# PROPERTY DEVELOPMENT RISK PROFILE IN A SELECTED PROJECT USING @RISK SOFTWARE PACKAGE AND PERTMASTER SOFTWARE

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**Abstract:** This study investigated the use of @Risk software and Pertmaster Project Risk software on a project based on a property development case study. The principles apply equally to any projects, including transport projects. The case study was a redevelopment of AMP Square located in the Melbourne CBD. The findings were subjected to cost only risk analysis using @Risk. Three delay scenarios based on certain critical activities were also analysed using critical path method Monte Carlo simulation capabilities of Pertmaster Project Risk. The results indicate a longer delay of the completion date if the delay occurs in a critical activity at the initial or middle stages of the project rather than in the last critical task. Separate cost simulation results indicate higher costs or losses if the same duration delay occurs in the last critical activity. Integrated time and cost simulation is recommended to produce reliable delay cost forecasts.

**Key Words:** time simulations, cost simulations, task delay, NPV, TDC.

## 1. INTRODUCTION

The development and execution of a project can be a risky and uncertain process. The risks and uncertainties depend on the size, complexity, novelty and technical sophistication of the project. The risks are often increased by the presence of constraints on time, resources and performance and are frequently exacerbated by the conflicting objectives of the parties involved (Ward & Chapman 1991). Gardiner (2000) claimed that these days project managers and project sponsors often do not believe anymore that the projects can be delivered "on time, to budget and at the required quality". Studies conducted by Morris and Hough (1987) found that approximately 50% of construction projects overran, with overrun values "typically between 40 and 200 percent". Similarly, Thompson and Perry (1993) reported that 75% of the World Bank funded projects encountered time overruns of at least 28%. Wright (1997) suggested adding 50% minimum to every time estimate and 50% to the first estimate of the budget.

Risk and uncertainty are intrinsic to all projects. Being aware of the existence of a risk in a project can help the decision-makers to successfully manage a situation subject to uncertainty. Berny and Townsend (1993) stated that the aim of risk analysis is to reduce the impact of a risk and/or to reduce the likelihood of its occurrence.

## 2. METHODOLOGY OF RESEARCH

This study aims at investigating and discussing risk profiles in a project by combining the logical approach of risk analysis with the use of @Risk software and Pertmaster Project Risk software. The case study selected to illustrate the process is a redevelopment of AMP Square, which is located in the western sector of the Melbourne CBD area. It was chosen because financial feasibility data was available in the form of an Excel spread sheet from a previous study. It should be noted that the methodology used and research findings are applicable to any type of project, including roads and bridges.

AMP Square, built in January 1970, is situated on a site of approximately7,743 $m^2$. Comprising a 26 storey 'A' grade office tower (AMP Tower) and a 7 storey low rise 'B' grade office and retail center (the St. James Building), AMP Square is considered as a primary legal precinct and a significant office area.

The proposed development plan involves demolishing the existing 7 storey St. James Building and the 26 storey AMP tower and constructing a new 50-storey tower with a basement car park, podium retail shopping and entertainment areas, high standard office spaces, luxury hotels and serviced apartments. The appropriate tower building and construction data for this study are taken from previous work.
Below is a sketch of the proposed development.

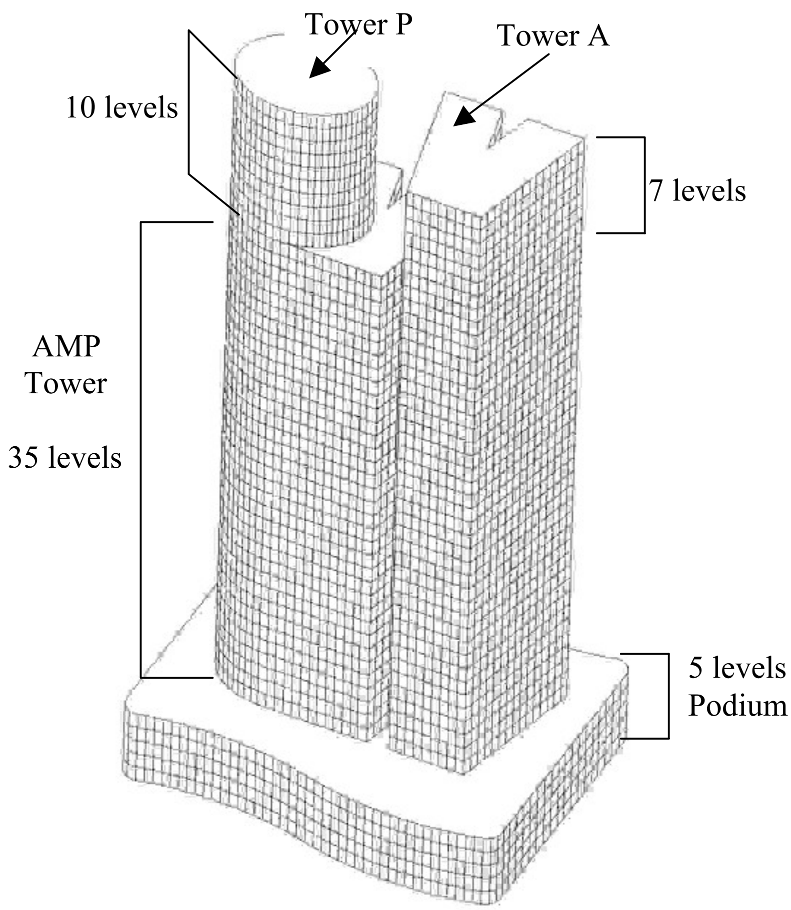



**Figure 1. Proposed New AMP Tower**

The top 7 storeys of the ‘A’ tower consist of a 5-star luxury hotel. Adjacent to it is the 10 storey high ‘P’ tower, comprising a 5-star luxury serviced apartment block. These hotels and serviced apartments accommodation will have breathtaking views over the City including the Melbourne Casino, Melbourne Exhibition Center, Dockland and Southgate Districts and out to the Dandenongs. The ‘AMP’ building, with 35 levels, comprises high standard offices, luxury hotels and serviced apartments. A 5-level podium consists of retail shopping areas and entertainment centers.

