REVIEW OF COST ESTIMATES

CROXLEY RAIL LINK

AUGUST 2007

Prepared for:

Hertfordshire County Council
County Hall
Pegs Lane
Hertford
SG13 8DN

Hertfordshire County Council Contact:
Mike Younghusband
[T] +44 (0) 1707 356 356
[F] +44 (0) 1707 356 380

Prepared by:

Mouchel Parkman Consulting
Highways House
41-45 Broadwater Road
Welwyn Garden City
AL7 3SP

Mouchel Parkman Consulting Contact:
Wil Morris
[T] +44 (0) 1707 356 200
[F] +44 (0) 1707 356 380

Hertfordshire Highways

Hertfordshire

mouchelparkman

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Executive Summary

Mouchel Parkman has been commissioned to consolidate a series of estimates for the Croxley Rail Link scheme prepared by three different organisations which have different perspectives on the scheme.

The estimates provided were based on a detailed design specification report prepared by Mouchel Parkman in 2006, which in turn was consolidated from previous work undertaken on behalf of London Underground Ltd, Railtrack and Hertfordshire County Council.

We have identified item costs, which we consider to be reasonable based on our own experience and taking account of each organisations experience and ability in providing their estimates.

A full risk assessment has been carried out utilising the risk register previously compiled by Mouchel Parkman and considering issues raised by the three organisations that provided the estimates.

Our estimate is :-

- Main Works £ 82,276,000
- Risk £9,700,000
- Inflation £32,376,000
- Total £124,352,000.

The above figures exclude for the following items which are to be separately priced for and added by Hertfordshire County Council:-

- Land costs
- Other Services costs in relation to TWA
- Other sundry Costs.
- VAT
- Third Party Compensation Claims

1.0 Introduction

1.1 Scope of Report

Hertfordshire County Council, is the lead partner for the Croxley Rail Link project, which aims to extend London Underground's Metropolitan Line from Croxley Green into Watford Junction. It has commissioned a number of studies to assist in its preparation of a Major Schemes Business Case.

In March 2006, Mouchel Parkman carried out a comprehensive review of the various studies and cost estimates that had been previously undertaken on behalf of London Underground Ltd, Railtrack and Hertfordshire County Council and consolidated the information in to a single 'design specification' report. The Council subsequently commissioned two contractors, First Engineering and Norwest Holst to 'price' the proposals based on that report.

Meanwhile London Underground Ltd (LUL) also commissioned Turner and Townsend to undertake a cost review of the scheme.

Each of the organisations commissioned to provide a cost estimate comes from a different background and thus could provide a different perspective on the project:

- First Engineering is a 'railway engineering' contractor, with a civil engineering capability supported by Edmund Nuttall.
- Norwest Holst is a 'civil engineering' contractor with railway engineering experience.
- Turner & Townsend are management and project consultants with experience of LUL projects and the PPP.

Mouchel Parkman was commissioned in April 2007 to review the costs estimates and the highlighted risks and issues with a view to producing a consolidated out turn cost estimate.

The report identifies item costs considered to be reasonable based on:

- Mouchel Parkman's experience
- Each organisation's experience and ability in providing their estimates
- The likely delivery route, which involves a 'civil engineering' led provision of the earthworks, structures and a 'railway led' provision of 'signalling and communications'. At this stage it is considered that the permanent way could be procured through either route.

1.2 Scope of Project

The Croxley Rail Link is a proposed extension of the London Underground Limited (LUL) Metropolitan Line to Watford Junction via Watford High Street. The scheme involves the construction of a viaduct to connect the existing Metropolitan line to the currently disused Network Rail owned Croxley Branch Line. The scheme would also involve the closure of the current LUL Metropolitan Line to Watford Metropolitan Station.

The length of new railway (structures, track and signalling) added to the existing Metropolitan Line is approximately 4.5km, although the scheme facilitates the closure of 1.3km of the existing Metropolitan Line between the new viaduct and Watford Metropolitan Station. This results in a net increase of operating track mileage of approximately 3.2km.

The length of the new link infrastructure (embankment and viaduct) connecting the existing Metropolitan Line to the disused Croxley Branch is approximately 0.4km

Stations served by the Metropolitan Line would be Ascot Road (replacing Croxley Green), Watford West, Watford High Street and Watford Junction Stations.

The existing Metropolitan Line service frequency between Watford and Central London of 6 trains per hour would operate between Watford Junction and Central London.

The Metropolitan Line services will share the track and station access with National Rail Network DC line services operating between Watford Junction and London Euston, from south of Watford High Street Station to Watford Junction Station.

A Transport & Works Act Order would be required to secure powers to acquire land and construct the rail link, and closure procedures would be required in relation to the existing Metropolitan Line north of the new link to Watford Metropolitan Station.

As of November 2007 the responsibility for these services, currently operated by Silverlink Metro, will transfer to Transport for London (TfL). This is likely to assist in the ongoing development of principles for joint running of services of the DC Lines.

2.0 Methodology.

The methodology for establishing a 'robust' cost estimate for the scheme was as follows:-

- To identify the full scope of the Construction Works as far as is possible, by consolidating previous feasibility studies, technical surveys and assessments to produce a 'Design Specification' for the scheme.

- To procure the 'expertise' of competent contractors – one from a civil engineering background and one from a railway engineering back ground to provide contemporary costs estimates, which could be compared with each other and those prepared on behalf of LUL based on the PPP.

- From the exercises carried out above to identify the following:

    - Any items and related values missed from either set of estimates

    - Any major cost differences between the various estimates

    - Any other issues or risks that need to be considered

The output from the above exercises has been consolidated onto the following Revised Cost Table. This schedule identifies all of the various items which we consider make up the scope of works, the values against each of these items from the First Engineering, Norwest Holst, Turner and Townsend and Mouchel estimate.

In examination of the above reports it is apparent that a considerable amount of work has been undertaken by the various organisations. It was therefore felt that there was no need to undertake another detailed estimate. We have therefore, utilised our experience of costing such work and our understanding of the expertise of the various organisations (above) to use the most appropriate costs from each report for each item.

As the estimates have all been compiled at different dates we have brought them all up to Q1 2007, for assessment.

Summary of Constrcution Costs.

