DECISION THEORY AND REAL ESTATE DEVELOPMENT

A Note on Uncertainty

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(NOT FOR QUOTATION. COMMENTS WELCOME)

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ABSTRACT

Real estate development appraisal is a quantification of future expectations. The appraisal model relies upon the valuer/developer having an understanding of the future in terms of the future marketability of the completed development and the future cost of development. In some cases the developer has some degree of control over the possible variation in the variables, as with the cost of construction through the choice of specification. However, other variables, such as the sale price of the final product, are totally dependent upon the vagaries of the market at the completion date. To try to address the risk of a different outcome to the one expected (modelled) the developer will often carry out a sensitivity analysis on the development.

However, traditional sensitivity analysis has generally only looked at the best and worst scenarios and has focused on the anticipated or expected outcomes. This does not take into account uncertainty and the range of outcomes that can happen. A fuller analysis should include examination of the uncertainties in each of the components of the appraisal and account for the appropriate distributions of the variables. Similarly, as many of the variables in the model are not independent, the variables need to be correlated. This requires a standardised approach and we suggest that the use of a generic forecasting software package, in this case *Crystal Ball*, allows the analyst to work with an existing development appraisal model set up in Excel (or other spreadsheet) and to work with a predetermined set of probability distributions.

Without a full knowledge of risk, developers are unable to determine the anticipated level of return that should be sought to compensate for the risk. This model allows the user a better understanding of the possible outcomes for the development. Ultimately the final decision will be made relative to current expectations and current business constraints, but by assessing the upside and downside risks more appropriately, the decision maker should be better placed to make a more informed and "better" decision.

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Introduction

The thesis of this paper is that uncertainty is an integral part of the development process and that this needs to be reflected in the development appraisal. However, as with any decision tool, the information needs to be conveyed to the user in a clear and appropriate manner. This paper concentrates upon the practical impact of uncertainty in development appraisal. This requires a standardised approach and we suggest that the use of a generic forecasting software package, in this case *Crystal Ball*[4], allows the analyst to work with an existing development appraisal model set up in Excel (or other spreadsheet) and to work with a predetermined set of probability distributions.

The Development Process

A development appraisal, also known as residual valuation, is a method used by an analyst/developer to decide whether a proposed development will be viable. In principle, the method of approach is to ascertain the capital value of an estimated future income (sale price of the completed development), and then to deduct from that the cost of all works needed to complete the development to a standard able to command such a future income. In essence it is a quantification of the development process to determine the value of some predetermined benchmark.

Residual to Land Value

GDV Gross Development Value: Value of the completed development	-	**Total Costs** All construction costs. Interest on construction, professional fees & Developer's Profit	=	**Gross Residual** Maximum bid for site includes acquisition costs, professional fees & finance of land purchase.

Residual to Profit

GDV Gross Development Value: Value of the completed development	-	**Total Costs** All construction costs as above but incl Land Value as a cost	=	**Developer's Profit**

Thus the residual figure can represent either the developer's/purchaser's maximum bid for the site (A) in question or, if land value has been included

4 An alternative would be to use @risk which is a very similar software package

the costs, the expected profit (B)[5]. But to do this it needs the valuer to assess the correct level of the inputs.

Property development involves many uncertainties, which it is difficult to take into account in traditional spreadsheet analysis. Many commentators (for example see MacFarlane, 1995), have argued that it is important to include uncertainty in an analysis of the financial feasibility of a property development. MacFarlane points out that Development Appraisals have generally only looked at the best and worst case scenarios and have focused on variation around the anticipated or expected outcome. This does not take into account uncertainty and the range of all the outcomes that can happen.

A fuller analysis should include an examination of the uncertainties in each of the variables that lead to that financial outcome such as rental, yield, costs and finance. Spreadsheet models usually restrict users to fixed-point analysis, so they have to determine what they think will happen for each of the critical variables. Investigations of the uncertainty surrounding these values is usually basic, and involves looking at what happens if everything goes better or worse than planned. This does not take into account what happens if some things are better, while others are worse. It is also difficult to investigate the interaction of variables in the models and to determine which variables are having the most effect on the results, leaving practitioners with only a limited understanding of what is really going on. If the developer underestimates the risks pertaining to the project, then the value is correspondingly overestimated (in the case of assessing land value) or the accepted level of profit is too low to compensate for the real risks involved. Research has shown that property developers consistently underestimate the risk associated with property developments (MacFarlane, 1995)

Unless developers have a clear idea of the risks they are facing then it is impossible to determine what returns they should be expecting to compensate for that risk. In a development model there is uncertainty in each input variable and these uncertainties should be included in the analysis if the model is to capture everything and show all possible outcomes.

Some of the inputs are also correlated, for example, if rent of the completed development is low then the corresponding all risk yield will probably be high. Cash flow appraisals are able to model sensitivity around the expected input values but they don't distinguish the correlations between the inputs, which means they proffer equal probability of each of the outputs in the sensitivity analysis. Whist a competent user of such a technique can intuitively differentiate between the likely and unlikely outcomes, to the untrained eye it can be confusing. This shortcoming needs to be addressed.

[5] The method can also be used as a project management tool setting cost ceilings for construction to ensure that a set profit is achieved at given land value (this method is not illustrated here)

It is also important to know what is having the largest effect on the change of outcomes and where the risk is. In doing this it is then possible to try to decrease the risks that are seen to be too high.

To include all these elements in models requires practitioners to move away from existing development appraisal models (even if they include sensitivity analysis) and to think more widely about the problems that they face. They need to look at the uncertainty that is in the situation they are modelling and try to quantify it, this means moving away from the idea of a best and worst estimate, to a range of outcomes and a distribution (see Byrne, 1995). Using *Crystal Ball*, the valuer can easily move away from fixed-point analysis and include the uncertainty they face in their models.

Decision Theory

Decision theory is the study of how people model "judgement" and from that how they determine their choice. These may be probability-based models; loss functions models or other forms of statistical representations of judgements.

Much of decision theory concentrates on 'how decisions *are* actually made' based on observation of previous decisions. Whilst the models that we are discussing in this paper are looking at 'how decisions *should* be made'. There is a strong body of evidence that the predicted rational models are rarely observable in practice. What people should do in theory is often very different from the final decision. This might be because the original predictive model was erroneous or that it failed to encompass the whole thought process which influenced the final decision. For example, in property development, a development appraisal might suggest that a particular project should be undertaken to maximise profit on that particular project but business risk (i.e. 'what are the competitors doing?') may require the developer to focus on a particular location to ensure that they are represented in that market. In this case the rational model is only part of the process.

