CONTENTS

1 Introduction

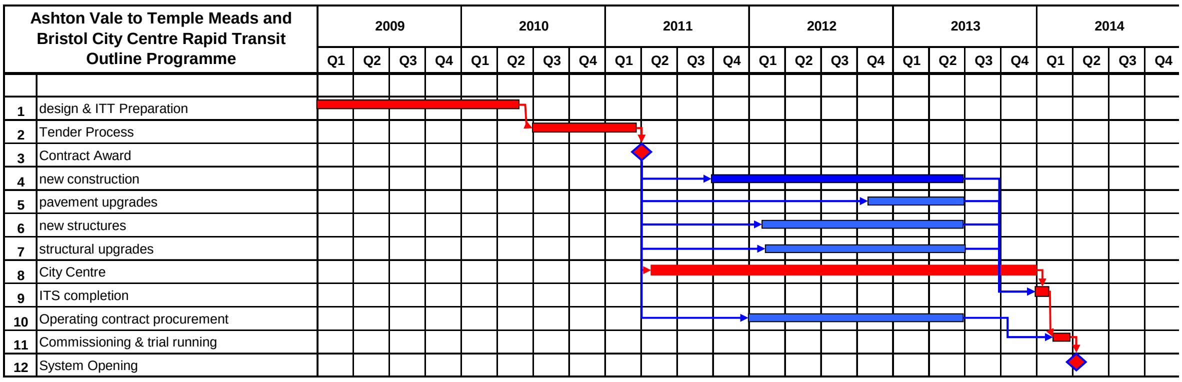
Quantitative Risk Analysis (QRA) has been carried out on the project to provide a rapid transit system from Ashton Vale to Temple Meads and Bristol City Centre. This section would be the initial part of the West of England Rapid Transit network. The main purpose of the analysis is to support the Programme Entry submission by predicting the level of capex contribution having a high level of confidence to cover the construction of the system, with due allowance made for risks. The QRA is confined to the capital cost elements of the project, and the construction programme. Risks to operational costs, performance or revenues have not been quantified.

The risk model has been constructed by Atkins using a Microsoft Excel spreadsheet, with a proprietary package, @Risk, adding the capability for probabilistic modelling. The Atkins approach integrates both cost and time within the risk model, so that in addition to producing predictions of out-turn cost, the model gives the project team a view of potential schedule slippage and generates risk-based predictions of possible cash-flow. The model aims to replicate the project being implemented several thousand times, potentially with a different result on each occasion. The distribution of results is plotted against their frequency of occurrence. These probabilistic predictions relating to cost and timescale allow project sponsors to plan budgets at their selected level of confidence.

2 Construction Programme

The baseline programme used in the risk model is shown in Figure 2.1. It assumes a target date for construction contract award in spring 2011, with the system opening three years later in spring 2014. It assumes that the operating contract is award in late 2013.

Figure 2.1 – Baseline Construction Programme



The expected critical path, shown in red, runs through the City Centre work, which (being complex and the least developed) also has the greatest uncertainty for its planned duration, particularly in respect to other developments likely to be taking place in the area. Although there are risks on the Segregated Corridor between Ashton Vale and the City Centre, which is still the major part of the project in terms of expenditure, they are unlikely to influence the completion date, providing the start is not over-delayed.

In practice, setting the appropriate stagger in start dates between the two work elements could be a difficult judgement: starting the Segregated Corridor too soon is likely to result in completion before it can be used – but delaying it too long could put it back on the critical path.

3 Risk Model Inputs

The principal inputs to the risk analysis consist of estimates of capital cost, the tolerance attached to elements within the estimates, and discrete risks. The text below expands on these three components.

3.1 Baseline Capital Cost Estimate

This represents a mid-point estimate based on current knowledge. For a project such as this, at a relatively early stage in its evolution, this knowledge is limited. For example the design is not yet fully developed, so that there is scope for variations in quantities and volumes, and in ground conditions and the state of existing structures. The work will also be competitively tendered, which will introduce uncertainty in relation to market conditions and pricing at that time. The programme and methodology to be followed by the appointed contractor is also an unknown factor at this stage.

The Segregated Corridor represents about 60%, and the City Centre work about 30% of the estimated baseline construction cost. The cost balance is made up of land and ITS costs, in roughly equal proportions.