Ref.	Description		T & T (Q3 - 05)	%	First (Q1 - 06)		Norwest (Q2 - 06)	%	Recommend
1	Ascot Road Station	£	4,261,000	£	3,233,000	**£**	**4,300,684**	£	4,300,684
2	Mods to Watford High St station	£	448,000	£	1,669,000	**£**	**502,706**	£	502,706
3	Mods to Watford Junct station	£	719,000	£	2,169,000	**£**	**754,603**	£	754,603
4	Reconstruct Watford West station	£	4,342,000	£	3,460,000	**£**	**4,387,837**	£	4,387,837
5	Viaduct	£	9,588,000	£	5,853,656	£	6,831,207	**£**	**7,540,000**
6	Cardiff Rd underbridge	**£**	**382,000**	£	134,469	£	132,546	£	382,000
7	Ascot Road underbridge	£	401,000	**£**	**487,338**	£	968,187	£	487,338
8	River Colne (S) underbridge	£	392,000	£	231,034	**£**	**252,397**	£	252,397
9	River Colne (N) underbridge	£	913,000	£	262,000	**£**	**530,107**	£	530,107
10	Tolpits Lane overbridge	£	559,000	**£**	**15,065**	£	48,992	£	15,065
11	Vicarage Rd overbridge	£	287,000	**£**	**14,672**	£	45,868	£	14,672
12	Wiggenhall overbridge	£	323,000	**£**	**18,340**	£	45,335	£	18,340
13	Cardiff Rd Arch overbridge	£	50,000	**£**	**24,549**	£	18,512	£	24,549
14	Culvert extension	£	65,000	£	31,679	**£**	**81,080**	£	81,080
15	Cuttings, retaining walls, embankments	£	3,771,000	£	1,345,517	£	1,083,776	**£**	**2,500,000**
16	Permanent way	£	8,065,000	£	5,762,688	£	-	**£**	**5,700,000**
17	Disposal of ballast contamination	£	224,000	£	-	**£**	**125,630**	£	125,630
18	AC electrification	£	2,341,000	£	7,946,000	£	-	£	2,000,000
19	DC electrification	£	5,969,000			£	-	£	6,150,000
20	Services diversions	**£**	**370,000**			£	-	£	370,000
21	Signalling	£	8,184,000	£	11,588,235	£	-	£	12,000,000
22	Telecomms	£	2,389,000			£	-	£	2,800,000
23	Fencing	£	917,000	£	235,000	£	419,640	**£**	**500,000**
24	Demolish Croxley Green station	**£**	**18,000**	£	3,000	£	2,091	£	18,000
25	Demolish Watford Stadium station	**£**	**18,000**	£	13,000	£	22,620	£	18,000
	Demolish canal & River Gade bridges			£	41,000	£	345,960	£	50,000
26	Environment protection/wildlife	£	350,000	£	-	£	489,375	£	350,000
		£	55,346,000	£	44,538,242	£	21,389,153	£	51,873,008
	Prelims 20%	£	11,069,200	15% £	6,680,736	21.5% £	4,615,537	21.3% £	11,023,014
	Sub Total	**£**	**66,415,200**	**£**	**51,218,978**	**£**	**26,004,690**	**£**	**62,896,022**
27	Profit and OH 7.5%	£	4,981,140					£	4,717,202
28	Design 12%	£	7,969,824	7% £	3,117,677			£	2,883,280
29	Project Management 5%	£	3,320,760	5% £	2,226,912			£	1,611,898
30	Assurance 8%	£	5,313,216	3% £	1,336,147			£	1,886,881
31	Third party Costs			15% £	6,680,736			£	7,780,951
32	Possession Costs							£	500,000
	Total Estimate	**£**	**88,000,140**	**£**	**64,580,451**	**£**	**26,004,690**	**£**	**82,276,234**

All figures adjusted to January 2007

3.0 Risk Analysis and Assessment

In addition to the review of the basic estimates, we have also been instructed to carry out a separate review of the likely project risks and their anticipated evaluation.

3.1 Source of risk categories and levels

As part of the cost estimate review carried out by Mouchel Consulting Ltd in June 2005 a risk workshop was organised. This exercise was attended by technical specialists from both the client organisation and rail industry.

The methodology adopted is described in Appendix 1.

This risk analysis draws on the outputs from that exercise and any issues highlighted by the cost comparison exercise.

The bracketed numbers refer to numbered risk sub-headings in the original risk register.

3.2 Contract Strategy & Programme

Scope

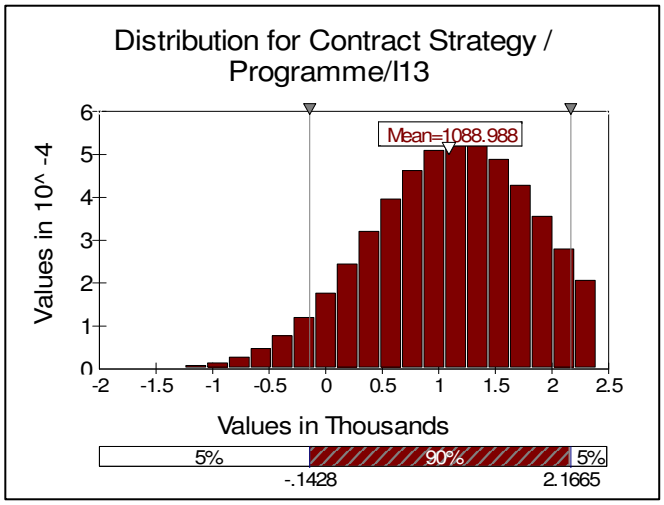
The long history of studies and feasibility under leadership of the three main organisations party to the delivery of the scheme has meant that there is a high level of scheme definition that the organisations 'own' and that have been subjected to public consultation. The key outstanding risk is associated with any recommendations emerging from the TWA public inquiry. It is impossible to assess and quantify this risk.

Adverse commercial conditions

These have been assessed in the register as having a maximum impact of £2.4M and an "assessed" impact of £1.2M. We have therefore developed a distribution curve which reflects this maximum and "most likely" outcome. The distribution chosen is a normal distribution. It is felt that commercial conditions may prove favourable and actually reduce the cost of the scheme slightly. For this reason, the distribution has been modelled to have a small amount of negative risk (or opportunity). We feel that it may be possible to reduce this risk further (increase the opportunity) by considering "partnering" type contract arrangements which incentivise reduction of scheme costs and/or early consultation with the contractor on how the costs could be reduced by amending the designs.

Programme delay

These risks have not been included in the assessment. The programme has not been defined and therefore it is hard to make any quantification of a risk. As can be seen from the distribution graph below, the mean outcome for the chosen distribution is around the £1.1M value with around a 95% confidence of not exceeding £2.2M



Comment: This risk outcome here is entirely dependant on the subjective input distribution for "adverse commercial conditions".

LUL/Opps/Interfaces

These risks have not been included in the assessment as these have been assessed by LUL separately and reflected in the scale of the capital contribution being made by TfL.

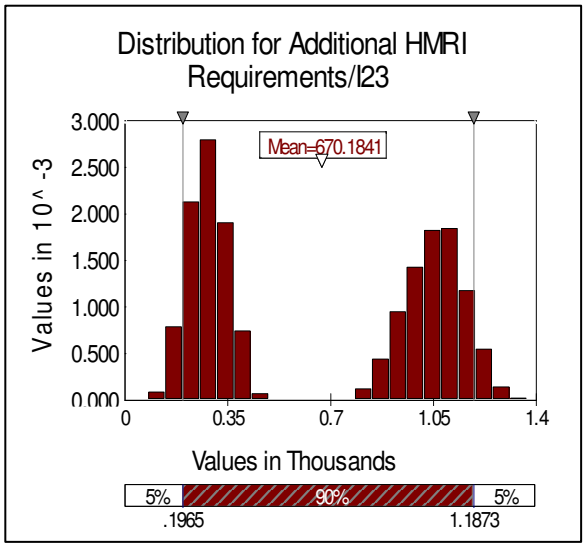
Rolling Stock

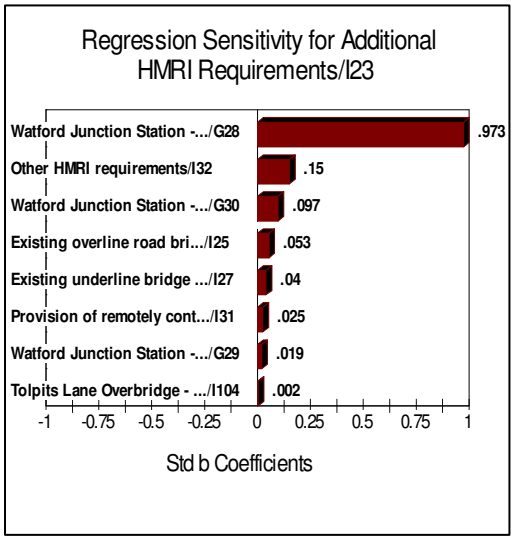
These risks have not been included in the assessment as these have been assessed by LUL separately and reflected in the scale of the capital contribution being made by TfL.