Findings of the feasibility and sensitivity analysis (Jovanovich 1999) of the project were subjected to risk analysis using @Risk software, with costs as the parameter. Risk analysis using the @Risk software package is a quantitative method to determine the outcomes of a decision situation as a probability distribution. It is necessary to gain historical data for each chosen risk variable to find the 'most likely' type of probability distribution to enable the risk analysis using the @Risk software to be run. It was decided to examine 3 risky variables due to the difficulties in finding the historical data of each variable in Melbourne. The variables were the interest rates, the occupancy rates and the office rental revenues. The findings were in the probability distribution forms of the NPV of the project. This aspect will be discussed further in section 3 of this paper.

As a further investigation, this study also chose to investigate time or duration risk only using Pertmaster v7. Based on the construction time schedule designed in MS Excel 2000, a project plan was set up using Pertmaster software. It involved entering tasks and milestones and adding logic to define task relationships. Using the Pertmaster risk analysis features also involved setting up risk duration distributions on each task. This meant that each task was assigned minimum, most likely and maximum durations, and a probability distribution shape for the durations was chosen (the default choice of a triangular distribution was chosen). These were all necessary to run the simulations in Pertmaster, which investigated project completion time or duration as the uncertain parameter. The outcomes were the prediction of finish dates based on the probability of occurrence. The section of risk analysis using Pertmaster software is discussed further in section 4 of this paper.

It was decided not only to run the time simulation on the basic construction schedule, but also on modified schedules produced by adding logic to the schedule; e.g. assuming there was a month-delay in certain critical tasks. The selected critical tasks for a month-delay scenario were the Basement Level 1-5 (middle position) and the External Works tasks (last task). After examining and analysing the outcomes of the time simulations, it was necessary to analyse the cost impacts flowing from the delays. This can be done using Pertmaster, provided the schedule includes cost information. In this case, the schedule did not include cost information, so cost simulations were run using the @Risk software.
Finally, all the risk simulation results were compared to the initial deterministic results and analysed to arrive at the conclusions.

## 3. RISK ANALYSIS USING MS EXCEL 2000 AND @RISK SOFTWARE

### 3.1 Feasibility and Sensitivity Analysis

The Melbourne CBD rental market and all the assumptions used in the feasibility analysis have been reviewed based on figures provided by 3 sources including Jones Lang LaSalle, Colliers Jardine (via the Property Council of Australia) and CB Richard Ellis (Major Real Estate Agents). The following table summarises the opinions of the three sources in respect of rental incomes of the proposed tower and all the assumptions made and applied to the feasibility study as in February 2002, as follows:

**Table 1. Rental Incomes of the Proposed Tower**

| Items | Rental Rates/p.a. | Items | Values |
|---|---|---|---|
| Retail Spaces | $650/ m2 | Rent increase rate | 3% p.a. |
| Offices | $420 / m2 | Occupancy Rate | 95% |
| Hotel | $600 / m2 | Interest Rate | 6% |
| Serviced Apartment | $400 / m2 | Escalation Rate | 4% |
| Car Park | $3000/ space | Discount Rate | 5% |

Sources: Jones Lang LaSalle, Colliers Jardine and CB Richard Ellis

The annual loan repayment over ten-year period was based on interest payment only. Outgoings for retail, office and car park were taken as 25% of gross revenue. The sale price calculated at the beginning of 11th year of the DCF analysis is based on 7% yield.

The development program, proposed project data in detail such as plot ratio, the building heights and areas, the construction program and the cost estimates used for feasibility analysis were obtained from work generated in major assignment in Property Development Analysis subject combined necessarily with the cost estimates based on Rawlinsons 2001 book. The project commencement was planned on 1st August 2002 and the project completion is forecast to be on 1st August 2005 (36 months).

Based on all the criteria, the results of the feasibility analysis using MS Excel 2000 are shown in Table 2 below:

**Table 2. Feasibility Analysis Results**

| Results | Debt Equity Ratio 80:20 | Debt Equity Ratio 50:50 |
|---|---|---|
| Net Rental Income | $35,888,110 | $35,888,110 |
| TDC (Total Development Cost) | $476,371,625 | $456,092,885 |
| NPV | - $253,455,724 | -$28,202,355 |
| IRR | -3% | 4.21% |
| Development Yields | 10.12% | 10.57% |

From the table, the project showed yields above 10%. However, since the feasibility analysis took into account the "Pay Back Period Factors" as the annual loan repayment and the principle repayment, consequently this project showed negative NPV and very low IRR, which meant that this project was financially not viable.

It is interesting to observe the sensitivity analysis of the NPV vs. the rent revenues by reducing all the rents in stages up to 30% and increasing them up to 40%, which is shown in figure 2 below.

