0819	0.0819	0.0727	0.0727	0.0727	0.0727	0.0727	0.0727	0.0727	0.0707	0.0707	0.0223
	Job creation	0.0549	0.0409	0.0819	0.0819	0.0819	0.0819	0.0727	0.0727	0.0727	0.0727	0.0727	0.0727	0.0727	0.0707	0.0707	0.0236
	Lifecycle Value	0.0886	0.0998	0.1322	0.1322	0.1322	0.1322	0.1174	0.1174	0.1174	0.1174	0.1174	0.1174	0.1174	0.1140	0.1140	0.0170
Political Risks	Council approval	0.0102	0.0156	0.0299	0.0299	0.0299	0.0299	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0389	0.0389	0.1370
	Political groups/activist	0.0186	0.0156	0.0543	0.0543	0.0543	0.0543	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145	0.0708	0.0708	0.0725
	Public inquiry	0.0337	0.0313	0.0988	0.0988	0.0988	0.0988	0.0263	0.0263	0.0263	0.0263	0.0263	0.0263	0.0263	0.1286	0.1286	0.0288
Social Risks	Community Acceptability	0.0460	0.0889	0.0239	0.0239	0.0239	0.0239	0.0235	0.0235	0.0235	0.0235	0.0235	0.0235	0.0235	0.0224	0.0224	0.0546
	Community's participation	0.0702	0.0509	0.0364	0.0364	0.0364	0.0364	0.0359	0.0359	0.0359	0.0359	0.0359	0.0359	0.0359	0.0341	0.0341	0.0227
	Cultural Compatibility	0.1194	0.0509	0.0620	0.0620	0.0620	0.0620	0.0611	0.0611	0.0611	0.0611	0.0611	0.0611	0.0611	0.0580	0.0580	0.0375
	Public Hygiene	0.0402	0.0889	0.0209	0.0209	0.0209	0.0209	0.0206	0.0206	0.0206	0.0206	0.0206	0.0206	0.0206	0.0195	0.0195	0.0203
	Social Needs for new development	0.0246	0.0194	0.0128	0.0128	0.0128	0.0128	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.0120	0.0120	0.0117
	Workforce Availability	0.0178	0.0194	0.0092	0.0092	0.0092	0.0092	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0087	0.0087	0.0077
Technological Risks	Accessibility & evacuation	0.0057	0.0038	0.0069	0.0067	0.0069	0.0069	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0069	0.0069	0.0124
	Amendments	0.0029	0.0267	0.0036	0.0035	0.0036	0.0036	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0035	0.0035	0.0171
	Constructability	0.0041	0.0206	0.0050	0.0048	0.0050	0.0050	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0049	0.0049	0.0152
	Durability	0.0194	0.0113	0.0236	0.0232	0.0236	0.0236	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0234	0.0234	0.0184
	Duration of development	0.0194	0.0113	0.0236	0.0232	0.0236	0.0236	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0234	0.0234	0.0184
	Facilities management	0.0199	0.0113	0.0242	0.0218	0.0242	0.0242	0.0158	0.0158	0.0158	0.0158	0.0158	0.0158	0.0158	0.0241	0.0241	0.0135
	Project integration & communication	0.0123	0.0064	0.0150	0.0139	0.0150	0.0150	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0148	0.0148	0.0094
	Project procurement	0.0068	0.0043	0.0083	0.0086	0.0083	0.0083	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0083	0.0083	0.0074
	Quality of construction works	0.0109	0.0064	0.0132	0.0130	0.0132	0.0132	0.0086	0.0086	0.0086	0.0086	0.0086	0.0086	0.0086	0.0131	0.0131	0.0121
	Transportation's convenience	0.0124	0.0117	0.0150	0.0197	0.0150	0.0150	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0149	0.0149	0.0135