Additional HMRI requirements

The resultant distribution for this sub-heading is bi-modal. There are effectively two separate cost distributions depending upon whether the Buffers are required at Watford Junction Station or not. If not required, the outcome is a peaky distribution centred on approximately £0.25M with a spread between £0.1M and £0.5M. Providing the buffers increases the scheme cost to a most likely outcome of £1.1M with a wider distribution due to the greater uncertainty over the two additional discrete risk profiles associated with the need for buffers – concomitant platform lengthening and signalling.

It can be seen that the Regression sensitivity chart for this sub- heading (Cell G28 of the spreadsheet) makes it clear that this risk distribution is (not surprisingly) very highly sensitive to the provision of buffers at Watford junction station. This risk element could be reduced significantly by determining whether or not buffers are actually required.





Comment: This is a distribution which demonstrates that a mean value is often meaningless as the cost of risk will either be much less than the mean or much more depending on one dominant "what if" scenario. The regression sensitivity chart identifies that cell G28 (provision of buffers at Watford Junction Station) is that dominant factor here. It helps to decide where best to concentrate further investigatory work. Effort determining this issue will be well spent (compared with, say, G29 or G30) since it reduces any uncertainty significantly.

Inflation (Start - April 08, Handover April 10)

This has been assumed at a fixed value in the risk register. There are options available for more accurately assessing risks of inflation. We recommend that these should be considered further in any future risk management/mitigation exercise.

Technology / Standards change during project

These risks have not been included in the assessment. The scope has not been fully defined.

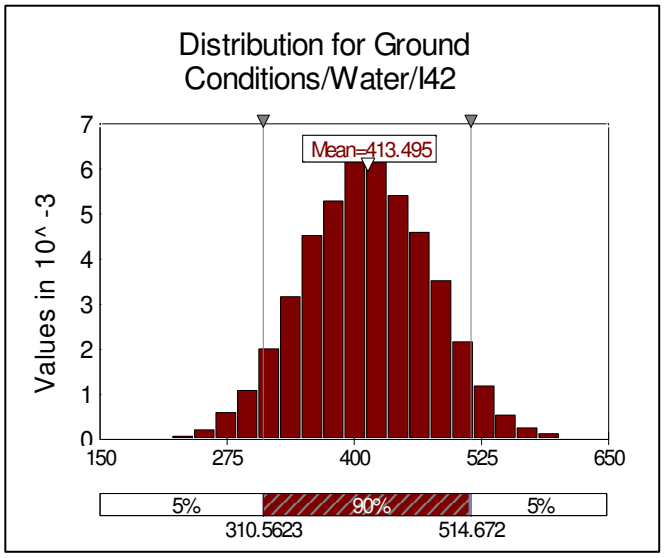
Provision of Professional services up to TWA

These risks have not been included in the assessment. Design costs have been included as a percentage. Until a detailed cost is done, we could be adding to the risk unnecessarily.

3.3 Site Risks

Ground Conditions / Ground Water

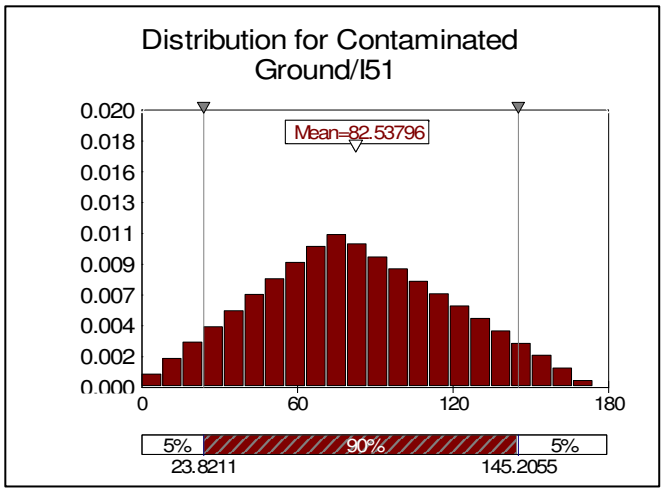
A series of triangular distributions give a classic normal distribution of risk centred on a mean of approximately £0.4M with a 95% confidence of being less than approximately £0.5M.



Comment: This is a distribution which demonstrates how a multi-independent-variable distribution where all variables have costs with the same order of magnitude will often result in a normal distribution curve which is a classic bell shape. If one variable is dominant, say an order of magnitude greater than the others the result will be a skewed distribution.

Contaminated Ground

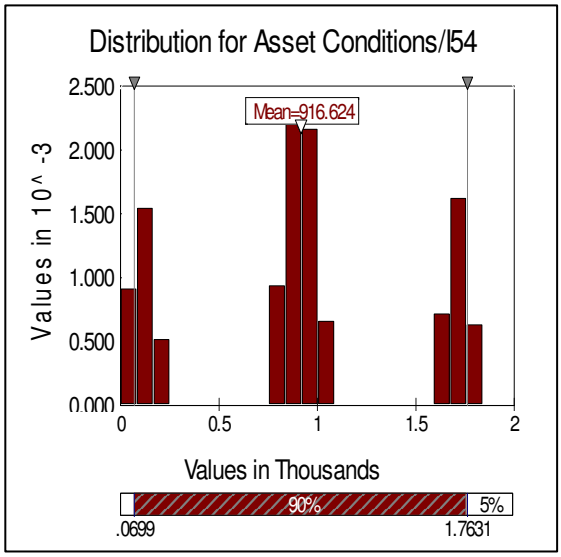
Here a straightforward triangular distribution has been applied to the initial conditions where zero is the minimum, £75,000 the most likely and £175,000 the maximum assigned risk.

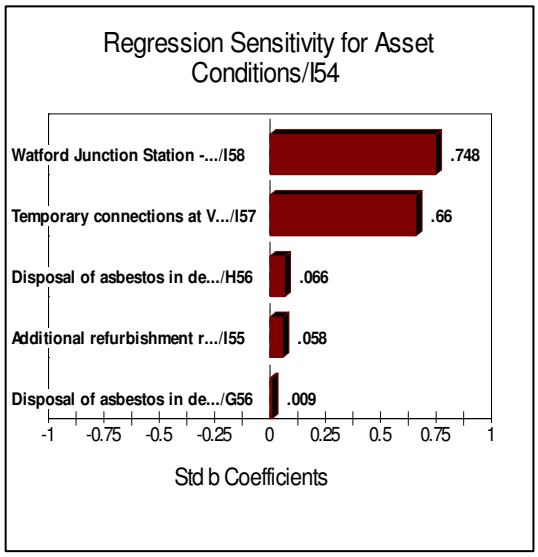


Asset Conditions

Here, there are two dominant factors (corresponding to cells I58 and I57 as indicated by the Regression sensitivity chart) which are fairly objective in their nature – the risks either occur or not (and we have assigned a 50:50 probability in the absence of more refined information). If and when they do occur, the cost is essentially fixed as indicated by the fact that the maximum cost and most likely cost being assigned nearly the same value.