Decision Models

Thus decision models can be divided into three distinct types;

Descriptive analysis - models which purport to describe how we do decide.

Normative analysis - models which suggest how we should decide.

Prescriptive analysis - models which uses normative models to guide the decision maker within other limiting cognitive parameters.

In this context, the development appraisal model is a rational normative model. If the user believes in the veracity of the inputs, then they will choose the optimum outcome based on their predetermined benchmarks of acceptability.

In reality there are anomalies between the behaviour that the normative theories encode and how developers actually 'do' make decisions. In other words, developers do not act in the way the theory (model) predicts. It can therefore be argued that normative theories may be of little use in guiding real decisions.

Normative theories do not take into account the internal inconsistencies that developers have or how their personal and professional values can be influenced and changed. Regret, anticipation, fear of failure, cognitive limitations in calculations are not included in the models. Yet, empirical studies have shown that all these things affect the choices of decision makers (French, 1996).

Normative theories are usually based on mathematical axioms, which define 'rational behaviour'. They are often of the form, *if the decision maker believes* (*a*) *and* (*b*)*, she should do* (*x*) *and* (*y*). This is the exact case with a development appraisal model. However, the additional element that is critical in the development process is time (see Atherton and S. French, 1997). Having made the decision it can be anywhere between 6 months and 10 years before the actual outcome is known. The development appraisal model, in its cash flow form (see on), discounts each possible outcome at a constant rate. Each future outcome is present valued by multiplying it by an appropriate discount factor. However, as the possible future value moves forward in time, so will the corresponding present value decreases as a geometric function (see French, 1986).

Descriptive models do not seek to aid people in making 'rational' decisions. They do not indicate how people can change the way they view decisions in order to avoid 'inconsistencies' or 'biases' in their choices. Indeed, words such as 'inconsistency', 'bias', and 'anomaly' only take meaning when descriptive theories are compared with normative theories. In this paper, we are not looking at the way in which developers have acted in the past. We are looking at the improvements that can be made in normative models in aiding the decision making process. Finding anomalies between normative theories and the way people act is only useful if it helps the decision maker to identify any shortcomings of the process and overcome their inconsistencies.

Prescriptive decision analyses seek to guide decision makers toward consistent, rational choices, while recognising their cognitive limits. They use descriptive theories of how people 'do' make decisions to understand people's cognitive processes, while using normative theories of decision making as the ideal way to make decisions. Prescriptive theories try to help people to analyse their decisions in the correct way and make rational choices (see Bell *et al,* 1988).

Prescriptive analyses focuses on trying to aid the decision maker. It recognises that care is needed to avoid decision makers' choices being biased through poor framing of the (internal) questions asked in the elicitation of their beliefs and preferences (input choice). Unlike normative analysis, prescriptive analysis does not assume that the decision makers come to the analysis with clear, well-defined opinions. It is often the case that decision makers do not know how they feel about certain aspects of the decision and part of the purpose of the analysis is to help them to develop their opinions. Prescriptive decision analysis is invariably an interactive process that guides the evolution of the decision makers' judgements and builds their understanding of their situation. The modelling is cyclic. The decision makers' beliefs and preferences are analysed and modelled, which gives insight into their judgements, often leading to revisions of the model. The process continues until no new insights are found. The decision makers' preferences and beliefs evolve as they understand both the situation and themselves better, thus helping them towards more informed, rational and consistent choices. It is in this context that we are proffering the use of the *Crystal Ball* model.

Prescriptive analysis can be built on the Bayesian characterisation of decision-making, but extends this to include: elicitation procedures, sensitivity analysis and remodelling cycles to enhance understanding until the modelling is *requisite*. Phillips (1984) describes a theory of requisite modelling:

'A requisite decision model is defined as a model whose form and content are sufficient to solve a particular problem. The model is constructed through an interactive and consultative process between problem owners and specialists.'

Thus, it can be seen that we can expand the development appraisal model and through the use of *Crystal Ball*, we can develop it into a requisite decision model. The developer's attitudes towards uncertainty and the possibility of negative outcomes need to be determined, so that utility functions can be created for each of the attributes. Some of the utility functions may be linear; in which case, detailed analysis will not be necessary. However, some may be non-linear and therefore require the decision makers to consider their preferences carefully. Often, developers' preferences are not well formed when they begin a decision analysis and part of the process is the creation and clarification of their preferences.

The Application of Decision Theory to Development Appraisal

As with any rational model, the development appraisal is only a quantification of processes. It takes input variables and applies them to produce an answer. In other words, it is the input values that are the driving force of the decision-making. The inputs should be the basis for the time and effort spent thinking about decisions (see Keeney, 1992).

Development appraisals are, by there nature, extremely sensitive to the precision of the inputs. A small change in any of the input variables (rent, cost, yield, time or interest rate) can disproportionately affect on the resultant residual figure (value or profit), rendering the technique open to, at best misinterpretation and, at worst, deliberate manipulation. In the case of development value, the variables of rent and all risk yield (of the completed development) are critical variables. Both of these are crucial to the projected income receipt (Gross Development Value, GDV) and yet, perplexingly, these are the two variables over which the developer has the least control. They are dependant upon the cycle of the market and will vary according to the respective demand for space in the occupational market and the corresponding view of attractiveness in the investment market. A co-dependant variable of the GDV will be "time" in the form of voids; if the demand for space is strong on completion then the rents will be high and the property will be occupied promptly, if it is low then the rent will stagnate[6] and the void period will extend. Again, this impact needs to be understood within the Development Appraisal Model.

The 'Traditional Residual' Approach to determine Profit

The traditional residual valuation looks at all these variables as a snapshot in time and can be used effectively as a "rough indicator" of a development's viability, but is not sufficiently detailed to provide a detailed analysis of the scheme's sensitivity to changes in the input variables. This can be illustrated by reference to a relatively straightforward development project. In the case study, we assume an 18-month development period for a single office building on a site bought at a net value of £2.5m. The developer plans to build 1,000 square metres of offices at an expected rent of £475 per square metre. The corresponding All Risk Yield (ARY) is 6.5%. Construction costs and professional fees are as indicated in the input fields below as indicated in Figure 1. An initial analysis by the traditional residual is shown in Figure 2. In this initial analysis, the development is expected to be let and sold 6 months after completion (the void period).