		Social Risks						Technological Risks									
		Community Acceptability	Community's participation	Cultural Compatibility	Public Hygiene	Social Needs for new development	Workforce Availability	Accessibility & evacuation	Amendments	Constructability	Durability	Duration of development	Facilities management	Project integration & communication	Project procurement	Quality of construction works	Transportation's convenience
Alternative Development Plans	Plan A	0.0225	0.0225	0.0240	0.0225	0.0100	0.0050	0.0163	0.0245	0.0047	0.0109	0.0065	0.0272	0.0261	0.0163	0.0163	0.0261
	Plan B	0.0075	0.0075	0.0060	0.0075	0.0200	0.0250	0.0163	0.0082	0.0280	0.0218	0.0261	0.0054	0.0065	0.0163	0.0163	0.0065
Ecological Risks	Adverse environment impacts	0.0117	0.0117	0.0117	0.0117	0.0117	0.0117	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0451	0.0205	0.0205	0.0205
	Land contamination	0.0117	0.0117	0.0117	0.0117	0.0117	0.0117	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0159	0.0205	0.0205	0.0205
	Pollution during development	0.0117	0.0117	0.0117	0.0117	0.0117	0.0117	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0149	0.0205	0.0205	0.0205
	Site conditions	0.0117	0.0117	0.0117	0.0117	0.0117	0.0117	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0063	0.0205	0.0205	0.0205
Economic Risks	Capital Exposure	0.0124	0.0143	0.0124	0.0124	0.0124	0.0124	0.0111	0.0111	0.0111	0.0111	0.0111	0.0111	0.0437	0.0111	0.0111	0.0118
	Demand and Supply	0.0201	0.0240	0.0201	0.0201	0.0201	0.0201	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0224	0.0180	0.0180	0.0182
	Development fund	0.0485	0.0000	0.0485	0.0485	0.0485	0.0485	0.0434	0.0434	0.0434	0.0434	0.0434	0.0434	0.0529	0.0434	0.0434	0.0435
	Interest rate	0.0308	0.0371	0.0308	0.0308	0.0308	0.0308	0.0276	0.0276	0.0276	0.0276	0.0276	0.0276	0.0349	0.0276	0.0276	0.0261
	Investment return	0.0804	0.0901	0.0804	0.0804	0.0804	0.0804	0.0720	0.0720	0.0720	0.0720	0.0720	0.0720	0.0591	0.0720	0.0720	0.0722
	Job creation	0.0804	0.0901	0.0804	0.0804	0.0804	0.0804	0.0720	0.0720	0.0720	0.0720	0.0720	0.0720	0.0591	0.0720	0.0720	0.0722
	Lifecycle Value	0.1297	0.1467	0.1297	0.1297	0.1297	0.1297	0.1163	0.1163	0.1163	0.1163	0.1163	0.1163	0.0884	0.1163	0.1163	0.1165
Political Risks	Council approval	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0331	0.0331	0.0331	0.0331	0.0331	0.0331	0.0331	0.0331	0.0331	0.0331
	Political groups/activist	0.0729	0.0729	0.0729	0.0729	0.0729	0.0729	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601	0.0601
	Public inquiry	0.1325	0.1325	0.1325	0.1325	0.1325	0.1325	0.1092	0.1092	0.1092	0.1092	0.1092	0.1092	0.1092	0.1092	0.1092	0.1092
Social Risks	Community Acceptability	0.0166	0.0166	0.0178	0.0166	0.0166	0.0166	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254
	Community's participation	0.0254	0.0254	0.0249	0.0254	0.0254	0.0254	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387	0.0387
	Cultural Compatibility	0.0431	0.0431	0.0424	0.0431	0.0431	0.0431	0.0658	0.0658	0.0658	0.0658	0.0658	0.0658	0.0658	0.0658	0.0658	0.0658
	Public Hygiene	0.0145	0.0145	0.0099	0.0145	0.0145	0.0145	0.0222	0.0222	0.0222	0.0222	0.0222	0.0222	0.0222	0.0222	0.0222	0.0222
	Social Needs for new development	0.0089	0.0089	0.0092	0.0089	0.0089	0.0089	0.0136	0.0136	0.0136	0.0136	0.0136	0.0136	0.0136	0.0136	0.0136	0.0136
	Workforce Availability	0.0064	0.0064	0.0108	0.0064	0.0064	0.0064	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098
Technological Risks	Accessibility & evacuation	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0074	0.0074	0.0074	0.0075	0.0074	0.0074	0.0350	0.0407	0.0492	0.0072
	Amendments	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0038	0.0038	0.0038	0.0036	0.0038	0.0038	0.0125	0.0294	0.0284	0.0035
	Constructability	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0053	0.0053	0.0053	0.0108	0.0053	0.0053	0.0288	0.0241	0.0219	0.0052
	Durability	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273	0.0250	0.0250	0.0250	0.0241	0.0250	0.0250	0.0178	0.0107	0.0141	0.0176
	Duration of development	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273	0.0250	0.0250	0.0250	0.0264	0.0250	0.0250	0.0148	0.0124	0.0079	0.0286
	Facilities management	0.0281	0.0281	0.0281	0.0281	0.0281	0.0281	0.0257	0.0257	0.0257	0.0238	0.0257	0.0257	0.0129	0.0109	0.0084	0.0273
	Project integration & communication	0.0173	0.0173	0.0173	0.0173	0.0173	0.0173	0.0159	0.0159	0.0159	0.0147	0.0159	0.0159	0.0097	0.0072	0.0061	0.0190
	Project procurement	0.0096	0.0096	0.0096	0.0096	0.0096	0.0096	0.0088	0.0088	0.0088	0.0095	0.0088	0.0088	0.0069	0.0041	0.0046	0.0154
	Quality of construction works	0.0153	0.0153	0.0153	0.0153	0.0153	0.0153	0.0140	0.0140	0.0140	0.0131	0.0140	0.0140	0.0035	0.0038	0.0036	0.0119
	Transportation's convenience	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0159	0.0159	0.0159	0.0133	0.0159	0.0159	0.0049	0.0036	0.0026	0.0112