3.2 Estimating Tolerance

This is applied to the baseline cost estimate (and also to the activity durations) to represent the combined effect of these uncertainties.

Estimating tolerances for the Segregated Corridor were developed by reviewing sub-elements of the work, and three-point estimates represent possible variations due to pricing and design risk. A default range was used for the majority of elements, with the most likely value set to allow for design development tending to have an upward pressure on cost. Several sub-elements in the Segregated Corridor estimate were considered to have a greater potential for uncertainty, which is reflected in the range selected. The input factors used in the risk model to apply to baseline costs are shown in Table 3.1.

Table 3.1 – Estimated Tolerances for Segregated Corridor

Segregated Corridor Element	min	m/l	max	comment
Series 100: Traffic Management	90%	115%	150%	range reflects provisional traffic management plans
Series 200: Site Clearance	80%	115%	160%	range reflects potential for design development
Series 300: Fencing	90%	110%	135%	default range
Series 500: Drainage	90%	115%	150%	range reflects potential for drainage to be required
Series 600: Earthworks	80%	100%	150%	range reflects potential variation in actual levels
Series 700: Pavements	90%	110%	135%	default range
Series 1200: Traffic Signs and Road Markings	90%	110%	135%	default range
Series 1700: Structures	90%	115%	150%	range reflects scope for unforeseen condition of structures
Series 3000: Landscaping and Ecology	90%	110%	135%	default range
Rogues	90%	110%	135%	default range

As the City Centre option was revised extensively at a fairly late stage, less detail was available, and a pessimistic uncertainty range is applied. This assumes that the minimum cost will be not less than 100% of the current baseline; the most likely value is 130%, and the maximum value would be 160% of the current baseline.

Tolerances of +/- 30% were applied to environmental works and land costs.

Table 3.2 summarises the baseline estimate, indicates the sources of baseline values and shows the estimating tolerances applied. All values used were subject to discussion and review by members of the project team (Sharon Daly, Bruce Slattery and Rob

Thompson, plus Peter Wood, Atkins risk advisor). Further minor adjustment was made following the review and revision of cost estimates issued on 13 March 2009.

Table 3.2 – Baseline Estimate, Sources and Estimating Tolerances

Baseline Estimate, Sources and Estimating Tolerances						
cost element	**baseline £k @ 2008**		**source**	**estimating tolerance min**	**m/l**	**max**
Segregated Corridor (excl stats)	£	17,772	Halcrow estimate	see text		
Segregated Corridor stats	£	100	"final cost 13 March 09"	50%		150%
City Centre	£	8,588	BCC	100%	130%	160%
ITS Costs	£	1,750	Steer Davies Gleave	90%	115%	140%
environmental works (Seg Corr)	£	804	Halcrow	70%		130%
environmental works (City Centre)	£	1,049	Steer Davies Gleave	70%		130%
land	£	1,685	Steer Davies Gleave	70%		130%
TOTAL	**£**	**31,749**				

3.3 Discrete Risks

These are possible events that have been identified as having a chance of occurring and of impacting the project programme and/or cost to some degree. An initial set of risks was identified in a risk workshop held on 12 November 2008. The attendees at the initial risk workshop are listed in Appendix A.

The risks identified at the workshop have been augmented following review by the members of the project team referred to above. Overall, 20 discrete risks have been included in the model. These are listed in Appendix B, together with a table showing the calibration used for probabilities and impacts.

The impact of nearly all of the risks is judged to be a delay to the programme. Almost half the risks, including those with the greatest potential effect, would delay the project before a contract has been signed either through a delay to the approval process or to procurement. The remaining risks delay the construction programme or the final commissioning, but also impact on capital cost.

During the risk workshop project, it was recognised that the contract conditions for the operating phase have not yet been defined, in particular whether demand risk would sit with the operator or the owner.

There is also an assumption that a contractor would be willing to provide vehicles, and their storage and maintenance facilities, without any contribution to the capital cost of this, recovering its investment through the operating revenue and subsidy, if relevant.

In the current economic climate this may prove unrealistic, with the consequence either that the procurement fails or that the initial capital cost to the employer increases. A possible mitigation would be to test the market for the appetite for this type of investment, but it might be difficult to obtain a reliable commercial view at this time. This risk has not been modelled as risks that have the potential to be "show-stoppers" cannot be managed through any normal contingency, and so tend to skew results.