Inputs - Offices		
Gross area of Offices	1,000	Square metres
Gross/net ratio for Offices	90%	
Rent for Offices	£475	Per Square metre
All Risk Yield - Offices	6.5%	
Cost of finance	12%	
Construction cost	£1,750	Per Square metre
Construction period	18	Months
Void period	6	Months
Land Value	£2,500,000	
Costs of land purchase	7.5%	

Figure 1 – Case Study Input Variables (Best Estimates)

[6] Interestingly, when the market is weak, rents tend to stagnate rather than downward adjust. This is because the developer prefers to entice the tenant with other forms of incentive (free fit out, rent free periods, breaks etc) rather than lower the starting rent.

GROSS DEVELOPMENT VALUE			**TOTAL (£)**
Rental Income	£ 427,500		
All Risk Yield	6.5%		
TOTAL GDV			**£ 6,576,923**
BUILDING COSTS			
Total Construction costs		£ 1,750,000	
Architect (of costs)	6.00%	£ 105,000	
Engineers (of costs)	2.00%	£ 35,000	
Quantity Surveyors (of costs)	3.00%	£ 52,500	
Agents (sales/letting) (of GDV)	3.00%	£ 197,308	
TOTAL BUILDING COST			**-£ 2,139,808**
FUNDING OF CONSTRUCTION[7]			
Interest rate (per qtr)	3%	£ 340,816	
Average time of borrowing is half of build period + void[8]	5		
TOTAL FUNDING COSTS			**-£ 340,816**
LAND COSTS			
Site		£ 2,500,000	
Costs of Land Purchase	7.5%	£ 187,500	
Interest on Land Purchase (qtr)	3%	£ 716,945	
is build period + void	8		
TOTAL LAND COSTS			**-£ 3,404,445**
GROSS RESIDUAL PROFIT			**£ 691,855**

Figure 2 – Residual Valuation to Profit

All the input values are assessed by reference to today's market. Thus the cost of construction is an average cost based on today's prices and similarly the estimated GDV figure is based on today's estimate of rent at the current all risk yield. In effect, it is an estimate of how much the development would sell for today if it were already completed. The residual figure is therefore a quick estimate of profit as an approximate present value.

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7 Note that it is assumed that all expenditure is borrowed from the bank regardless of their actual equity position. This is a generally accepted simplification, which effectively assumes that the opportunity cost for the developer's own funds is equivalent to the rates charged by the bank

8 It should be noted that as this is a static calculation, the finance costs need to be taken into account by "averaging" out the building period (normally by half) adding the void period and then applying interest to this figure. In this case interest is calculated at 3% for 5 quarter periods (i.e. half the actual building period of 6 quarters plus 2 quarters of void).

Initially, the simple deduction of total costs from GDV produces a Gross Residual Profit (GRP) of €691,855. This represents the expected profit that a developer can expect if he buys the land for £2.5m plus costs and the development is completed in 18-months as determined in the 'best estimate' inputs. Thus, this approach can be a useful approximation of profit but as a static model it fails to take into account the time value of money. The reality of timing can have a significant impact upon the financing of the scheme and thus any resulting savings will be passed through to the residual profit. Similarly, the ballpark model fails to account for present valuing at the developer's target rate and thus ignores the perceived risk inherent in the project. An alternative and preferred method is a cash flow approach.

The 'Cash Flow' Approach to determine Profit

A better and more accurate analysis should, therefore, take into account differences in the development's likely cash flow, so that the capital outstanding at any point in time is known, and an accurate estimation of finance charges can be made. The use of a "cash flow" approach also allows for voids and changes to other variables over time. In this paper we will consider the cash flow approach to profit as illustrated in Figure 4 overleaf using the same inputs as in Figure 1 but amended to allow for the timing of construction over the build period of 18-months. This is shown in Figure 3.

TOTAL BUILDING COST		**£ 1,750,000**
TIMING	**CONSTRUCTION**	**EXPENDITURE**
Period 1	10.0%	-£87,500
Period 2	15.0%	-£131,250
Period 3	20.0%	-£262,500
Period 4	30.0%	-£350,000
Period 5	15.0%	-£262,500
Period 6	10.0%	-£262,500
Total	**100%**	**£ 1,750,000**

Figure 3 – Case Study: Timing of Construction Expenditure

In this paper we have assumed that there is no explicit building inflation. It is obviously possible that the estimate of the cost of £218,750 in period 7 could be higher if costs have risen over this period. However, it was decided that we should keep this figure fixed for the purposes of illustration, particularly as this is a variable that we test for uncertainty later in this analysis.

Cash Flow Development Appraisal[9]

Months	Period	Construction costs	Professional fees Construction	Professional fees sales/let	Income	Land cost (incl costs)	Net cash flow	Capital outstanding beginning	Interest @ 3%	Capital outstanding end
0	0					-£2,687,500	-£2,687,500			-£2,687,500
3	1	-£175,000	-£19,250				-£194,250	-£2,687,500	-£80,625	-£2,962,375
6	2	-£262,500	-£28,875				-£291,375	-£2,962,375	-£88,871	-£3,342,621
9	3	-£350,000	-£38,500				-£388,500	-£3,342,621	-£100,279	-£3,831,400
12	4	-£525,000	-£57,750				-£582,750	-£3,831,400	-£114,942	-£4,529,092
15	5	-£262,500	-£28,875				-£291,375	-£4,529,092	-£135,873	-£4,956,340
18	6	-£175,000	-£19,250				-£194,250	-£4,956,340	-£148,690	-£5,299,280
21	7						£0	-£5,299,280	-£158,978	-£5,458,258
24	8			-£197,308	£6,576,923		£6,379,615	-£5,458,258	-£163,748	£757,609
	TOTAL	**-£1,750,000**	**-£192,500**	**-£197,308**	**£6,576,923**	**-£2,687,500**				

IRR Project	**4.97%**
IRR Project pa	**21.43%**
Total Profit at end of Development	**£ 757,609**
NPV of profit @ 4.0%	**£ 553,578**

Figure 4 – Cash Flow Residual Valuation to Profit

[9] An alternative to the cash flow technique is the discounted cash flow residual. the DCF method doesn't allow for the interest payments explicitly, instead it calculates the present value of each individual element of the net cash flow at the cost of finance and sums the individual PVs. This produces the same NPV answer as the cash flow approach but this is only true when the discount rate is equal to the cost of finance.