There are therefore 3 modes to the distribution corresponding to i) neither, ii) one or the other or iii) both dominant risks occurring. Obviously the second "what if" scenario where one or the other occurs has a higher area under the curve corresponding to the fact that it is (very roughly) twice as likely as both or alternatively, neither occurring. It can be seen that if work is done to establish whether the connections at Watford Junction Station or for testing purposes on the Metropolitan Line are needed or not, this level of uncertainty or risk can be reduced greatly.



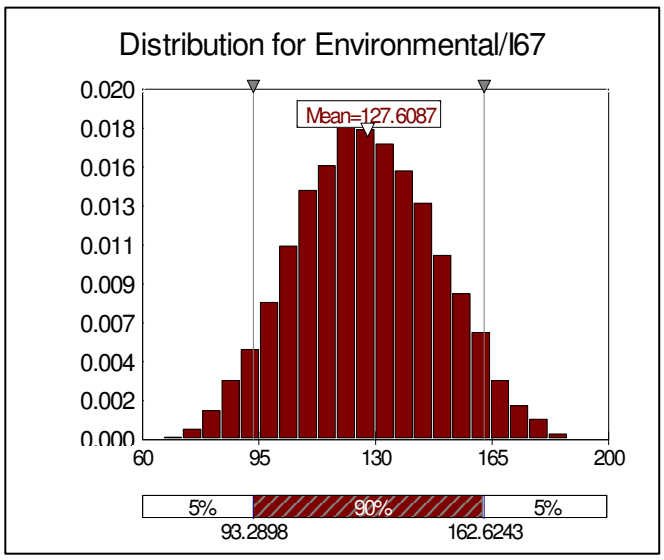


Comment: This type of distribution shows how simulation identifies complicated interaction of risks in a manner which is, when presented graphically, actually fairly intuitive. Here we see that we are essentially tossing two coins the most likely outcome is a "head and tail" combination with two heads and two tails the lesser alternatives. What is less intuitive is the "background noise" of the other risks but this chart gives us a great deal of information about how to manage the risk and where to concentrate further investigative effort.

Access

These risks have not been included in the assessment. Access has not been fully defined, therefore hard to quantify.

Environmental



Land Costs

These risks have not been included in the assessment. Land Cost are not in the estimate there cannot be included in the risk,

Restricted Working Hours

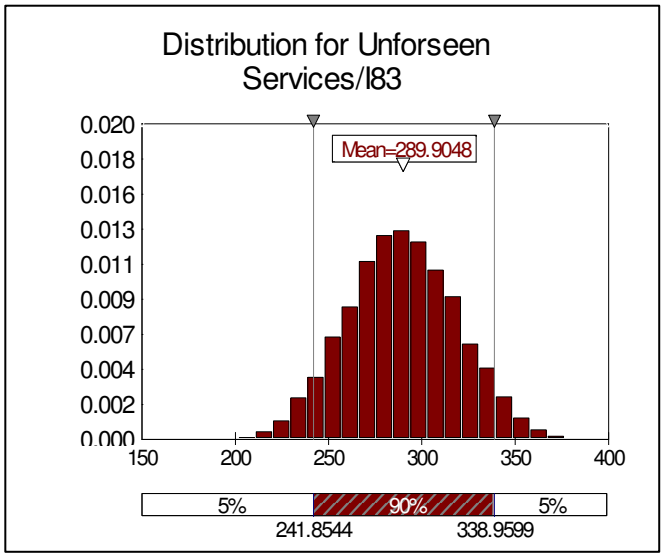
These risks have not been included in the assessment. Programme and work scope need defining before an assessment can be made.

Building over live roads, rails etc

These risks have not been included in the assessment. Programme and work scope need defining before an assessment can be made.

Unforseen Services

Normal distribution. Mean £0.29M 95% confidence of less than £0.34M.



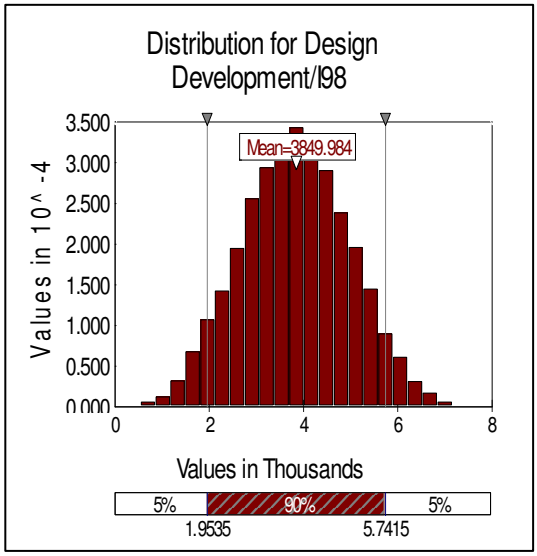
(2.10) Interfaces to existing roads / paths / drains / services

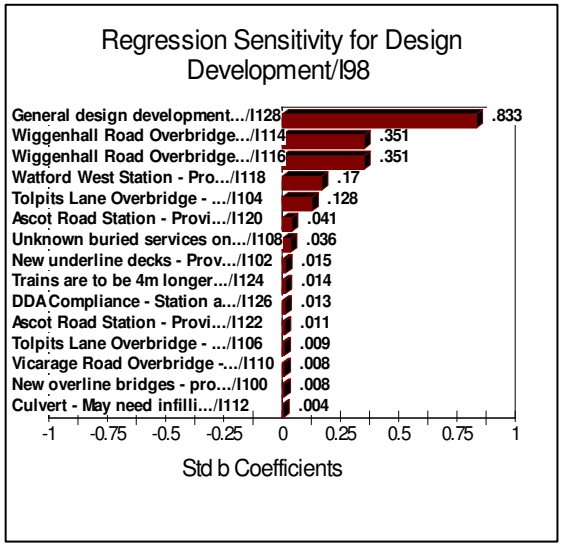
These risks have not been included in the assessment. Programme and work scope need defining before an assessment can be made.

3.4 Design Risks

Design Development

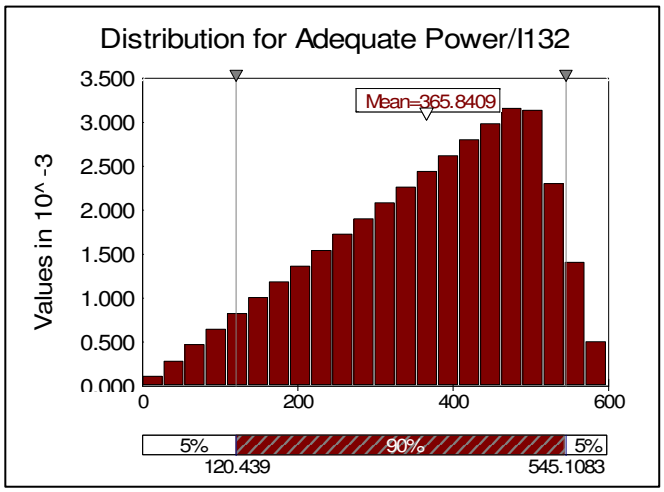
This is the most significant contributor to the overall risk of the scheme. As such we have included a copy of the Regression Sensitivity Chart to identify which are the significant factors which contribute to this risk distribution. It can be seen that cell I,128" General design development" is a significant contributor.





Adequate Power

This has been currently modelled as a triangular distribution based on an expected value of £0.5M and a maximum of £0.6M. It is not clear, but this cost appears to be associated with the construction of a new sub-station if required. If this is the case, it is obviously not going to incur costs below a threshold of say £0.4M for the sub-station construction. It may, therefore be more appropriate to model this as an event which either does or does not happen (with, say a 50:50 chance of occurrence – or what ever other ratio the project team deem appropriate). In simulation runs where this risk does occur, it then should be assigned a triangular distribution starting at £0.4M rising to £0.5M down to a maximum of £0.6M. For now it has been left to model a level of expenditure to deal with possible temporary local power generation during the construction phase and assumed to be the triangular distribution shown below.