4 Risk Model Outputs

4.1 Programme Results

This table shows the risk model predictions for contract award and completion at defined levels of confidence.

Programme Results		
	contract award	**system open**
baseline	Apr-11	Mar-14
20%	Jul-11	Sep-14
50%	Sep-11	Dec-14
80%	Oct-11	Apr-15
mean	Sep-11	Jan-15

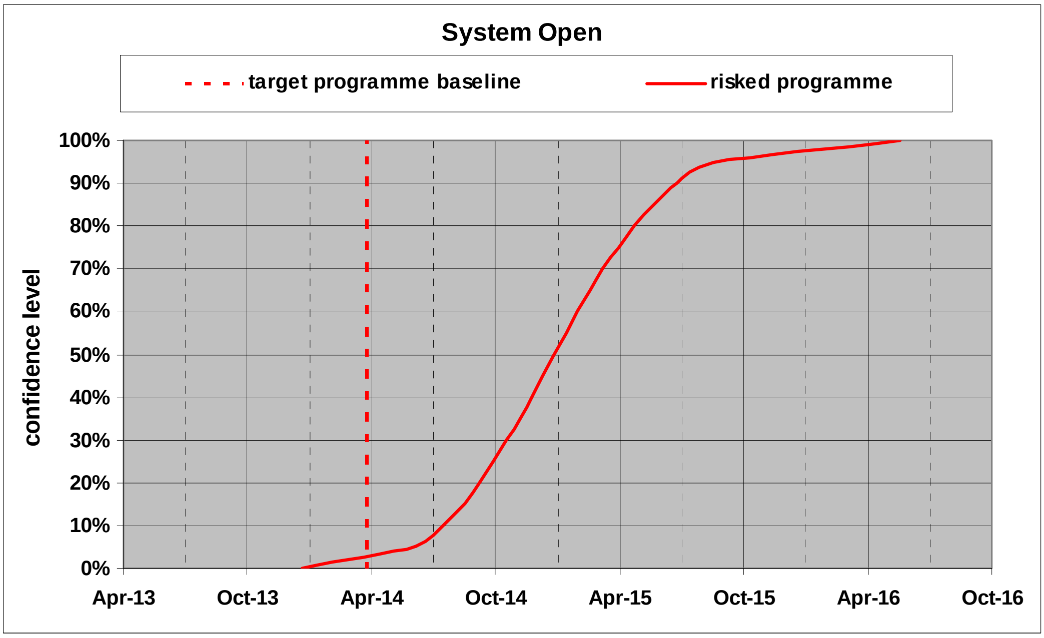
These results are derived from 5,000 iterations of the risk model and can be interpreted to predict that, compared with a baseline completion date of March 2014, there is a 20% chance of operations starting by September 2014; an evens chance of the system opening by the close of 2014; and an 80% chance of opening by April 2015 or sooner. A pessimist might also infer that there is a 20% chance of opening later than April 2015.

The results also indicate that delay to reaching contract award is a factor in the overall delay. Whilst an overall completion delay of between six and thirteen months is quite likely, the delayed award of a construction contract could be contributing between three and six months to the overall delay. It follows that, if the programme performance of the project is to be improved, initial effort should be focussed on the activities leading up to contract award.

However, whenever the contract award is made there is a high risk that the City Centre work, having the longest duration of the construction elements and a high degree of uncertainty, will extend the completion date further.

Figure 4.1 shows the cumulative distribution of results, expressed as an 'S' curve, from 5,000 iterations of the risk model for the completion date.