Note that in this example (Figure 4) all the variable costs have been kept the same as those used in the traditional residual model illustrated in Figure 2. Yet, the Gross Residual Profit figure has increased to £757,609, which on first appearance gives a higher profit (than the traditional figure of €691,855) to the developer. However, this is a future value as it represents the sum of money "left over" as profit at the end of the development in 18 months time. This figure needs to be discounted to give a present value figure. The discount rate used should reflect the developer's risk perceptions for the development and should always be above the finance rate[10]. In this case we use 4% per quarter, giving a present value of profit of £ 553,578 (NPV); lower than the traditional method. This simply illustrates that the traditional method is no more than a very rough approximation. The cash flow approach should be preferred for accuracy of the outputs as the cash flow approach takes the net cash flow and calculates the accrued interest to each payment/receipt and carries it forward to the next period. The total accumulation is the end profit, which is then expressed as a NPV.

Expressions of Profit

Whilst it is useful to determine the profit in absolute terms, the cash flow methods allow the valuer to express the profit as an Internal Rate of Return figure (either including or excluding the effect of finance). This figure can then be compared with the IRR from other investments. Although there are certain problems with the use of the IRR as a benchmark, the IRR is a very convenient way of measuring the financial attractiveness of an investment as it provides a comparative measure between projects as a percentage return. Many developers only look at projects on the basis of IRR. An alternative measure of profit is to look at the NPV as calculated above. In this paper, we look at both measures by way of illustration, accepting that different users will use the benchmark that they feel is appropriate for their circumstances[11].

However, regardless of the measure chosen to reflect profit, the question of the veracity of the inputs remains with each method. The difference between the traditional residual and the cash flow model is that the latter attempts to model the development process allowing for a clear estimate of the timings. Indeed as time is now a component of the development appraisal (in the form of the construction period and the void period), it is now possible to test the impact of time on the outcome along with the other variables.

[10] In many examples of cash flow residuals to profit, the discount rate used is the finance rate. This would not be appropriate as it suggest that the developer is receiving a return on the risk of the project equal to that required by a bank for lending money. The rate must be higher as the risk in development is higher. However, when the cash flow method is used to derive land value, the finance rate is the discount rate as the calculation is allowing for the cost of finance on the land value.

[11] Other benchmarks that are often used are related to capital employed in the form of "return on capital" or an "IRR on Equity". As our examples are assuming 100% borrowing, these measures are not illustrated here.

Conventional allowances for Uncertainty: Sensitivity Analysis

Uncertainty impacts upon the process in two ways; firstly the cash flows from developments are, to varying degrees, uncertain and secondly the resultant profit figure is therefore open to uncertainty. A small change in any of the input variables may have a disproportionate impact on the resultant output. This sensitivity to change applies regardless of the residual technique used. The analysis is dependant upon the professional judgement of the developer/analyst involved in identifying the critical variable and understanding their susceptibility to change through time.

In Excel, a simple sensitivity analysis can be carried out using "Data: Table"[12] looking at the impact on a chosen outcome, based on changes to two input variables. In Figures 5, we have illustrated this sensitivity analysis by looking at changes to Rent and Finance relative to NPV and Rent and ARY to annual IRR, respectively.

	Rent vs. Finance Rate [change to NPV]					
				Finance Rate		
		11.5%	**11.75%**	**12.0%**	**12.25%**	**12.5%**
	£485	£684,613	£668,195	£651,715	£635,173	£618,570
	£480	£635,544	£619,126	£602,646	£586,105	£569,501
Rent	**£475**	£586,475	£570,057	**£553,578**	£537,036	£520,432
	£470	£537,407	£520,989	£504,509	£487,967	£471,364
	£465	£488,338	£471,920	£455,440	£438,899	£422,295
	Rent vs. ARY [change to Annual IRR]					
				All Risk Yield (ARY)		
		6.0%	**6.25%**	**6.5%**	**6.75%**	**7.0%**
	£485	28.95%	25.86%	22.95%	20.21%	17.62%
	£480	28.16%	25.08%	22.19%	19.47%	16.89%
Rent	**£475**	27.36%	24.31%	**21.43%**	18.72%	16.16%
	£470	26.56%	23.53%	20.67%	17.97%	15.42%
	£465	25.76%	22.74%	19.90%	17.21%	14.68%

Figure 5 – Conventional Sensitivity Analysis

Here it can be seen that the sensitivity analysis in each case produces a matrix of 25 possible outcomes in the form of NPV or IRR. In each case, the input

[12] When using Data: Table in Excel, the input variables in the table must be simple numbers (i.e. not formulae) and the table must be inserted on the same worksheet as the original input cells.

variables tested are shown in the first row and first column of each respective table. It is normal convention to test the chosen input in the original model by varying the inputs by suggesting new inputs above and below the original value used. For example, in the first table the original Finance Rate is 12% and the table tests the sensitivity of this input by looking at two figures below this measure (11.5% and 11.75%) and two figures above (12.25% and 12.5%). The same is done with the rent column. Thus the central outputs (highlighted bold) in each of the tables correspond with the original output in the cash flow model in Figure 4. The surrounding outputs represent the impact on the chosen measure around the "best estimate" output.

In our case study, it can be seen that if the ARY in the market decreases to 6% (indicating that the investment market is more buoyant[13]) and the rent also increases to £485, then the IRR increases from 21.43% to 28.95%. This is logical as the change in both variables indicates increased buoyancy in the market. The variables are naturally correlated and have both moved in a way that is consistent with a positive increase in market activity. However, the problem with this type of sensitivity analysis is that it fails to allow for such correlations and thus we also have displayed an outcome where the ARY has increased (say to 7%) at the same level of rental increase. This gives an answer of 17.62%. Yet, this answer is erroneous as it is highly unlikely that the investment yield (ARY) would increase, indicating that this type of property is less attractive, at the same time as the rent increasing, indicating that the occupational market has high demand. In other words, the natural correlation between these input figures has been ignored. Obviously, an experienced user can identify the outputs that are consistent with observed correlations (as illustrated by the darker grey shading in the second table in Figure 5) but in its original form the Data: Table can be misleading. Indeed, even by discounting the outputs that are counterintuitive, the remaining outputs (in darker grey) do not tell the whole story. Each output appears to be equally weighted and thus its outcome equally likely. This is not the case. The valuer chose the original inputs as they were believed to be the "best estimates" for those variables. In other words, they were the most probable. By definition, as the variables move away from those chosen figures, it suggests that the likelihood of the new test variable occurring is less as the variable moves further and further away from the original input figure.

In simple terms, the sensitivity table, whilst giving an indicative view of the upside and downside risk of the project, fails to allow for the probability of the different outcomes and the correlation between the two input variables tested. Indeed, it only allows for testing two variables at one time and any interrelationship with other variables in the model is ignored.