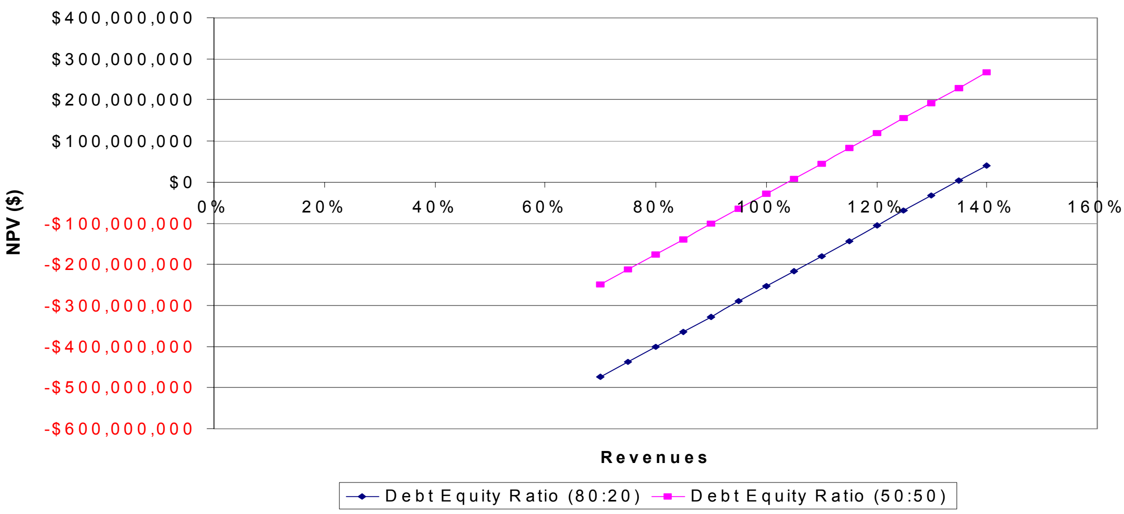



**Figure 2. NPV vs. Rental Revenues**

From the table, the break-even point of the project on changing the rents was 134% (increasing the rents 34%) for 80:20 debt equity ratios and 103.8% (increasing rents 3.8%) for 50:50 debt equity ratios.

The following table shows a review of approved and future planned construction indicative stock levels in Melbourne as in 2002:

**Table 3. Reviews of Stock Levels**

| Period End (Year) | New Constructions (Sq. m.) | Full Refurbishment (Sq. m.) | Partial Refurbishment (Sq. m.) | Total (Sq. m.) |
|---|---|---|---|---|
| 2001 | 0 | 59,478 | 9,978 | 69,456 |
| 2002 | 0 | 53,040 | 0 | 53,040 |
| 2003 | 81,000 | 0 | 550 | 81,550 |
| Mooted | 16,800 | 55,875 | 0 | 72,675 |

Source: Jones Lang LaSalle

Demand is independent of supply. Supply could increase, as forecast, but demand could increase more. However, as can be seen from the table 3 above, the approved and future planned construction is: 69,456m2 in 2001; 53,040m2 in 2002 and a further 81,550m2 in 2003 for a total of over 204,000 by 2004. The risk factors, such as vacancy rates and the future rent forecast predict a fall in demand due to new supply coming onto the market. Therefore, it is not possible to increase the rent up to 3.8% in 2002 economic condition related to figure 2 above. Thus, this project, which is already risky to be carried out, may become more risky.

### 3.2 Risk Analysis Using @Risk Software Package

Risk analysis using the @Risk software package version 3.5.2 is based on a quantitative method to determine the outcomes of a decision situation as a probability distribution (Palisade Corporation, 1995). Quantifying risk means determining all possible values a risky variable could take and determining the relative likelihood of each value. The software assists in evaluating the impact of variables such as: interest rate, office rents and occupancy rates. In @Risk, uncertain variables and cell values are entered as probability distribution functions, for instance:

- RiskNormal (mean, standard deviation)
- RiskTriang (minimum, most likely, maximum)
- RiskBetaSubj (minimum, most likely, mean, maximum)

The distribution functions can be placed in worksheet cells and work just like any other Excel functions. The comparison of risk analysis methods using MS Excel and the @Risk software is summarized in table 4 such as follows (Murtha 1995):

**Table 4. The Benefits of Risk Analysis Using the @Risk Software**

| MS EXCEL 2000 | @Risk Software v3.5.2 |
|---|---|
| • Deterministic approach | • Scenario approach. |
| • Changing only one parameter at a time. | • Changing combined parameters at a time using simulation. |
| • Single best estimate outcome | • Showing all possible outcomes. |
| • No probability of occurrence | • Showing the probability of occurrence of all possible outcomes |

MS Excel uses a deterministic approach, which means that it uses a single best estimate for all input variables. For example, 6% interest rate. While doing sensitivity analysis MS Excel can only change one parameter at a time. For instance, changing only the interest rate from 3% to 12%, the Excel user can observe the NPV trend. Furthermore, the estimation only can produce one NPV value as a single best estimate outcome, without showing the probability of its occurrence.

In contrast, risk analysis using the @Risk software uses a scenario approach, which establishes the worst case, the most likely and the best-case scenarios. It needs historical data, such as 15-20 year interest rate records, to determine its best-fit probability distribution. Furthermore, when it runs the simulation, the @Risk software will automatically use combined parameters. Finally, it will show all possible outcomes as a cumulative distribution and the probability of the occurrence of all the outcomes.