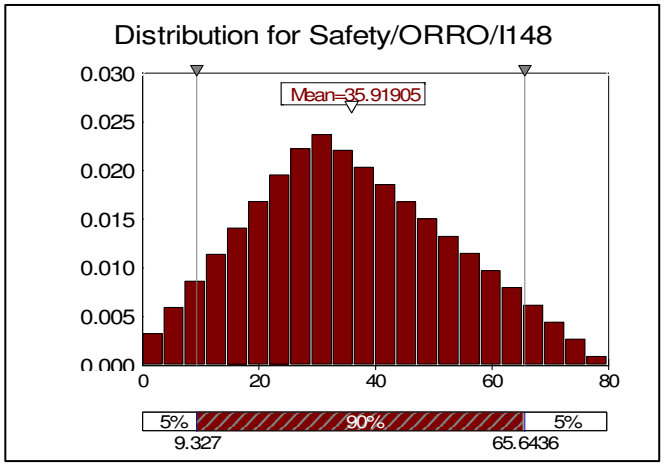


Signalling

Based on recent signalling experience the cost estimate is founded on the assumption that all potential costs will be realised . A risk value would be double booking the costs.

Safety / other requirements for rail operators

This is a straightforward triangular distribution based on initial conditions of: minimum zero, most likely £30,000 and maximum £80,000.



Third Party Risks

These risks have not been included in the assessment. An assessment in the estimate is based on a percentage. Which by its nature includes an amount for risk. Therefore to included a risk item here would be double booking to some extent.

3.5 Discussion and Conclusions

Compound Distribution - Total (excluding inflation)

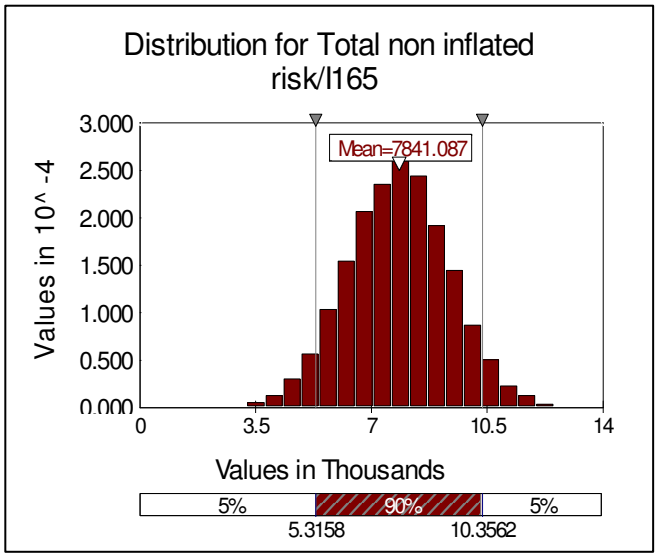
The final distribution curve shows that the risks involved in the scheme are represented by a deltoid distribution, indicating a high minimum and relatively low maximum level of value of risk. The characteristic risks (worst credible and best credible – based on 5% and 95% confidence levels) are approximately £10.4M and £5.3M respectively.

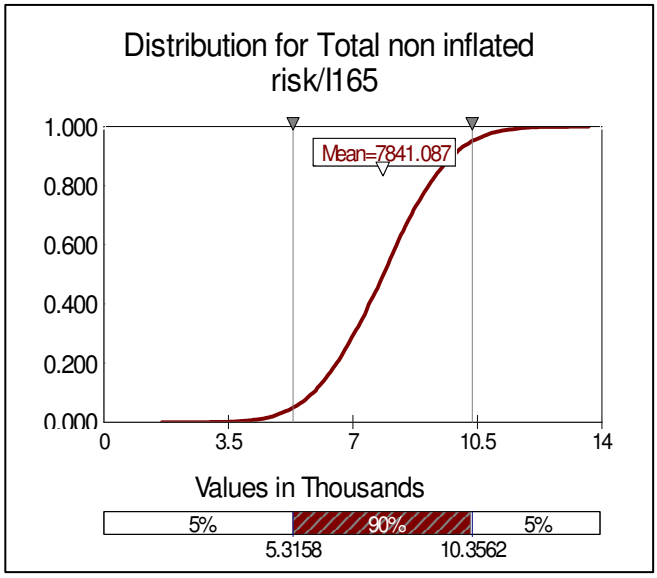
The 50%ile level of risk risk is valued at £7.9M

The £5.3M minimum characteristic level may be considered high. This appears to be due to the fact that there may be some risks with fixed minimum costs which have been considered at too high a strike rate. In general where items incur a high minimum cost but it is not clear if they will occur or not, we have modelled such risks with a 50:50 ratio of occurrence : non-occurrence. This may be too high for some unlikely but expensive risks and this should be given further consideration in any future risk mitigation exercise.

From the Regression sensitivity chart (tabulated in full for clarity below) it can be seen that the biggest impact on the overall risk is due to General Design Development. General Design development has been entered as an *ad valorem* figure and is not based on any qualitative definition of contributing risks. Thought should be given to refining and defining this risk to assist in its management and mitigation. If this cannot be done then it should be treated as a pure unknown. Since such a risk is unknown it is impossible to effectively manage. Removing it from the model (although keeping it as a scheme contingency if necessary) will assist in concentrating on those risks which can be effectively managed and reduced as it highlights what otherwise may disappear in the “background noise” of the analysis.

In a similar fashion, Cell I,15 “Onerous Commercial Conditions” is a poorly defined generalised risk (indeed the only identified potential opportunity) which should be given further thought. ECI and Partnering procurement strategies may significantly reduce the overall scheme risk.

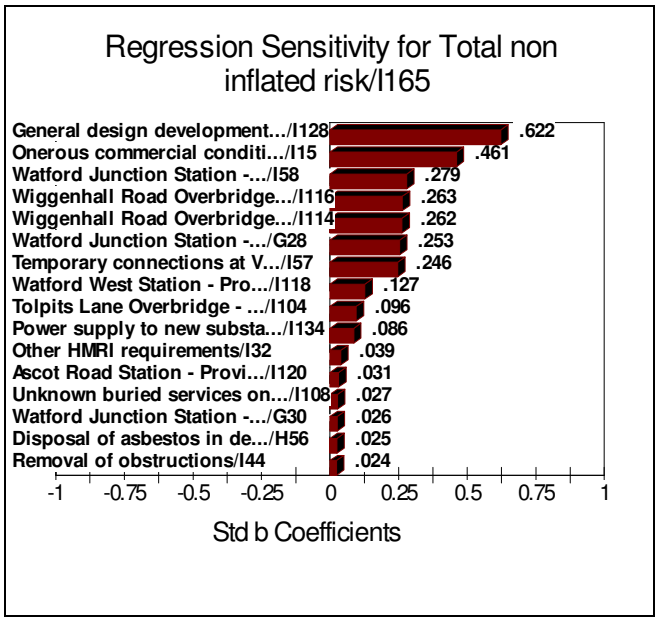




As a result of changes in parapet practice, risks ranked 4 and 5 which appear to be concerned with P6 parapets and possible ensuing bridge reconstructions, may now have been determined. Again overall scheme risk can be reduced by moving this cost to the scheme estimate if known to be required or eliminating altogether if not.