[13] The ARY reacts in inverse to the market. As the attractiveness of the property in the market increases, the ARY decreases. Conversely, as the market declines, the ARY increases. This is because it is the reciprocal of the ARY that determines the multiplier used in the capitalisation model. Thus a lower ARY will result in a higher multiplier and a higher price for the completed development.

Thus, the conventional sensitivity analysis only looks at the best and worst scenarios above and below the original “best estimates” and has focused on variations from the anticipated or expected outcome. Whilst this does provide the decision maker with a degree of understanding about the critical variables, it does not fully address the issue of uncertainty of all the variables, the correlations between variables and the resultant range of outcomes that can occur. A fuller analysis should include examination of the uncertainties in each of the variables in the model and account for the appropriate distributions of the inputs. In this way it is possible to look at the underlying uncertainty in the development appraisal.

The Application of *Crystal Ball* to Development Appraisal

Conventional development appraisal models that give single point outcomes are failing to direct the user to understand the importance of the inputs, and the uncertainty of each, in the overall process. The model is output driven and thus, even where the user incorporates some form of conventional sensitivity analysis, the expected or anticipated output is the focus of the user’s attention. Although the ascribed inputs in the conventional cash flow model were ascertained by an analysis of the market, the actual figures chosen are single point “best estimates”. The user will not be 100% certain of any of the input figures, yet the model assumes them to be “correct”.

In the *Crystal Ball* model, the same underlying cash flow analysis is undertaken but with the added dimension of trying to identify the substance and the characteristics of the uncertainty that applies to each of the inputs involved. Thus we need to address the probability and range relating to the inputs. The outcome can still be described as a single profit figure but within the context of a range of other possible outcomes. The simulation analysis effectively tests the robustness of the single point estimates and produced a range of possible outcomes. The mean (or any other chosen measure of central tendency) which can be considered to be the expected profit and the maximum and minimum results show the extent of the range and thus give an indication of the uncertainty pertaining to the single point figure.

The end effect of such an analysis is to change the normative nature of the conventional cash flow model into a requisite model proffered by prescriptive analysis. Here the use of the model itself is as important as the outcome of the model. An integral part of the analysis is to question and determine the developer’s preferences and beliefs so that they can understand the process better and thus move them towards a more informed and rational choice.

Statistical Allowances for Uncertainty in *Crystal Ball*

Thus the *Crystal Ball* model expands the analysis by fully questioning the veracity of each of the chosen inputs into the cash flow model. It does this by looking at specified critical variables such as ‘building costs’, ‘rental value’, ‘timing of future sale’, ‘anticipated yield on sale’ and so on. Such an analysis can account for the appropriate distributions of the variables. For example, rent is sometimes skewed to the left. That is, you could do better than you expect, but you could also do very much worse. In this paper we use standard statistical technique to allow for the skew in the relative distributions.

This lack of symmetry can mean that the statistical measures do not coincide, so the mean, median and modal values are different. *Crystal Ball* automatically shows these to the user so that the decision maker can see which gives the most reasonable measure for the data in question. Similarly, as many of the variables in the model are not independent, the package allows this to be modelled by making the variables correlated. Once the ‘best’ alternative has been identified, it is necessary to evaluate how ‘robust’ the decision is. Any parameters that were vague can be varied to show their effect on the decision. The developers’ preferences for attributes can also be varied to discover their effects. This allows the developer to see how changes in the input values in the model affect the outcome. It may also be useful to vary several values at once, to see their combined effect, as this may give more insight into the decision.

Crystal Ball also expands the use of sensitivity analysis. Not only does the main model look at probability of correlated inputs to produce a corresponding range of outputs, there is an additional tool that analyses the impact of each variable on a chosen range of end results. This may highlight the need for more analysis, or further modelling of certain aspects of the decision. The purpose of sensitivity analysis is to show the decision makers how their decision may alter given changes in their input values, and therefore the important aspects of their decision.

The basis of the *Crystal Ball* model is the incorporation of probability analysis within a Monte Carlo simulation (see Hertz, 1964). The analysis is an iteration process that carries out multiple calculations of the cash flow by randomly selecting an input figure for each of the critical variables identified. It randomly selects a value for the first chosen variable from the ascribed probability distribution and (within the constraints of any predetermined correlations) includes this with the similarly chosen inputs for the second, third, fourth, etc variables. It then runs the cash flow model using these inputs and produces an output (profit figure). It then repeats this exercise for a determined number of simulations[14] and thus produces a range of outcomes. The output is expressed as the mean (or other central tendency) of all the calculated values.

In statistics there are many forms for probability distributions, which describe both the range of the input values and the likelihood of their occurrence. The normal distribution (bell distribution) is the most well known and its parameters, the mean and the standard deviation, are the most used. In our analysis the most likely figure will be represented by the central figure (the mean) and the uncertainty by the range around that number. There is equal probability that the observed figure will be above or below the central assumed figure. The majority (99.74%) of the possible observations will lie within plus

[14] We chose 10,000 iterations as it is sufficient to allow consistent results between different simulations

or minus three standard deviations of the mean. The standard deviation is a measure of how widely values are dispersed from the average value (the mean). The exact standard deviation will vary according to the uncertainty pertaining to the average value; the greater the uncertainty the higher the standard deviation. Equal likelihood of the adopted figure being higher or lower would be a symmetrical distribution; an unequal probability would result in a skewed distribution. In the real world, and particularly in the property market, market values, interest rates and other factors might be skewed and this model allows the user to develop the analysis on this basis if required.

The *Crystal Ball* 'Cash Flow' Approach to determine Profit

The *Crystal Ball* cash flow model requires the developer to identify their beliefs in relation to each critical input variable. We do this by defining the probability distribution for each chosen input in statistical terms (mean, standard deviation, minimum, maximum, etc.). The size, shape and dispersion of the distribution will affect the selection of the variable during the random iteration.

For this case study, the following assumptions about the inputs were chosen:

Input	Distribution	Mean	St dev	Min	Max
Market values					
Office Rent	Normal	£475	25	400	550
Office YP (1/ARY)[15]	Normal	15.38	0.60	13.30	17.00
Costs					
Building Costs	Normal	£1,750	100	1,000	1,600
Timing					
Build Period	Normal	18 months	2	12	24
Void Period	Normal	2 quarters	0.20	0	4
Interest Rates %					
Finance Rate	Normal	12%	0.6	11.00	14.00

Figure 6: Probability Distributions of Chosen Variables

In Figure 6, the chosen figures are determined by an analysis of the market. The minimum and the maximum values are the limits of (approximately) three standards deviations in market values and costs. These limits are duly adjusted if experience suggests that they are less or more than the numbers identified by the statistical analysis.