**3.2.1 Best-Fit Distributions**

In the @Risk software package, there is a program called BestFit that can assist the user to find the distribution that best fits the input data. BestFit does not produce an absolute answer; it identifies a distribution that *most likely* produced your data. The results of a best-fit calculation are only a "best estimate" as it is nearly impossible to find a distribution that exactly fits the data. Therefore it is important to evaluate the BestFit results quantitatively and qualitatively, examining both the comparison graphs and statistics before using the results.

The main steps in determining, interpreting and analysing the best-fit distribution of the input of historical data are summarised from the BestFit "help" tool as follows:

- Calculate parameters of each distribution function that maximise the likelihood of the distribution given a set of observation data using *Maximum-Likelihood Estimators*

(MLEs). For any density distribution *f(x)* with one parameter α and a corresponding set of observational data *Xi*, an expression called the likelihood (*L*) may be defined:

$$L = \prod_{i=1}^{n} f(Xi, \alpha) \rightarrow \frac{dL}{d\alpha} = 0$$

- Measure how "good" each distribution is at fitting to the input data using *goodness-of-fit* statistical tests such as: chi-square, Kolmogorov-Smirnov and Anderson-Darling tests. In this study, it was decided to use the chi-square test, which is the most common *goodness-of-fit* test. The strengths of the chi-square test are that it can be used with any type of input data (sample, density or cumulative) and any type of distribution function (discrete or continuous). The weakness is that there are no clear guidelines for selecting intervals. The chi-square statistical value is defined as:

$$\chi^2 = \sum_{i=1}^{n} \frac{(P_i - p_i)^2}{p_i} \qquad (2)$$

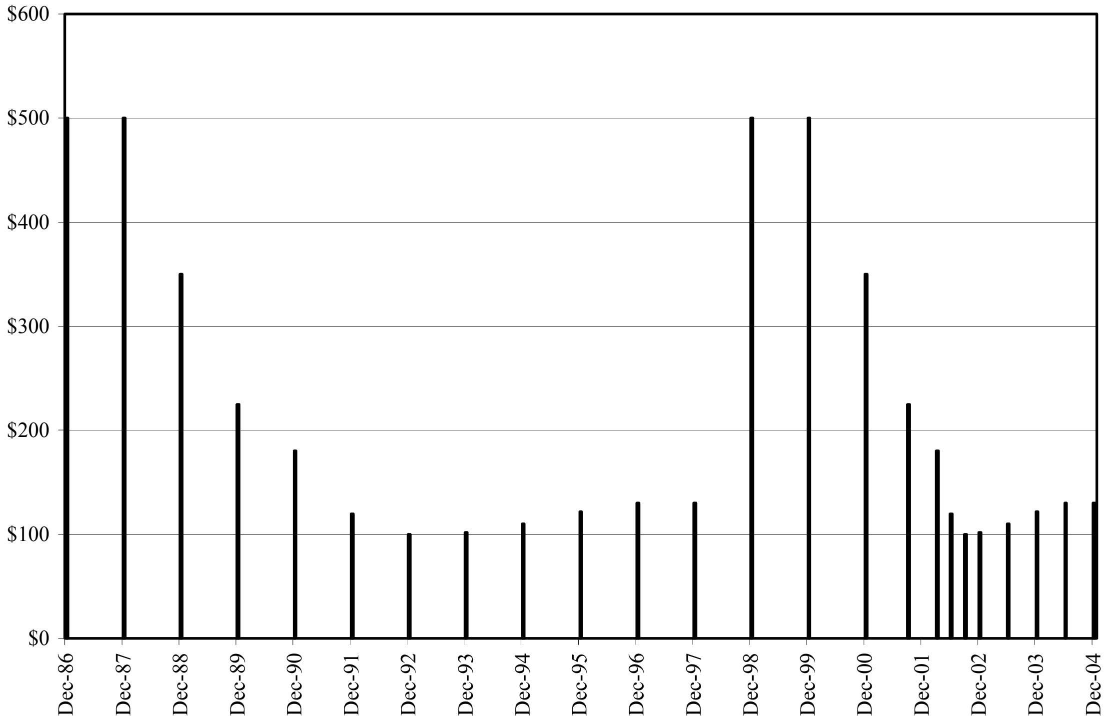
$P_i$ = the observed probability value for a given histogram bar
$p_i$ = the theoretical probability that a value will fall with the *X* range of the histogram bar.
The lower the chi-square value the better the distribution is.

- Compare the chi-square statistical value with the *critical value* calculated by the BestFit program. This provides a criterion for decision-making. When the chi-square statistical value is larger than the critical value, then the null hypothesis (the test is valid) should be rejected (not a good fit). Therefore, a good fit distribution is found when the chi-square statistical value is smaller than the critical value.

- Consider the confidence (certainty) level and the rank of each distribution.