The Buffers and Connections at Watford Junction Station and the temporary connections associated with the Viaduct to existing Metropolitan lines are also key risk contributors.

Sensitivity			
Rank	**Name**	**Regr**	**Corr**
#1	General design development / I128	0.622	0.625
#2	Onerous commercial conditions / I15	0.461	0.448
#3	Watford Junction Station - Connections / I58	0.279	0.284
#4	Wiggenhall Road Overbridge - Provision of metal safety fences on road approaches and over bridge decks if the 206mm departure is accepted / I116	0.263	0.248
#5	Wiggenhall Road Overbridge - Departure from absolute minimum by 206mm may not be granted - risk of having to rebuild the entire bridge / I114	0.262	0.260
#6	Watford Junction Station - Buffers / G28	0.253	0.247
#7	Temporary connections at Viaduct to existing Metropolitan Line / I57	0.246	0.234
#8	Watford West Station - Provision of mobility impaired lifts on both sides / I118	0.127	0.134
#9	Tolpits Lane Overbridge - 65mm departure from absolute minimum may not be granted - cut back abutment faces by 33mm each side, otherwise rebuild bridge / I104	0.096	0.069
#10	Power supply to new substation from Croxleyhall substation / I134	0.086	0.091
#11	Other HMRI requirements / I32	0.039	0.049
#12	Ascot Road Station - Provision of mobility impaired lifts on north side / I120	0.031	0.041
#13	Unknown buried services on overline bridge decks to be replaced / I108	0.027	0.035
#14	Watford Junction Station - Changes to track and signalling / G30	0.026	0.026
#15	Disposal of asbestos in demolished stations / H56	0.025	0.031
#16	Removal of obstructions / I44	0.024	0.029



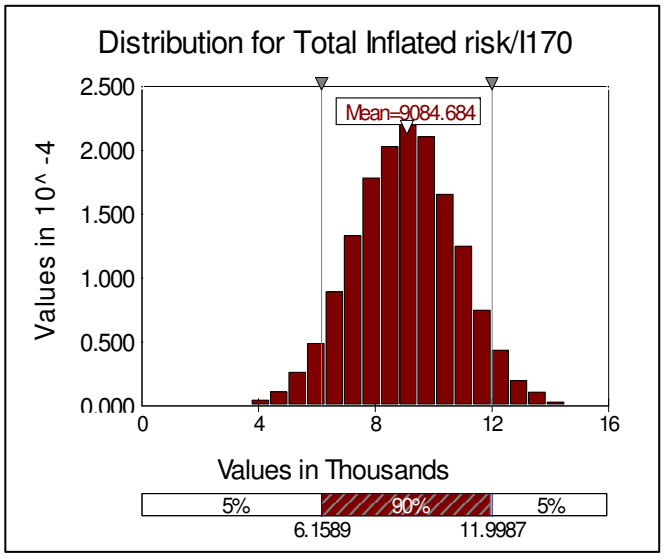
Summary Statistics			
Statistic	**Value**	**%tile**	**Value (£1000s)**
Minimum	1624.897461	5%	5315.79834
Maximum	13633.69824	10%	5873.770996
Mean	7841.086846	15%	6244.355957
Std Dev	1524.787893	20%	6540.724609
Variance	2324978.119	25%	6798.750977
Skewness	-0.003957655	30%	7027.77002
Kurtosis	2.942367715	35%	7266.33252
Median	7855.905762	40%	7458.169434
Mode	8283.836367	45%	7670.495605
Left X	5315.79834	50%	7855.905762
Left P	5%	55%	8046.121094
Right X	10356.19629	60%	8233.693359
Right P	95%	65%	8425.72168
Diff X	5040.397949	70%	8632.293945
Diff P	90%	75%	8874.134766
#Errors	0	80%	9122.639648
Filter Min		85%	9425.075195
Filter Max		90%	9785.514648
#Filtered	0	95%	10356.19629

Compound Distribution - Total (including inflation)

Inflation has been included as a simple factor in accordance with the risk register's defined value for inflation. There are however, several more detailed methods of analysing the risks associated with delay of contracts into the future variable inflation rates in the future. These can also take account of bank rates of interest available to the procuring body and indexes appropriate to the type of work. This should be considered in greater detail as part of any future risk management exercise.

The final distribution curve show characteristic risks (worst credible and best credible – based on 5% and 95% confidence levels) are approximately £12M and £6.8M respectively.

The 50%ile level of risk is valued at £9.1M



Summary Statistics			
Statistic	**Value**	**%tile**	**Value**
Minimum	1883	5%	6159
Maximum	15796	10%	6805
Mean	9085	15%	7235
Std Dev	1767	20%	7578
Variance	3120943.594	25%	7877
Skewness	-0.003957665	30%	8142
Kurtosis	2.942367668	35%	8419
Median	9102	40%	8641
Mode	9598	45%	8887
Left X	6159	50%	9102
Left P	5%	55%	9322
Right X	11999	60%	9540
Right P	95%	65%	9762
Diff X	5840	70%	10001
Diff P	90%	75%	10282
#Errors	0	80%	10569
Filter Min		85%	10920
Filter Max		90%	11337
#Filtered	0	95%	11999

Appendix 1 – Risk Assessment Methodology

Narrative on categories of risk considered

The original risk register divides the risks considered into main headings, sub-headings and individual risks. Levels of risk are determined either objectively (where the "cost" of a risk and its likelihood are well known) or subjectively (where the "cost" and likelihood are based on an individual's or group's opinion). The objective of this analysis is to use these initial conditions to compile a cogent risk analysis model.

As it stands, the original register is relatively simple in terms of the risk analysis modelling methods used and has identified a subjective assessed financial impact or "most likely" risk outcome for each of the parameters, summing them to define the total scheme assessed risk. This type of risk assessment, when applied to a multi-variable risk model, is prone to give assessments which are, in general, higher than the actual overall total risk value. Firstly, the real possibility of all the risks occurring together is low. It is true that some of the risk outcomes will be higher than the "most likely" and some will be lower; there is no way of defining a spectrum of possible outcomes (or distribution) in such a simple model. The refined model, which is the subject of this report, sets out to quantify and define such distributions. It goes on to determine a further (compound) probabilistic distribution under each risk group sub-heading and then as an overall scheme compound distribution. Secondly, some of the individual risks interact with each other and others may be mutually exclusive. For example, if the buffers are required at Watford Junction station, there will be concomitant costs associated with increased platform lengths and signalling costs. In any "what if" scenario where the buffers are not required, the second two risk items are automatically not required either. In compiling the refined model, we have tried to determine the interaction of the various risks with each other.

Narrative on analysis techniques employed

Simple modelling techniques rely on people with knowledge of the scheme defining the likely outcome of the individual subjective risks. It is very difficult to take this any further intuitively and make a subjective assessment of how these risks interact to give an overall risk distribution. A common way of looking at the interaction is to undertake several "what if" scenarios but these are time consuming and limited in scope. The original assessment consists of only two "what if" scenarios. The first reflects the assessed risk, which is simply the sum of all "most likely" outcomes for individual risks. The second determines a "worst case" scenario by summing up the maximum values for each risk. It can be seen that this is a very basic approach and is only really useful as a very coarse indicator.