Any interrelationship between the chosen variables is then addressed in a correlation setting as identified in Figure 7. These correlations are obviously influenced by observed historic correlations of the same variables suitably adjusted to reflect the developer's view on how they might interrelate in the future.

[15] In the *Crystal Ball* analysis, it was decided that the test variable should not be the ARY but the resulting multiplier called the Years Purchase or YP. The reason for this was one of illustration. The rent and the YP are positively correlated and thus a sensitivity analysis of the importance of each variable is easier to represent when two variables work in tandem.

	Office Rent	Office YP	Building Costs	Finance Rate	Void Period
Office Rent		+0.50			-0.80
Office YP	+0.50			-0.20	-0.20
Building Costs				+0.25	
Finance Rate		-0.20	+0.25		
Void Period	-0.80	-0.20			

Figure 7: Correlations between the Chosen Variables

A perfect positive correlation will have a value of +1 and a perfect negative correlation will have a value of –1. A variable that is totally independent will have a correlation of 0. As can be seen, *Crystal Ball* allows for multi-correlations between variables, which is a better representation of reality.

The variation of the time will have a significant impact on the development. Time is one of the critical variables that is often ignored in the conventional cash flow model. In our example, the conventional sensitivity analysis tested input variables such as rent and finance rate but didn't consider an increase or decrease in the void and building period. Of course, this could have been incorporated into the Data: Table analysis but the same problem of lack of correlation between variables (for example, if Rents are increasing, indicating an increase in demand, it is reasonable to expect the void period to be less) remains. In the *Crystal Ball* cash flow model, the correlations and the impact of time have both been addressed.

Using these numbers, we used *Crystal Ball* to run the cash flow development appraisal 10,000 times using Monte Carlo simulation. This produced 10,000 outcomes, the statistics for which are illustrated in Figure 8.

	Value
Trials	10000
Mean	509,725
Median	497,047
Standard Deviation	445,049
Skewness	0.18
Kurtosis	2.89
Display[16] Range Minimum	-689,124
Display Range Maximum	1,708,554

Figure 8: *Crystal Ball* Cash Flow Analysis to Profit (Statistics)

Here it can be seen that the expected mean (profit) is £509,725, which is lower by some 10% than the figure of the £553,578, produced by the conventional cash flow model. This is because the conventional model only considered fixed estimates for the build period (18 months) and void (6

[16] The Display range is between +/- 2.6 standard deviations, which includes 99% of the distribution.

months). In the *Crystal Ball* analysis, scenarios with time estimates 6 months either side of these mean estimates have been included, the financial impact of the periods being extended is greater than the corresponding saving if the periods are less. Thus the overall impact on the mean of the outputs is to suggest a lower profit. However, as discussed, the advantage of the Monte Carlo simulation is that it provides additional information about all the outcomes and their predicted distribution. This is illustrated graphically in Figure 9.

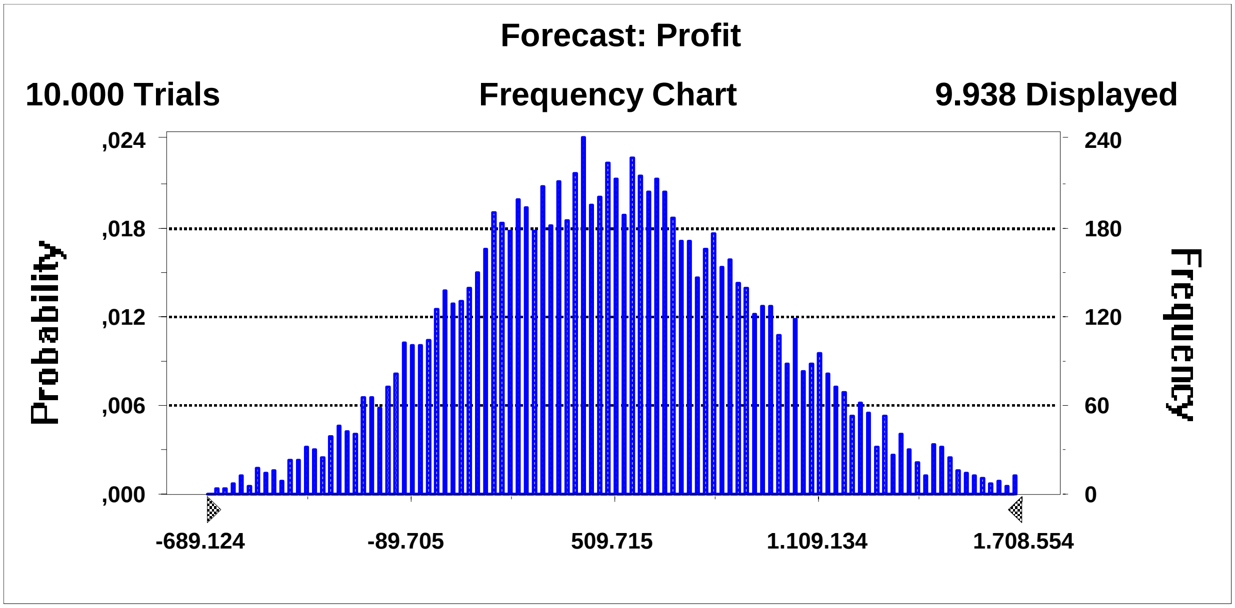

Figure 9: *Crystal Ball* Cash Flow Analysis to Profit (Graph)

In this case, the standard deviation (of £445,049) is a representation of the uncertainty. The skewness (of 0.18) represents the degree of asymmetry of the distribution around its mean. In this case study, the output (as can be seen graphically) is near normal but with a positive skew on the right side (i.e. increased profit) with a display output range[17] from -£689,124 to £1,708,554.

Because we have modelled the uncertainty in the inputs, the analysis has allowed the developer to determine the uncertainty in the output profit and as has it can be seen that the mean profit level using *Crystal Ball* is £509,725, which is significantly less than the £ 553,578 produced by the conventional cash flow.

But a simple comparison of the two single point figures from the two models is only part of the process; it is the range around the mean that is important as this suggests that the figure could be as high as £1,708,554, or, conversely, as low as -£689,124 (at the 99% level). More over, the probability of the possible outputs is also calculated so that the developer can place the single point

[17] This captures 99% of possible outcomes based on approximately 2.6 standard deviations from the mean

estimate in context. In Figure 10, it can be seen that at the 50% percentile that there is a 50% probability that the profit will be above the median figure of £497,047. But equally, the downside is that there is a 50% chance that it will be below the median. Similarly, at the top end, there is only a 5% chance that the profit will be above £1,261,508, which is the 95% percentile marker.