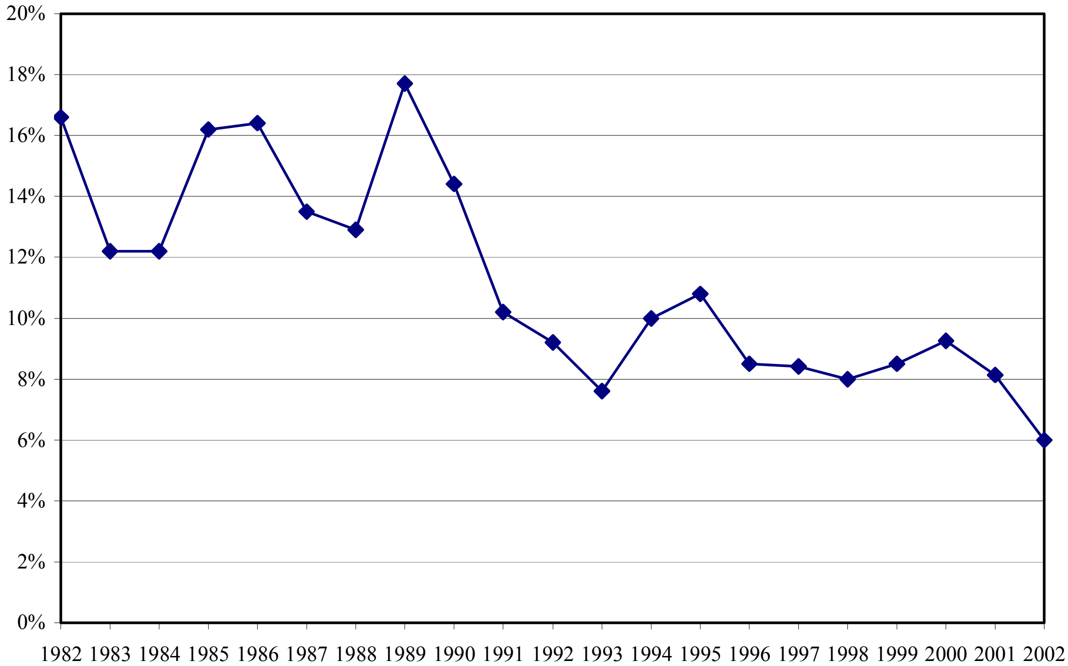
- Consider the closeness of the match to the mean (μ) or in the tails (skewness). The skewness indicates the degree of asymmetry in a distribution.

Below are the figures of historical and predicted data of the three examined variables, which were obtained from various indicated sources:



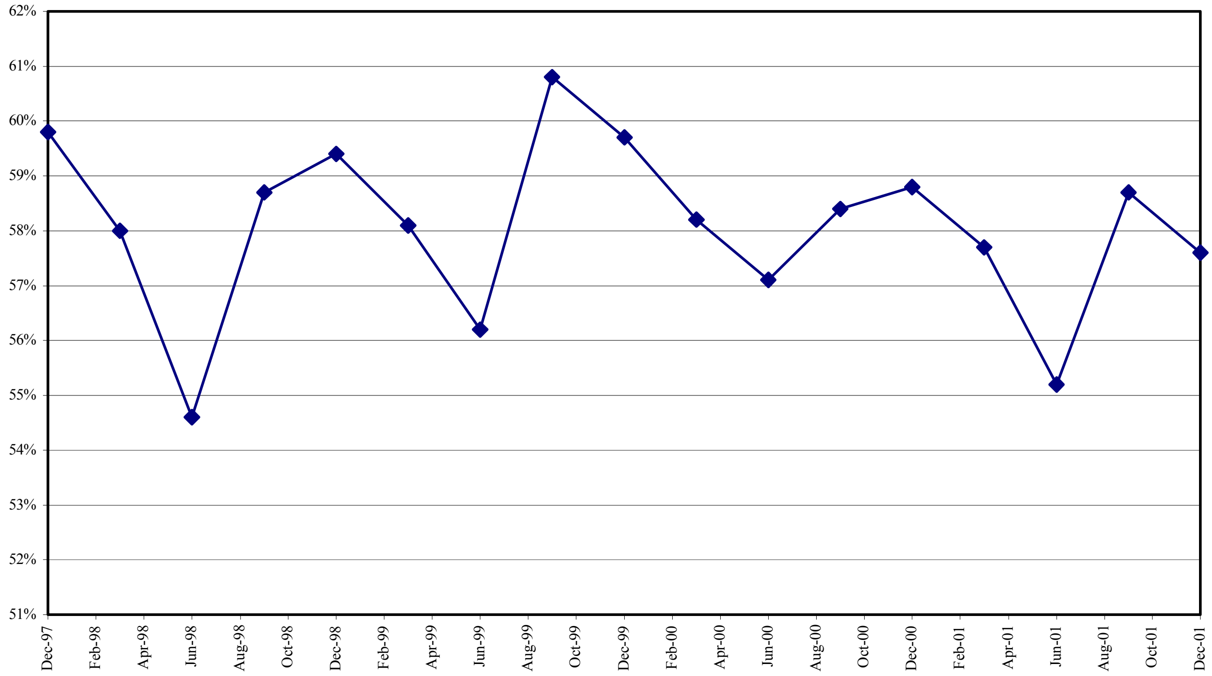

(Source: http://www.propertyoz.com.au/trendsnet/cyberstats/PropRents_gl3as)

**Figure 3. Historical and Predicted Net Effective Premium Office Rents – Melbourne**




(Source: http://www.abs.gov.au/ausstats/
and http://www.aph.gov.au/library/pubs/histmesi/histmensi4.4.htm)

**Figure 4. Historical Interest Rate Trend - Australia**




(Source: http://www.propertyoz.com.au/trendsnet/cyberstats/OccupancyRates_m21.asp and ABS Catalogue No. 863501)

**Figure 5. Historical Occupancy Rate Trend – Melbourne**

After testing with The Chi Square Test in different class intervals (6, 8 and 10 classes) and considering the results such as the mean, the confidence levels, the statistical and critical values and the graphs using chi-square test, the results were analysed to obtain the *most likely* distribution for the three variables as follows:

1. **Rent Income:** Beta Distribution with the figure to be used in the @Risk simulation equal to AS$332.
2. **Interest Rate:** Beta Distribution with the figure to be used in the @Risk simulation equal to 11.27%.
3. **Occupancy Rate:** Triangular Distribution with the figure to be used in the @Risk simulation equal to 57.87%.