Mathematical techniques exist which enable accurate predictions of the overall compound risk distribution from the initial component risk distributions, in effect mathematically covering an infinite set of "what if scenarios". These mathematical techniques require an in depth knowledge of statistical and probabilistic analysis to determine a final probabilistic outcome. These types of analysis can end up being a "black box" where it is not clear to the Engineer or Surveyor, who has defined the initial

conditions, how the output stems from the input. Due to the complexity and impenetrability of these techniques (and therefore inability to check validity), these techniques are rarely used in practice where risks are complex and interrelated.

With readily available computer power, a third option is now available – simulation. Simulation enables the user to undertake many thousands or even millions of iterative "what if" scenarios based on the initial conditions set by the individual or group with engineering/quantitative knowledge of the scheme. It combines the intuitive nature of the simple analysis with the accuracy and comprehensive "what if" scenario coverage of the mathematical analytical methods.

In this refined Croxley rail link model, an analysis of the initial conditions has been carried out using a technique, sometimes called Monte Carlo simulation (see Note below), to generate a distribution of possible outcomes from the input distributions. A distribution of the possible outcomes is generated by letting the computer recalculate the spreadsheet over and over again, each time using different randomly selected sets of values for the individual risks, based on the initial conditions set by the project team. In effect, the computer is trying all possible "what if" scenarios, that is to say, all valid combinations of the input variables, to simulate all possible outcomes. It then builds up a distribution curve based on the range of outcomes and their frequency of occurrence.

The result is a simulation which gives fairly intuitive results which can be assessed by examining a set of easily understood distribution graphs. This allows further conditioning of the model by those with the knowledge of the scheme rather than assumption that an statistical expert, with limited scheme appreciation, has properly understood the initial conditions and their interactions and constructed a valid mathematical model.

Note: Although often referred to as Monte Carlo analysis, the type of sampling used in the refined model is not classical "Monte Carlo sampling" but a form known as Latin Hypercube Sampling. The details of this are beyond the scope of this report but in essence, the sampling method forces sampling from each of several intervals on the distribution curve defined by the cumulative frequency curve and more accurately reflects the initial condition distributions.

Appendix 2

Data set (Reference Only)

Summary Information	
Workbook Name	March MP Croxley Risk Register Summary Jun 05.xls
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	46
Number of Outputs	12
Sampling Type	Latin Hypercube
Simulation Start Time	27/03/2007 12:09
Simulation Stop Time	27/03/2007 12:09
Simulation Duration	00:00:15
Random Seed	27045159

Appendix 3 Risk Register

CROXLEY RAIL LINK

RISK REGISTER REV A

Ref	Risk Description	Probability High / Medium / Low	Impact High / Medium / Low	Maximum Financial Impact	Assessed Financial Impact	Mitigation / Notes	Risk Register Reviewed July 2007
1	**EMPLOYER'S RISKS**						
1.1	**Scope**	-	-	-	-		
	Increase in Employer's Scope					Qualify estimate. Estimate based upon current scope of works	Estimate based on current scope as specified
1.2	**Contract Strategy / Programme**	-	-	**2400**	**1200**		
	Onerous commercial conditions	-	-	2400	1200	Civil works costs based upon standard form of contract. Onerous conditions may effect civil estimate. Assessed financial impact is 2.5% of current estimate	No Change
	Programme Delays	-	-	-	-	Programme delays will lead to higher inflation costs. Qualify estimate. Estimate set at 1st Q 2011	Estimate set at xx
1.3	**LUL / Train Ops / Interfaces**	-	-	-	-	Qualify estimate. Evaluated and dealt with outside this estimate	No Change
1.4	**Rolling Stock**	-	-	-	-	Qualify estimate. Evaluated and dealt with outside this estimate	No Change

Ref	Risk Description	Probability High / Medium / Low	Impact High / Medium / Low	Maximum Financial Impact	Assessed Financial Impact	Mitigation / Notes	Risk Register Reviewed July 2007
1.5	**Additional HMRI requirements**	M	M	**1520**	**1090**		
	Existing overline road bridges - provision of steps up & down cutting to cross the road above and provision of lockable gates			100	60	HMRI may request additional works. Cost allowance included in risk register	No further scheme development, potential risks still valid
	Existing underline bridge decks - steps down embankments to cross the road below			75	45	HMRI may request additional works. Cost allowance included in risk register	No further scheme development, potential risks still valid
	Watford Junction Station - Buffers			240	240	HMRI SPG 2B section 7 requires appropriate energy absorbing buffers on terminated tracks for new works. Sliding buffer cost allowance included in risk register.	No further scheme development, potential risks still valid
	Watford Junction Station - Increased platform length			140	105	Platform lengths may need to be increased by 20m in order to accommodate sliding buffers and 10m to match Ascot Road platform length of 144m	No further scheme development, potential risks still valid
	Watford Junction Station - Changes to track and signalling			600	450	If platform lengths are increased by 30m, this will effect the track and the signalling arrangements	No further scheme development, potential risks still valid
	Provision of remotely controlled DC track isolating switches in lieu of hook switches			75	50	It is anticipated that HMRI will not accept hook switches on this section of line. Remotely controlled DC track isolating switch are likely to be preferred	No further scheme development, potential risks still valid
	Other HMRI requirements			290	140	Other HMRI requirements not identified at this stage	No further scheme development, potential risks still valid
1.6	**Inflation (Start - April 08, Handover April 10)**	H	H	-	-	Qualify estimate. Inflation set at 1st Quarter 2011	Inflation set at xxx

Ref	Risk Description	Probability High / Medium / Low	Impact High / Medium / Low	Maximum Financial Impact	Assessed Financial Impact	Mitigation / Notes	Risk Register Reviewed July 2007
1.7	**Technology / Standards change during project**	L	L	-	-	Low probability. No costs effect.	No change
1.8	**Provision of Professional services up to TWA**	-	-	-	-	Evaluated and dealt with outside this estimate	No change
2	**SITE RISKS**						
2.1	**Ground Conditions / Ground Water**	M	M	**775**	**440**		
	Dewatering costs			100	50	Carry out site investigation to determine level of dewatering at structure locations	No further scheme development, potential risks still valid
	Removal of obstructions			175	100	Carry out site investigation	No further scheme development, potential risks still valid
	Uncertainty relating to the condition of embankments and cuttings and infrastructure owner's requirements			100	50	Carry out investigations	No further scheme development, potential risks still valid
	Settlement of new embankment			150	75	Carry out site investigation. Design ground improvement as required and construct early in the programme	No further scheme development, potential risks still valid
	Viaduct - Change in pile type			25	15	The strength of the chalk may preclude the practicality of using CFA piles. Additional cost of using alternative piling solution	No further scheme development, potential risks still valid
	Piles required to new station			50	25	Risk of new station being piled. Carry out detailed site investigation	No further scheme development, potential risks still valid
	Other unforeseen ground conditions			175	125		

Ref	Risk Description	Probability High / Medium / Low	Impact High / Medium / Low	Maximum Financial Impact	Assessed Financial Impact	Mitigation / Notes	Risk Register Reviewed July 2007
2.2	**Contaminated Ground**	M	M	**175**	**75**		
	Disposal of contaminated material from existing earthworks operations			175	75	Carry out site investigation to determine level of contamination. Disposal of hazardous material where necessary	No further scheme development, potential risks still valid
2.3	**Asset Conditions**	M	M	**1860**	**1755**		
	Additional refurbishment required to stations			160	80	Costs of carrying out additional refurbishment. Carry out a detailed station survey	No further scheme development, still valid
	Disposal of asbestos in demolished stations			100	75	Additional costs associated with disposal of asbestos. Carry out asbestos survey	No further scheme development, still valid
	Temporary connections at Viaduct to existing Metropolitan Line			750	750	2 temporary connections are required for testing purposes	No further scheme development, still valid
	Watford Junction Station - Connections			850	850	Additional requirement for 1 cross over and 1 turnout at Watford Junction Station	No further scheme development, still valid
2.4	**Access**	L	L				
2.4.1	Rail	-	-	-	-	Included in cost estimate	No change
2.4.2	Civils	-	-	-	-	Included in cost estimate	No change
2.5	**Environmental**	L	L	**200**	**125**		
	Vegetation clearance			50	25	Carry out survey	No further scheme development, still valid
	Environmental constraints associated with vegetation removal including SSSI risks			150	100	Carry out survey and consultation with relevant bodies	No further scheme development, still valid