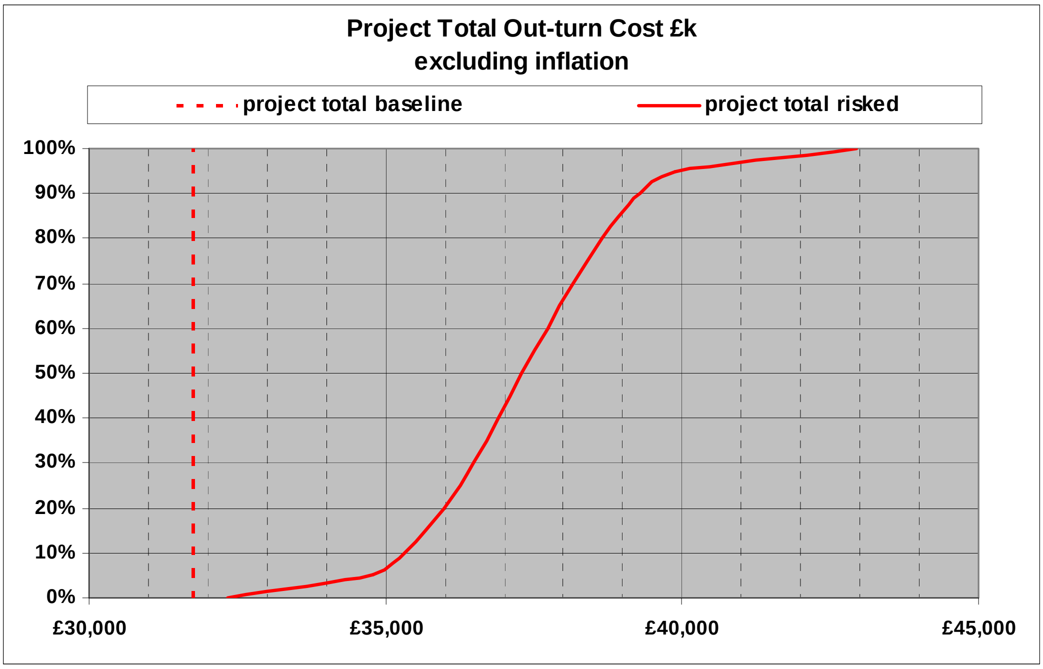
Figure 4.1 – System Opening Date - Cumulative Distribution



4.2 Cost Results (excluding inflation)

Figure 4.2 shows the cost results predicted by the risk model.

Figure 4.2 – Project Outturn Costs – Cumulative Distribution



In Figure 4.2, the dotted vertical line represents the baseline estimate excluding contingency on construction costs. The risk curve indicates the possible range of outcomes against confidence levels, and predicts that between confidence levels of 20% to 80% the total project out-turn cost is likely to be between about £36m and £38.7m.

Expressing this in terms of contingency, the model predicts that a risk allowance of 18% of baseline cost (£5.6m) has an evens chance of being sufficient. Increasing the risk allowance to 22% of baseline cost (£6.9m) increases the level of confidence to 80%, as shown in this table.

Risk Values £k and % (uninflated)		
confidence level	2008 prices	% risk allowance
50%	£ 5,556	18%
80%	£ 6,906	22%

These values are all at November 2008 values. The possible effects of inflation are discussed below.

4.3 Cost Results (with inflation)

Under current funding rules, the authority owning the project carries the risk for construction cost inflation, so the funding application should make due allowance for this.

This raises the question of what data the allowance should be based on. We understand that the current regional advice for this purpose is to assume 6% inflation each year, although it seems that this guidance pre-dates the present recession. For some time, construction inflation has been above RPI, driven by high demand and global increases in commodity prices, including oil, steel and cement, so that, prior to the recession, 6% would have been a reasonable mid-range estimate.

At present construction input prices are flat, and demand is falling, so that increased competition may well result in a fall in tender prices over the next year or so. On the other hand, public sector infrastructure projects are insulated to some extent from demand changes in the private sector, and sooner or later a recovery in the global economy will stimulate a recovery in commodity prices. One possible trend is for construction prices to match or fall behind RPI in the short term, then catch up and overtake it when recovery comes, but there is plenty of scope for wider variation.