Percentile	Value
0.0%	-793,403
2.5%	-320,862
5.0%	-198,883
50.0%	497,047
95.0%	1,261,508
97.5%	1,425,161
100.0%	2,273,031

Figure 10: *Crystal Ball* Cash Flow Profit: Analysis by Percentiles

We can also identify the impact of each critical variable on the final output. In the sensitivity analysis below (Figure 11), it identifies the correlation of each chosen variable on the outcome.

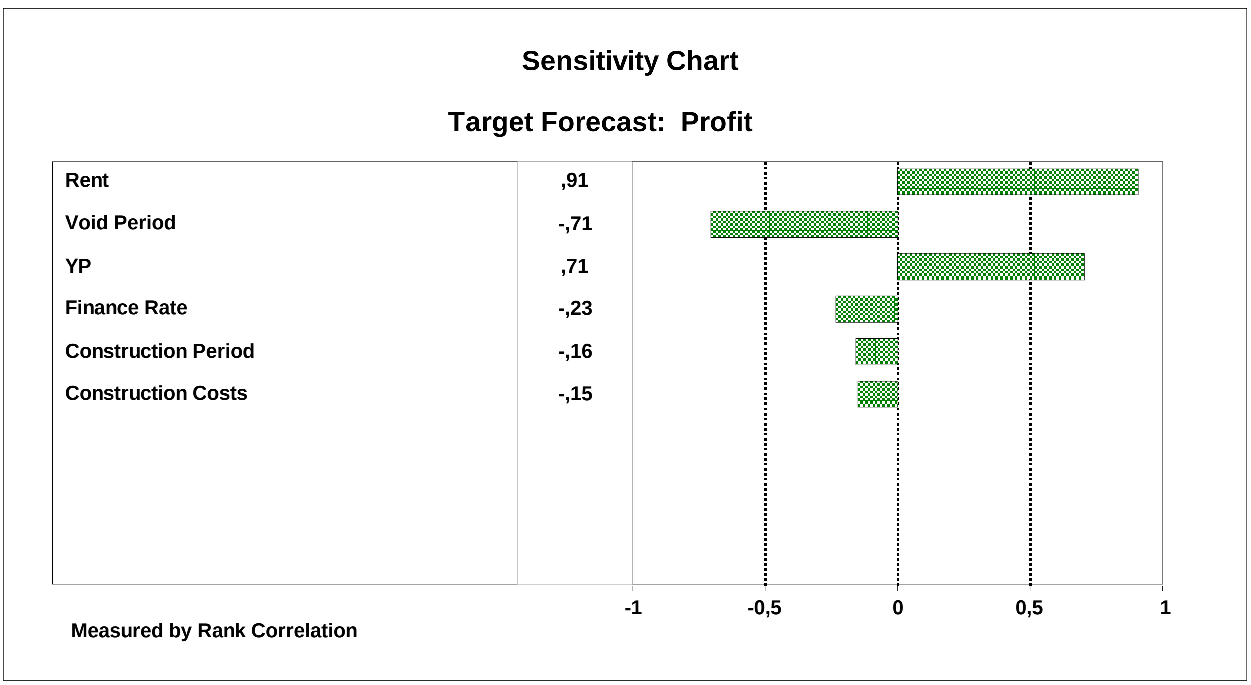

Figure 11: *Crystal Ball* Cash Flow Profit: Sensitivity Analysis/Correlation

Here it can be seen that the profit is highest when the Rent and the YP are correspondingly high and that they are the most crucial variables in determining a high profit. However, this simply confirms what intuitively seemed to be the case. The advantage of the *Crystal Ball* model is that it allows the developer to quantify the correlation. In this case, the rent correlated to profit at 0.91 and the YP at 0.71. Both significantly higher than all the other correlations (ignoring signs) except the void period. The next most important variable is the length of the void period, with the level of profit being negatively correlated to the increase in void at –0.71.

The assumption with the highest sensitivity ranking (in this case rent) can be considered the most important one in the model. As the impact is so large, the developer may wish to investigate this assumption further in the hopes of reducing its uncertainty, and therefore its effect on the profit. The assumption with the lowest sensitivity ranking, construction costs, is the least important one in the model. The effect of this assumption on the profit is not as great as the others and could be ignored[18].

Similarly, we know that there is a large range of possible outcomes and that the mean is simply a measure of a central tendency. What is more useful is to identify the probability of the result being within an accepted range. Thus the developer may ask, what is the probability of the profit being between a lower acceptable figure of (say) £300,000 and a reasonable high limit of (say) £700,000? This can be done by assessing the Certainty Level. This is a key statistic and it shows you the confidence of achieving your required results. In this case, there is a 34.30% certainty of achieving a profit figure between £300,000 and £700,000 figure.

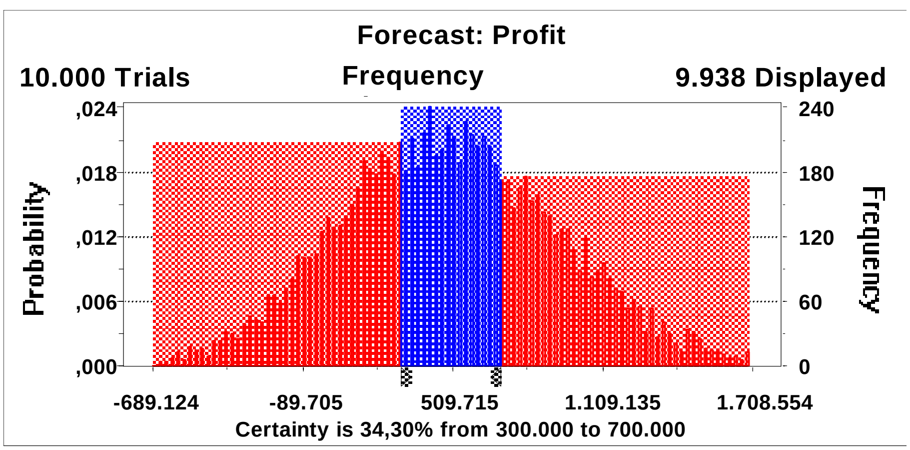

Figure 12: *Crystal Ball* Cash Flow Analysis: Certainty of Profit (Graph)

18 The Crystal Ball Sensitivity Analysis may produce erroneous answers where variables are correlated. We therefore ran the same analysis without correlations and the rankings remained constant albeit at lower ranked correlation values. This confirms that the variables discussed should be investigated further.