Ref	Risk Description	Probability High / Medium / Low	Impact High / Medium / Low	Maximum Financial Impact	Assessed Financial Impact	Mitigation / Notes	Risk Register Reviewed July 2007
2.6	**Land Costs**	-	-	-	-	Land costs excluded from estimate	No change
2.7	**Restricted Working Hours**	L	L	-	-	Included in cost estimate	No change
2.8	**Building over live roads, rails etc**	L	L	-	-		
	Traffic management					Included in cost estimate	No change
	Restricted site access					Included in cost estimate	No change
2.9	**Unforeseen services**	M	M	**430**	**290**		
	Bring site services onto site			80	40	Early consultation with STAT's	No further scheme development
	Way leave issues			75	50	Early consultation with landowners.	No further scheme development
	Diversion of existing services			175	125	Cost of diverting existing services not shown on drawings	No further scheme development
	Repairs to existing services			100	75	Carry out condition survey of existing services	No further scheme development
2.10	**Interfaces to existing roads / paths / drains / services**	M	M	**60**	**30**		
3	**DESIGN RISKS**						
3.1	**Design development**	H	H	**6970**	**3640**		

Ref	Risk Description	Probability High / Medium / Low	Impact High / Medium / Low	Maximum Financial Impact	Assessed Financial Impact	Mitigation / Notes	Risk Register Reviewed July 2007
	New overline bridges - provision of lineside path past abutment both sides of track by increasing bridge spans			30	30		
	New underline decks - Provision of lineside path both sides of deck by widening deck			35	35		
	Tolpits Lane Overbridge - 65mm departure from absolute minimum may not be granted - cut back abutment faces by 33mm each side, otherwise rebuild bridge			700	90	Mitigation is to cut back abutment faces. Maximum risk is to rebuild the bridge if 65mm departure from absolute minimum is not granted	No further scheme development, potential risks still valid
	Tolpits Lane Overbridge - Provision of metal safety fences on road approaches and over bridge decks if cutting back the abutment faces, or 65mm departure, are accepted			30	30	If P6 parapets are not required metal safety fences will be constructed on road approaches and over bridge. If P6 parapets are required the bridge deck will need to be reconstructed. These costs are included in the rebuild costs	No further scheme development, potential risks still valid.
	Unknown buried services on overline bridge decks to be replaced			200	100	Carry out services survey	No further scheme development, potential risks still valid.
	Vicarage Road Overbridge - Provision of metal safety fences on road approaches and over bridge decks			300	30	If P6 parapets are not required metal safety fences will be constructed on road approaches and over bridge. If P6 parapets are required the bridge deck will need to be reconstructed.	No further scheme development, potential risks still valid.
	Culvert - May need infilling with concrete if it is in poor condition and is not redundant			10	10	Carry out condition survey and also check if it is redundant	No further scheme development, potential risks still valid.

Ref	Risk Description	Probability High / Medium / Low	Impact High / Medium / Low	Maximum Financial Impact	Assessed Financial Impact	Mitigation / Notes	Risk Register Reviewed July 2007
	Wiggenhall Road Overbridge - Departure from absolute minimum by 206mm may not be granted - risk of having to rebuild the entire bridge			800	800	Early consultation to establish if departure from absolute minimum by 206mm may not be granted. Likely rebuild	No further scheme development, potential risks still valid.
	Wiggenhall Road Overbridge - Provision of metal safety fences on road approaches and over bridge decks if the 206mm departure is accepted			30	30	If P6 parapets are not required metal safety fences will be constructed on road approaches and over bridge. If P6 parapets are required the bridge deck will need to be reconstructed. These costs are included in the rebuild costs	No further scheme development, potential risks still valid.
	Ascot Road Station - Provision of pedestrian controlled crossing to car park and pedestrian guard rails both side of road			50	50	Provide safe access to new car park with the provision of a pedestrian controlled crossing and guard rails	No further scheme development, potential risks still valid.
	Trains are to be 4m longer - The impact on platform lengths to all stations			75	50	Platforms may need to be 4m longer in order to accommodate the longer trains. Surveys are required to reveal the extent of this risk	No further scheme development, potential risks still valid.
	DDA Compliance - Station alterations to comply with DDA requirements not identified elsewhere			60	60	Increase corridor widths, door openings, disabled toilets etc to comply with DDA	No further scheme development, potential risks still valid.
	General design development			4650	2325	General changes to design through the design development process. Assessed financial impact represents 5% of the base estimate	No further scheme development, potential risks still valid.

Ref	Risk Description	Probability High / Medium / Low	Impact High / Medium / Low	Maximum Financial Impact	Assessed Financial Impact	Mitigation / Notes	Risk Register Reviewed July 2007
3.2	**Adequate Power**	H	H	**600**	**500**		
	Power supply to new substation from Croxleyhall substation	-	-	600	500	Investigate location of power supply to feed the new sub-station. Cost associated with new sub-station being fed by Croxley Hall sub-station	No further scheme development, potential risks still valid.
3.3	**Signalling**	M	M				
	Signalling requirements from Croxley to Watford Met Station	-	-	-	-	Presently in Metronet commitment and therefore these costs are excluded from this estimate	No further scheme development, potential risks still valid.
	Existing interlocking complexity at Watford Met Station	-	-	-	-	Currently Metronet's commitment is to supply a moving block radio based distance-to-go signalling system using the Westinghouse Westrace interlocking to control train movements between Croxley and Watford Met. These costs are excluded from this estimate	No further scheme development, potential risks still valid.
	Omissions of the terminus Watford Met	-	-	-	-	There is a reduction in complexity at Watford Met as no signalling is required. These values are excluded from this estimate	No further scheme development, potential risks still valid.
	Interface complexity at Watford Junction	-	-	-	-	There is increased signalling complexity at Watford Junction due to the interface with Network Rail. These costs are excluded from this estimate	No further scheme development, potential risks still valid.

Ref	Risk Description	Probability High / Medium / Low	Impact High / Medium / Low	Maximum Financial Impact	Assessed Financial Impact	Mitigation / Notes	Risk Register Reviewed July 2007
	Acceleration charge	-	-	-	-	There may be an acceleration charge if the link line works is required in advance of other met line works. These costs are excluded from this estimate	No further scheme development, potential risks still valid.
3.4	**Safety / other requirements for rail operators**	M	M	**80**	**30**		
4	**THIRD PARTY RISKS**						
4.1	**Planning / public enquiries**	H	H	-	-	Qualify estimate. Estimate assumes a start date of 1st Quarter 2011	
5	**OTHER RISKS**						
5.1	**Local Market Conditions**						
5.1.1	Civils	L	L	-	-		
5.1.2	Rail	L	L	-	-		
5.2	**Government Legislation**	Qualify	Qualify	-	-	Changes in future government legislation are excluded form this estimate	
			Running Total	15070	9175		