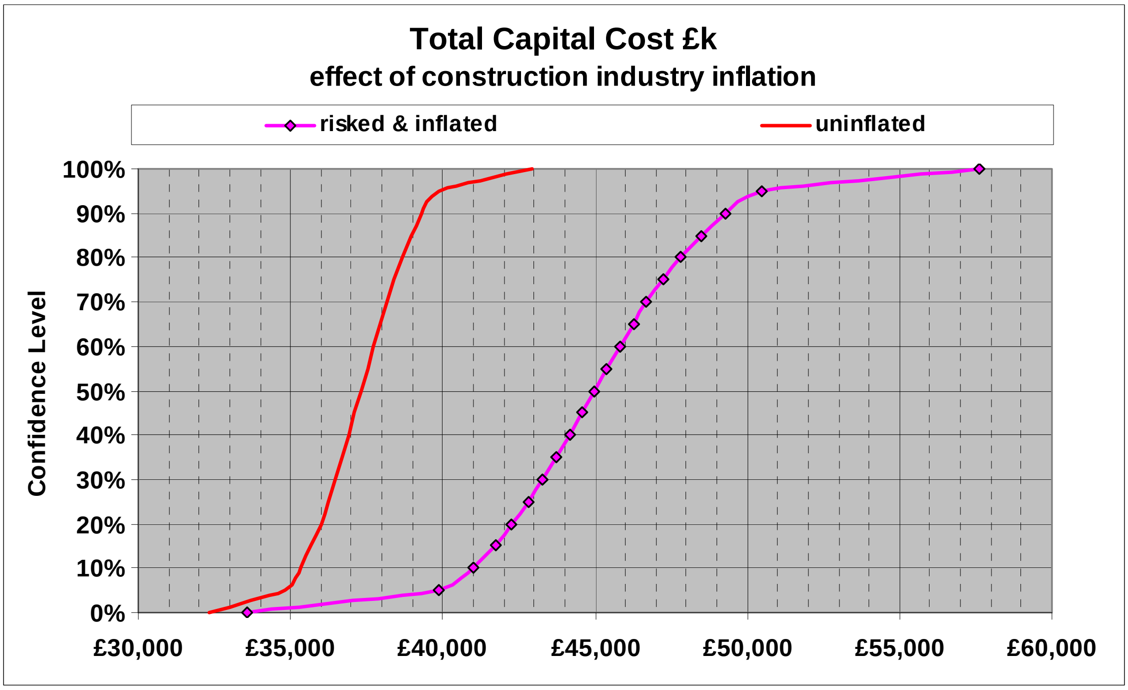
For the purpose of this analysis, the potential uncertainty has been modelled with the input ranges shown in Table 4.1. It assumes a central trend climbing from parity up to 6% above RPI over a four year period. A tolerance of +/- 6% is then applied in any one full year ie from 2009-10.

Table 4.1 – Modelled Construction Industry Inflation

Construction Industry Inflation as modelled (possible annual changes in construction industry price inflation)								
	2008-9	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
low	-3%	-3.5%	-2%	-1%	0%	0%	0%	0%
mean	0%	2.5%	4%	5%	6%	6%	6%	6%
high	3%	8.5%	10%	11%	12%	12%	12%	12%

The results obtained for the total project cost using these inputs is shown in Figure 4.3.

In Figure 4.3, the plain red 'S' curve is the un-inflated risk result shown earlier, and the marked S curve is the result with inflation applied in accordance with Table 4.1. The risk model predicts that a total project budget of £45m would have a 50% chance of being adequate. To achieve a confidence level of 80% the budget would need to be increased to £47.8m.