The *best-fit* distribution function outcomes were then entered into the spreadsheet data (the feasibility analysis) to run the @Risk simulations using 1000 iterations (Palisade, 1995) to get the ranges of NPV and IRR.

This paper does not report all details of findings of the @Risk simulations due to the lack of feasibility of the project.

The next section discusses the process and results of risk analysis using Pertmaster software (time simulations), which were used to derive cost impacts on delays using the @Risk software. The Pertmaster software can simulate cost distributions of such delay simulations, but Pertmaster was a late addition to the investigation and the appropriate data was not derived.

## 4. RISK ANALYSIS USING PERTMASTER SOFTWARE

Pertmaster Project Risk (v7.5) software can be linked to Primavera P3 and Microsoft Project critical path method (cpm) schedules. A schedule risk analysis can be performed and certain calculated risk parameters updated back into the project schedule. Pertmaster provides similar functionality to the Primavera Monte Carlo product. An advantage of Pertmaster is that it links to P3e (Primavera Enterprise) as well as P3, whereas Monte Carlo only links to P3. Pertmaster also has an easy to use graphical interface that is being actively developed by Pertmaster and supported by Primavera (Pertmaster v7.5 Manual and Help 2002).

Risk analysis using Pertmaster Software allows a project manager to analyse a cpm project schedule using probability distributions of the task durations. Similarly to @Risk Software, Pertmaster requires the minimum and maximum durations as well as the best guess at the task duration, i.e. the most likely duration. Using Pertmaster Software can assist the project manager to answer questions related to the project such as (Pertmaster Project Risk v7.5 Manual and Help 2002):

- What is the chance of finishing the project on time?
- What chance do I have of finishing by a particular date?
- What date can I be 80% confident of finishing by?
- What tasks are most likely to cause project delay?

Pertmaster can also simulate probabilistic branching to tasks that may or may not exist, but this was not investigated.

This study used the triangular distribution to model the duration of each task since it is commonly used for more pessimistic tasks (Evans 1993). In addition, Pertmaster's simple set of parameters (min, most likely, max) makes it easy to relate to real life. Triangular distributions are often skewed to the left. This is because a lot of tasks cannot physically be completed in less than certain durations, but all tasks can generally be delayed for any number of reasons. This leads to the minimum duration being closer to the most likely than the maximum duration (Pertmaster v7.5 Manual and Help 2002).

To run risk analysis in Pertmaster, firstly it is necessary to set up a cpm schedule, which includes entering tasks and milestones and adding logic to define task relationships. Secondly, the risk duration distribution on each task is set up, which means that each task is assigned minimum, most likely and maximum durations. The task relationships (SS, SF, FS, FF) and durations enable the cpm calculations of the scheduling software to define the critical activities. In this case study, the critical activities were the Basement Level 1-5, Building A Level 41-47, Building P Level 41-50 and External Works in the precedence network.

Duration risk analysis using Pertmaster software was applied to two risk variables, namely the interest rate and rental revenues for premium office space. These two variables are generally sensitive to the time parameter. In contrast, the occupancy rate is more sensitive to the cost parameter. In addition, it is considered necessary in this case to do the simulations only for 50:50 debt equity ratios, since even without considering the historical data, this project is financially not viable for the higher debt equity ratio.

Generally, a basic simulation was run on each of the two variables (the interest rate and the premium office revenues) using the Pertmaster software to examine the distributions of completion dates. The basic simulation used the initial data, construction program and DCF analysis. The two risk variables used RiskBetaSubj functions, with 11.27% as the mean of interest rate and $332/sq.m as the mean of office rental revenues.

It was further decided to run two other types of duration risk simulation using Pertmaster, and subsequent cost analysis in @Risk software on each risk variable separately. The other two types of simulation were as follows:

- **Simulation 1**: What if there were a month-delay in Basement Level 1-3 task (middle critical activity)? What is the 85% confidence in finishing this project? What is the probability of still finishing the project on time?
- **Simulation 2**: What if there were a month-delay in External Works (last critical task)?

Which task from the two simulations is the more likely to cause the project delay? How much would both delays cost the project, as determined by the @Risk software? How much will the development cost increase? What are the results from the two simulations and the findings from the @Risk software related to cost simulations?

### 4.2 Pertmaster's Simulation Results

After running the duration simulations on both interest rate and rental revenues variables using Pertmaster software for each type of simulations and observing the impacts, it was apparent that changes in costs due to changing the selected variables did not affect the simulation results. It meant that there were no different outcomes when varying either the interest rate or rental revenues for each type of simulation. The outcomes for the three simulations are shown as in Table 5 below:

**Table 5. Pertmaster's Simulation Results**

| Simulations | Finish Dates (100% Confidence) | Finish Dates (85% Confidence) | Delayed Finish Dates (workweeks) |
|---|---|---|---|
| Basic | 31 July 2005 | 8 September 2005 | - |
| Simulation 1 | 7 November 2005 | 18 October 2005 | 8 |
| Simulation 2 | 13 December 2005 | 5 September 2005 | 6 |

The planned completion date for the project with no delay *(basic simulation)* is 31 July 2005. From Table 5, if there is a month delay in Basement Level 1-5 task *(simulation 1)*, then the completion date will be delayed by 8 workweeks for the 85% confidence (from 31 July to 18 October 2005). Furthermore, if there is a month delay in External Works task *(simulation 2)*, then the 85% confidence of completion date will be delayed by 6 workweeks from the planned finish date (from 31 July 2005 to 5 September 2005). The data in Table 5 above is summarized from the charts of the distribution of completion dates that resulted from the use of Pertmaster software for each type of simulation. Figure 5 below is an example of a project completion date probability distribution chart from Simulation 2.