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APPENDIX III

Table 3
A comparison of alternative plans

Attributions	**Descriptions**	**Plan A (the current)**	**Plan B (the purposed)**
Social	Community acceptability	Strongly accepted to new T5	Neither accepted nor rejected
	Community's participations	Surrounding communities clearly understood the development proposal	Surrounding communities clearly understood the development proposal
	Cultural compatibility	Attached with 200,000 ft^2 retail area, 150 shops and 25 restaurants	Only 100,000 ft^2 retail area , 80 shops and 15 restaurants
	Public hygiene	Compliance with NHS standards	Compliance with NHS standards
	Social needs for new development	Both local and UK highly needs such development	Only business sector requires this development
	Workforce availability	Employed 68,000 posts	Employed 40,000 posts
Technological	Accessibility & evacuation	Accessed and evacuated via M25 and Personal rapid transit system	Accessed and evacuated via M25 but without the personal rapid transit system
	Amendments	No such further amendments required in 5 years	No such further amendments required in 5 years
	Constructability	Gross building area of 3 million ft^2 with 3 terminals Approximately dimension of 580 X 1,300 X 130 ft. (w. x l. x h.), construction materials are the combination of fabricated Steel and pre-cast elements	Reduced gross building area to 2 million ft^2 and only 2 terminals constructed. Dimension reduced to 300 X 1000 X 100 construction materials are the combination of fabricated Steel and pre-cast elements
	Duration of development (whole project)	120 months (2002-2011)	84 months (2002-009)
	Durability *	Not available	Not available
	Facilities management	To serve 27 million passengers a year	To serve 15 million passengers a year

Technological (Cont'd)	**Descriptions**	**Plan A (the current)**	**Plan B (the purposed)**
	Project integration & communication	Involved with 60 contractors	Involved with 40 contractors
	Project procurement	T5 Agreement created, requiring all suppliers to work in fully integrated team	Design-bid-build method
	Quality of construction works	Compliance with GTAA standards	Compliance with GTAA standards
	Transportation's convenience	Attached with railway station and bus station	Attached with bus station only
Ecological	Adverse environmental impact *	Not available	Not available
	Land contamination *	Not available	Not available
	Pollution during development	CO_2 reduction of 11,000 tons per annum	CO_2 reduction of 8,000 tons per annum
	Site conditions	Incorporated with twin river diversion to facilitate construction	Incorporated with twin river diversion to facilitate construction
Economic	Capital exposure *	Not available	Not available
	Demand and Supply	Serve for 102 destinations (both in UK and internationals), for BA only	Serve for 70 destinations (internationals only), but serve for BA and its alliance airlines
	Development fund	Sponsored by BAA, BA and HM government	Loan from commercial banks
	Interest rate	Varied from 6.00 – 8.50%	Varied from 7.00 – 9.50%
	Investment return	Approximately IRR 23% for total investment	Approximately IRR 18% for total investment
	Job creation	15,000 jobs created, 3,000 loss	10,000 jobs created, 1,500 loss
Political	Lifecycle value	£4.2 Billion	£2 Billion
	Political groups/activist	Local communities protests	Local communities protests
	Council approval	26 months	20 months
	Public inquiry	46 months	30 months

Note: the items with * mean there is no available information/data for this study