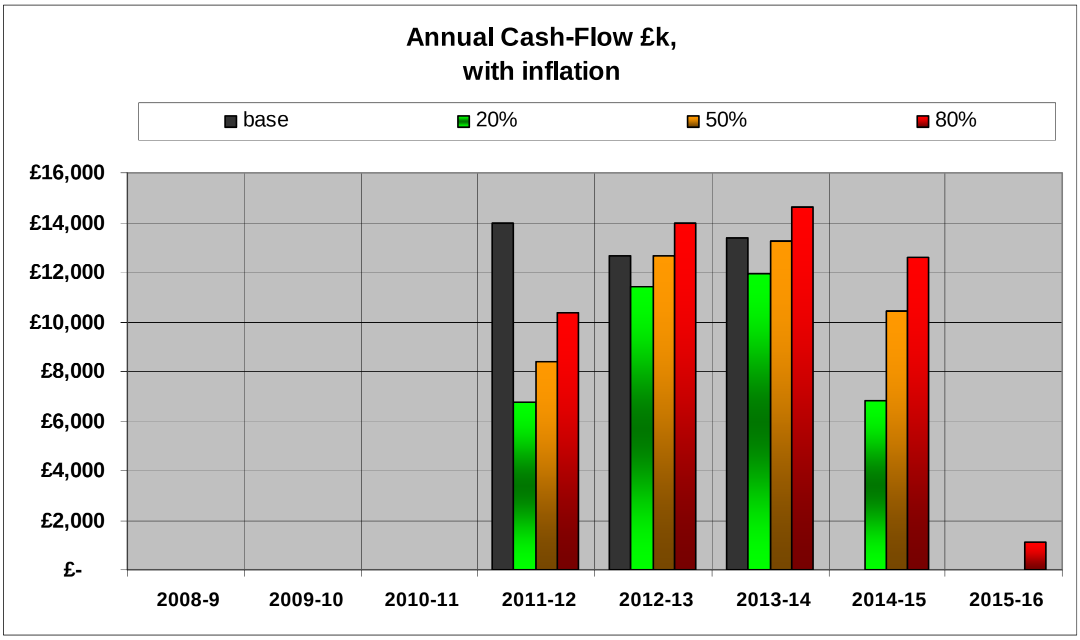
4.4 Cash-flow

It follows that as the risk model predicts that construction on the project is highly likely to start and finish later than the current target programme; construction will take longer than the baseline programme; and out-turn costs will be higher than the baseline estimate then the annual flow of expenditure will be different to that which might be expected.

Figure 4.4 compares the deterministic, or base, cash-flow projection to that predicted by the risk model at various levels of confidence. It shows for example that in year 2011-12 the probable funding needed is fairly unlikely to exceed £8m, as against the £14m that might have been expected working on baseline values.

In 2012-13 and 2013-14 the expenditure is likely to be similar to the deterministic value, but in the following year, when construction would be complete according to the baseline plan, the actual expenditure could be between £6m and £12m.

Figure 4.4 – Annual Cash Flow



The purpose of this cash-flow forecasting is to inform budget holders (a) that the actual cash-flow will almost certainly be different to anything calculated by normal deterministic means, and (b) that they may need the ability to manage expenditure between quite wide boundaries.

The spread of expenditure over time is sensitive to the overall duration of the City Centre work, which is at an early stage in programming terms, and in the timing of the other works in relation to the City Centre.

Depending on when the budget holders need to be making their plans, and how far ahead they must plan, cash-flow modelling can be refined as the project develops and milestones become less uncertain, and allow budget planning to have improving accuracy.

Appendix A

Attendees at initial risk workshop held in Bristol on 12 November 2008.

Bill Davies	West of England Partnership
Helen Dibble	Halcrow
Bruce Slattery	Halcrow
Peter Wood	Atkins
James Wilcock	North Somerset District Council
Mike Buck	Bristol City Council
Rob Thompson	Atkins
Sharon Daly	Steer Davies Gleave
Colin Walker	Bristol City Council

Appendix B

Risk Log and Risk Calibration

Long Ashton to Bristol City Centre - risks as modelled			evaluation		
ref	Description	Impact	prob	time	cost
R1	authorities don't allow design work to proceed at risk	preparation of ITT delayed	M	H	
R2	uncertainty in formation and ToRs of delivery vehicle	preparation of ITT delayed	M	L	
R3	delayed DfT approval in programme entry	preparation of ITT delayed	H	H	
R4	delayed DfT full approval	preparation of ITT delayed	H	H	
R5	delayed DfT approval of TWA	preparation of ITT delayed	M	H	
R6	lack of market interest	can't obtain ops commitment	L	H	
R7	lack of market interest	forced to re-run tender process	L	H	L
R8	budget constraints / lack of funding	award of contract delayed	L	M	
R9	tender process extended	award of contract delayed	M	M	
R10	commissioning problems	system opening delayed	L	H	
R11	delays in ops tender process	system opening delayed	L	M	
R12	service provider not ready by planned date	system opening delayed	M	M	
R13	unforeseen ground conditions increase work	extra cost and delay	L	M	M
R14	additional work needed to existing structures	extra cost and delay	L	H	H
R15	work in City Centre delayed due to other work	extra cost and delay	H	H	L
R16	work at Temple Meads can't start due to other work	extra cost and delay			
R17	additional rail closures required	traffic management	L	L	M
R18	additional cost of dealing with existing rail equipment	earthworks	M	L	M
R19	potential for flooding forces change in method	raised haul road to serve bridge works	M		L
R20	unforeseen utiities eg cables / gas main	utility diversion required	L	L	M

calibration used in risk model					
		days delay		£	
	prob	min	max	min	max
L	10%	10	30	10,000	50,000
M	30%	30	90	50,000	150,000
H	50%	90	180	150,000	750,000