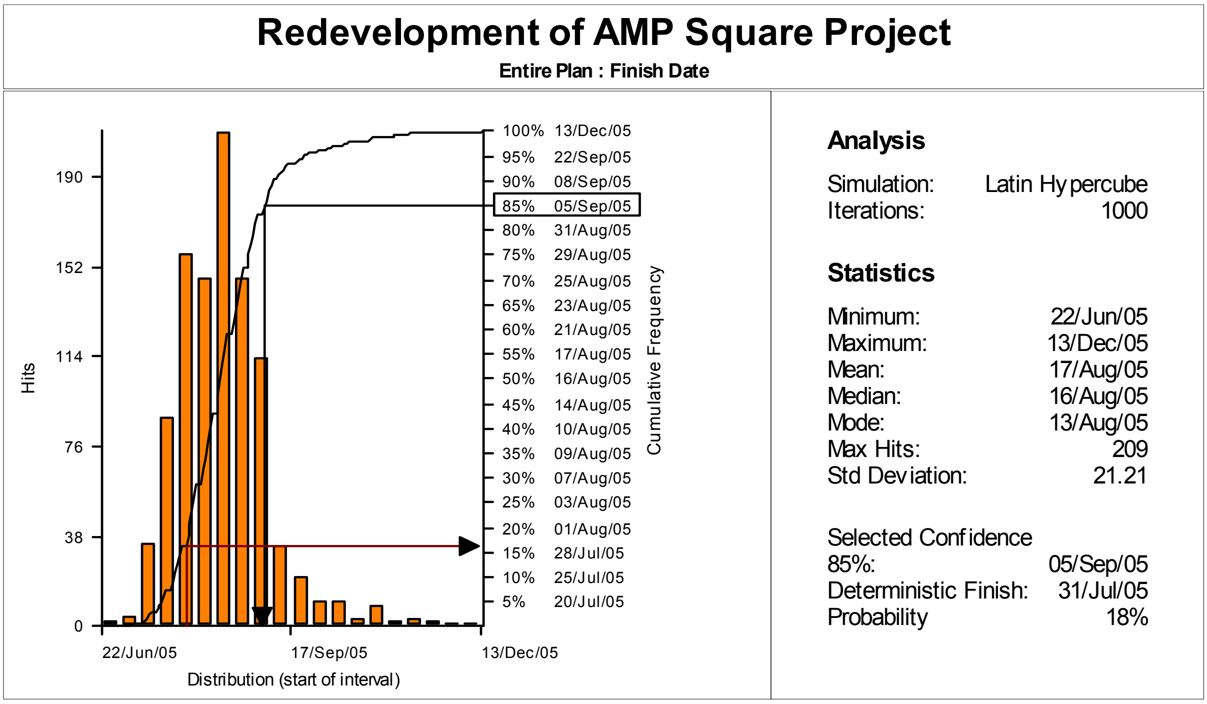



**Figure 6. Distribution of Completion Dates – Simulation 2**

It can be observed from Figure 6 above that the probability of the (deterministic) planned completion date (31 July 2005) being achieved or bettered, when there is a month-delay in last task, is only 18%.

In conclusion, a month-delay in Basement Level 1-5 task will affect the project more in delayed completion date than a month-delay in External Work Task (last work). The Basement Level 1-5 task is a critical activity in a middle position of the precedence network. Therefore, if a delay occurs in that task, it will affect the next critical activities and so on, which consequently cause more delays in the project than if the delay occurs in the last activity.

The next section discusses which task delay would affect the project cost more, based on running the two types of simulations in @Risk analysis on each risky variable (interest rate and rent revenues).

### 4.2.1 Impacts of Interest Rates

- **Statistical Results Summary**: The outcomes of varying the NPV, IRR and the input of interest rates are summarised in Table 6 below. From Table 6, it can be seen that a one month-delay in both Basement Level 1-5 and External Works tasks causes increased losses (NPV) and lower IRR. This is also due to the increased Total Development Costs (TDC) in each type of simulation.

**Table 6. Statistical Result Comparisons – Interest Rate**

| | Simulations | NPV | IRR | Interest Rates |
|---|---|---|---|---|
| MIN | Basic | -$509,189,500 | -8.15% | 5.70% |
| | Simulation 1 | -$512,133,100 | -8.17% | 5.72% |
| | Simulation 2 | -$545,725,700 | -9.73% | 5.71% |
| MEAN | Basic | -$230,550,000 | -1.10% | 11.27% |
| | Simulation 1 | -$239,806,000 | -1.31% | 11.27% |
| | Simulation 2 | -$251,839,900 | -1.37% | 11.27% |
| MAX | Basic | -$17,665,430 | 4.51% | 17.94% |
| | Simulation 1 | -$24,141,790 | 4.33% | 17.69% |
| | Simulation 2 | -$28,965,750 | 4.19% | 17.97% |