Crystal Ball offers a number of other tools to allow the user to analyse the data in different ways. In the case of development appraisal, one of the more appropriate is the "Tornado" tool. This differs from the correlation-based sensitivity chart in Figure 11 as it tests each input variable included in the model independently. It does this by choosing an "at worst" and "at best" value for the chosen input variable and then calculating the profit at these values whilst freezing each of the remaining variables at their mean. In our example it takes the "at best" to be the 90% percentile for each variable and the "at worst" to be the corresponding 10% percentile.

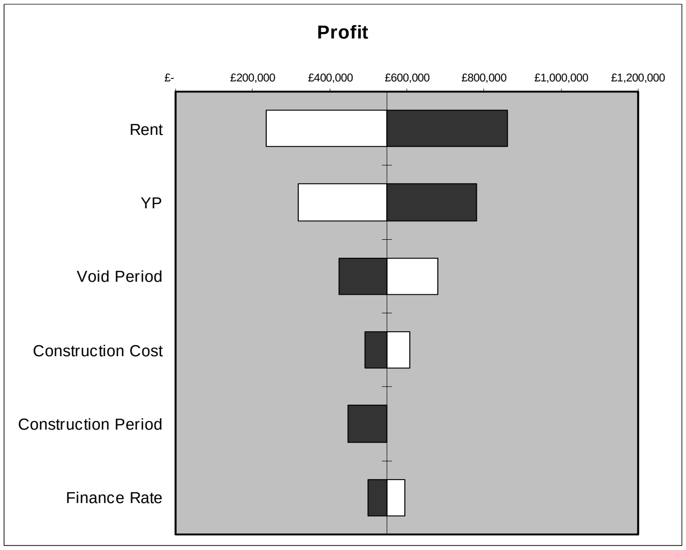

Figure 13: *Crystal Ball* Cash Flow Analysis: Tornado Chart

Thus the analysis tests the effect of each variable on profit whist removing their effect of the other variables. The tornado chart (Figure 13) illustrates the swing between the maximum and minimum profit for each variable, placing the variable that causes the largest swing at the top and the variable that causes the smallest swing at the bottom. The bar colours indicate the direction of the relationship between the variables and the forecast. For variables that have a positive effect on profit, the upside of the variable (shown in dark) indicates that the chosen value for that variable is higher than the mean and, conversely, the downside of the variable (shown in white) shows that the value is less than the mean for that variable. For variables that have a reverse relationship with profit, the bars are reversed. In this case, it can be seen that the rent is the most crucial variable and that at the "at best" value it has a positive impact on the profit (as would be expected). Conversely, a change in the void has significantly less impact on profit although this time the "at best" figure is obtusely a higher void period and thus the graph shows the "at worst" (lower) void is the one to have a positive impact on profit as intuition would suggest.

	Profit			Input		
Variable	*Downside*	*Upside*	*Range*	*Downside*	*Upside*	*Base Case*
Rent	£ 236.586	£ 862.171	£ 625.585	£443	£507	£475
YP	£ 317.880	£ 779.767	£ 461.887	14,61	16,14	15,38
Void	£ 679.592	£ 424.195	£ 255.396	1,11	2,89	2,00
Construction costs	£ 608.448	£ 490.309	£ 118.139	£1.686	£1.814	£1.750
Construction period	£ 549.378	£ 447.431	£ 101.948	15,45	20,55	18,00
Finance rate	£ 593.813	£ 499.636	£ 94.177	11,36%	12,78%	12%

Figure 14: *Crystal Ball* Cash Flow Analysis: Tornado table

The Fig. 14 gives the impact of each variable, where "at best" value is the upside figure while the "at worst" is the downside figure. The table displays their influence on the value of the outcome, the profit. As previously analysed, the finance rate shows the lower range between the upside and the downside figures of the profit. Conversely, the rent shows the widest range meaning that its influence in the outcome is the most significant.

The Application of a Prescriptive Model to the Development Process

By itself, the analyses carried out above, whilst adding something to the decision making process, doesn't give a full picture. The *Crystal Ball* model is, in our opinion, a form of prescriptive decision analysis. In other words, it is not the model itself that is the most important element; it is the process of using the model. The whole process is an interactive exercise that guides the developer's judgements and understanding of the situation. The modelling is cyclic.

In the first analysis, we modelled the developer's beliefs and preferences by analysing and discussing the chosen ranges for each critical input. This first analysis is only one step in the overall process that adapts and evolves to help the developer understand both the situation and himself better. This, in turn, will lead to a more informed choice.

The *Crystal Ball* model is a requisite model that builds on the original elicitation procedures; produces initial results; allows for detailed sensitivity analysis and then remodels as required. Throughout the process the developer is developing a better understanding and thus will feel more comfortable with the final decision.

In our example, the developer has identified that the critical variables are rent and YP (or ARY). This is obviously true for most developments but to a lesser and greater degree. In this case, the impact is highly significant. Thus the developer may wish to revisit the quantification of these variables and run the model again on a smaller range. However, any variation needs to be placed in the context of the market. Ranges can't just be changed to produce the required answer; any variation has to be researched and verified. In other words, the developer may ask for further research to identify the range of these variables and thus change them accordingly, as it would be reasonable to assume that if the user had more information about the variables in question, there would be less uncertainty and thus a smaller range. Alternatively, it may be the case that the model is already using the best estimates and ranges possible and that the impact of rent and the YP is simply inherent in the process. These are two variables over which the developer has little control in a speculative development and, as such, it may be prudent (given the importance of these variables to this particular development) to consider a pre-let and pre-sale at an agreed rent and YP respectively. The agreed level may be lower than the higher percentiles of the forecast range but equally as soon as these numbers are fixed, the uncertainty of the project is substantially reduced. The GDV is known, the void is known and, assuming a well-managed construction period, the resulting profit will be much less volatile.

But this is just one example of how the developer may choose to review the project. The significance of the prescriptive model is that the user reviews and refines the decision as more understanding and information about the possible outcomes is revealed. The numbers become secondary to the context.

Conclusion

Without knowledge of development risk, developers are unable to determine the anticipated level of return that should be sought to compensate for the risk. The advantage of a prescriptive model (using *Crystal Ball*) is that it allows the user a better understanding of the possible outcomes for the development. Ultimately the final decision will be made relative to current expectations and current business constraints, but by assessing the upside and downside risks more appropriately, the decision maker should be better placed to make a more informed and “better” decision.

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