The increased losses and TDC for both simulations using the @Risk function for the interest rates (ranging from 5.7% to 17.97%) with normal office rents ($420 as assumed in Table 1) are summarised in Table 7 below:

**Table 7. Increased Losses and TDC – Interest Rate**

| ITEMS | Simulation 1 | Simulation 2 |
|---|---|---|
| Increased TDC | $3,847,280 | $4,307,311 |
| Increased Losses | 2.9M – 9.3M | 11.3M – 36.5M |

The increased TDC is calculated by subtracting the TDC in simulation 1 or 2 from the TDC of the basic simulation. Similarly, the increased losses are calculated by subtracting the range of NPVs in each simulation 1 or 2 from the range of NPVs in the basic simulation. Based on the table above, the one month-delay in Basement Level 1-5 task would increase the loss between 2.9M and 9.3M, whereas the one month-delay in External Works would increase the loss between 11.3M and 36.5M. Therefore, the External Works task delay affects the project more in both increased costs above, due to the interest rates. The closer the project approaches the completion date, the higher is the invested capital and the higher the loan interest to be paid per unit of time. It is the reason why a delay in the last task will cost more finance to the project than an earlier delay of equal duration. However, taking into account the likelihood that an earlier delay will be magnified through subsequent activities (see Section 4.2), more reliable cost impact forecasts are likely to be obtained from integrated time and cost simulations.

### 4.2.3 Impacts of Premium Office Rental Revenues

- **Statistical Result Summary**: The outcomes of ranges of NPV, IRR and the input of premium office rental incomes are summarised in Table 20 below, which shows that a month-delay in External Work task causes more losses to the project.

**Table 8. Statistical Result Comparisons – Premium Office Rental Revenues**

| | Simulations | NPV | IRR | Rental Revenue |
|---|---|---|---|---|
| **MIN** | Basic | -$135,051,600 | 0.87% | $100.48 |
| | Simulation 1 | -$141,168,600 | 0.70% | $100.58 |
| | Simulation 2 | -$146,657,100 | 0.52% | $100.11 |
| **MEAN** | Basic | -$57,766,390 | 3.29% | $331.59 |
| | Simulation 1 | -$63,906,920 | 3.12% | $331.62 |
| | Simulation 2 | -$69,233,930 | 2.96% | $331.63 |
| **MAX** | Basic | $62,597,040 | 6.63% | $691.53 |
| | Simulation 1 | $58,402,520 | 6.52% | $697.38 |
| | Simulation 2 | $52,027,350 | 6.35% | $694.25 |

The table 9 below is the comparison of increased losses and the TDC for both simulations using the @Risk function for premium office rental revenues (range from $100 to $695) with normal interest rate (6% as assumed in Table 1).

**Table 9. Increased Losses and TDC – Premium Office Rental Revenues**

| ITEMS | Simulation 1 | Simulation 2 |
|---|---|---|
| Increased TDC | $4,362,699 | $4,438,451 |
| Increased Losses | 4.2M – 6.1M | 10.6M – 11.6M |

Simulation 2 has higher rate of increase in TDC and higher losses than simulation 1. This is due to the fact that the annual loan repayment in simulation 2 is higher than simulation 1. Annual loan repayment is related to the total amount of loan paid monthly. Therefore, an equal duration delay in the last activity (External Works) causes higher finance cost (interest charges) than a delay of earlier activities.

In conclusion, the time simulation using Pertmaster software forecast longer delay of the completion date if the delay occurred in the initial or middle critical activity than in the last task. However, separate cost simulation using the @Risk software resulted in higher costs or losses if the same length delay occurred in the last critical activity. Which effect (longer consequential delays from an earlier delay or higher financing costs from a shorter later delay) would be more influential is best determined by using a simulation technique that integrates time and cost uncertainties. Pertmaster has that capacity, but that was not explored in this investigation.

## 5. CONCLUSION

Financial feasibility analysis on the redevelopment of AMP Tower project has been undertaken using MS Excel 2000, @Risk software v3.5.2 and Pertmaster Project Risk software v7.5. The following is a brief summary of findings:

- The use of an aborted redevelopment of AMP Square as a case study was unfortunate because it was not viable.
- Risk analysis performed in this study using Pertmaster software v7.5 was focused on time impacts on the project, whereas the risk analysis using @Risk software v3.5 investigated

cost impacts on the project. Both types of software produce their results in probability distributions, whereas MS Excel 2000 software and scheduling software only produce single best estimate outcomes.

- It is possible to examine the cost impacts on projects using Pertmaster software by assigning a resource to each task and applying a risk distribution to the cost of the resource. This is a more involved process than for costs using @Risk software, but offers the advantage of integrating cost and time risk analysis, functionality not available in the version of @Risk used.
- When considering the historical data of the three chosen variables, i.e. premium office rental revenues, the interest and occupancy rates using the BestFit program, the types of distributions which *best* fit each variable are BETA distribution for the office revenues and the interest rate and TRIANGULAR distribution for the occupancy rate.
- The time simulation using Pertmaster software forecast longer delay of the project completion date if the delay occurred in the initial or middle critical activity than in the last task. However, the cost simulation using the @Risk software forecast higher costs or losses if the same delay occurred in the last critical activity, due to higher loan repayment costs resulting from higher project invested borrowings at the end of the project. This work did not resolve which effect was more decisive for the total project cost because the time and cost risk analyses were separate. Integrated cost and time analysis could enable the overall effect to be realistically forecast.

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