Reducing the Technical Complexity and Business Risk of Major Systems Projects

Alan Thorogood
PhD Candidate
Australian Graduate School of Management
University of Sydney and University of New South Wales
Tel: +61 2 9931 9249
Fax: +61 2 9662 7621
Email: alant@agsm.edu.au

Philip Yetton
Commonwealth Bank Professor of Management
Australian Graduate School of Management
University of Sydney and University of New South Wales
Tel: +61 2 9931 9257
Fax: +61 2 9662 7621
Email: phily@agsm.edu.au

Abstract

Shared IT infrastructure achieves returns to scale and facilitates co-ordination. Determining the optimal investment is difficult because demand is derived from business projects that can "free-ride" once the infrastructure is established. Organisations control infrastructure investments by justifying them in business projects that are Net Present Value (NPV) positive, such as business process re-engineering projects. This increases the technical complexity of the business project and misleadingly couples the project's business goals with shared infrastructure goals.

Field research uncovered an alternative “deviant” model where a flexible, or agile, infrastructure is installed and justified ahead of the business needs. Those needs were then satisfied with multiple small business application projects, as each became NPV positive. The managers’ intuition was that this gave them valuable options to capture benefits from uncertain future business scenarios.

This paper draws on these insights to uncouple infrastructure projects from business projects while still aligning the two. Real options theory is applied both to control the costs and to specify the infrastructure flexibility. The assumption is that uncoupling would reduce technical complexity and lower business risk. The paper then shows how to improve business performance by using infrastructure flexibility either to suppress the cost variance of the IT projects or to amplify their business benefit variance, as called for by McGrath [1] and Sambamurthy et al. [2]

1. Introduction

Organisational change is both challenging and expensive [3]. In addition, organisational change programs involving Information Technology (IT) add considerably to the downside risk because IT projects have a poor track record [4]. Interfaces to other IT systems can also cause failure to cascade through Enterprise Resource Planning (ERP), E-Commerce and Customer Relationship Management (CRM), to other business divisions and companies. This is particularly so for innovative business projects that use cutting edge IT infrastructure to deliver IT-based strategic change to support new strategies.

Such strategic IT projects suffer from two weaknesses. First, the mix of business unit requirements and corporate IT infrastructure is complicated, involving trade-offs across multiple business units and the corporate office [5]. Second, uncertainty and unreliability in large infrastructure upgrades and changes to IT applications have led to cost overruns, late product launches and poor functionality [4].

This paper argues that an alternative management framing of the issues could improve performance by both redefining the decision process and restructuring the implementation of major IT projects. This is motivated by two insights. First, field research revealed what was initially thought to be a deviant case – the upgrading of IT infrastructure in anticipation of an organisational change. Second, an interpretation of McGrath’s [1] framing of technology positioning would value IT infrastructure as the cumulative price that business units would be willing to pay to acquire the options to develop future IT business projects. These business projects have uncertain commercial returns and generate different technical challenges.

The first insight contradicts the dominant Business Process Re-engineering (BPR) assumption that re-engineering the business processes precedes the installation of the technology [6]. Instead, the argument here is that by separating the infrastructure upgrade from the business application development, the technical
complexity is reduced in that there is a portfolio of smaller, quasi-independent projects.

The business risk is also reduced with the flexibility to delay commitment to the application development. In addition, the upgraded infrastructure flexibility shortens the time to market of the application [7]. The decision to build the new business application can be taken in a timely fashion, essentially concurrently with the development of the new market opportunity.

The second insight supports this shift in IT strategic thinking. A decision framework is needed in which line management can “buy” the option to acquire future business applications on the new infrastructure. Real options theory [8], as described by McGrath [1] in her framing of technology positioning, explicitly and formally models such choices. Essentially, the business applications are treated as call options whose values justify the infrastructure upgrade.

The remainder of this paper is structured in the following manner. First, the theory is developed to uncouple technical complexity and business risk, while at the same time aligning IT and business strategies. Then an analysis of Net Present Value (NPV) framing of investment decisions shows how, by bundling decisions, it leads to complex high-risk infrastructure upgrade projects. The next section shows that the real options pricing model not only unbundles the decisions but also identifies how to maximise the value of the projects. Finally, the discussion draws on field research to demonstrate how this approach works in practice, and where it is most applicable.

2. Background Literature and Theory Development

The dominant model for IT investment is shown in Figure 1. Here, the business benefits are used to cost justify an infrastructure project. In practice, managers continue to add features and their benefits until the infrastructure costs are covered. In Figure 1, the combined NPVs of the five business application features A-E, justify the infrastructure upgrade. IT infrastructure is shown here to include applications, data, technology and human resources, a definition of infrastructure that is in use elsewhere to analyse related flexibility [9].

An NPV analysis of such a project discounts future cashflows to reflect the time value of money. As illustrated in Table 1, infrastructure upgrades show steep initial outflows followed by long term cash inflows as the application features yield results.

Table 1. Stylised Net Present Value calculation

<table>
<thead>
<tr>
<th>Year</th>
<th>Develop application features $60</th>
<th>Infrastructure upgrade $40</th>
<th>Benefits of all application features $50 p.a. over 3 years, then $0 p.a.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-100</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

Year 0 1 2 3

Benefits of all application features $50 p.a.$50 over 3 years, then $0 p.a.$

PV $24

Assumes cash flow received at the end of the year with a discount rate of 10%

In contrast, within an entrepreneurial analytical framework, the business applications would be treated as a portfolio of project investments, some of which will fail and be divested [10, 11]. In that case, an option to invest in a business project has value because it limits the downside risk to the cost of the option while retaining the potential to capture the upside. Infrastructure upgrades generate options to commit to future business application developments. Justifying the infrastructure on the value of the options aligns IT deliverables with business needs through timely infrastructure availability and speed to market with shortened application development timeframes. Optional business projects are only developed as the market is developed.

Operationalising this approach requires an evaluation model that separates the corporate-owned infrastructure decision from the business-division owned applications decisions, while combining them for valuation purposes. The infrastructure would then be designed and built for the business applications using the best technical tools available. Each new business project could then be justified using NPV, which works well for single business applications. Within this framework, BPR is equivalent to exercising all the options immediately, on the assumption that any delays would reduce business value.

This new framework is presented in Figure 2. It shows an expanded portfolio of options from those considered in Figure 1. In the example, Application project C would not be selected because, over time, it did not become NPV positive. The other application projects would be implemented, as they became NPV positive.

An infrastructure that delivers managers a portfolio of options, any one of which may be exercised or allowed to lapse, reduces the cost of divestment to the price of an option. By reducing the cost, it also increases the range of options within the portfolio. In particular, as in the
case of an SAP upgrade reported by Taudes, Feurstein, and Mild [12], it would include high risk entrepreneurial options which are obviously NPV negative but have high upside potential. For example, project X, which became NPV positive, is shown in Figure 2 but excluded from Figure 1.

2.1. Technical Complexity and Business Risk

Organisations tend to place themselves in high technical complexity and high business risk scenarios when project evaluation requires infrastructure costs to be deducted from the business benefits derived from a project. As noted earlier, sponsors continue to search for benefits and features until the project clears investment hurdles. The additional features increase the complexity of the project, which becomes harder to achieve. Such stretch goals may motivate teams to produce at high levels of attainment but also increase performance variance and, hence, risk [13].

So, when a major infrastructure upgrade is required, organisations typically find that they are faced with large, complex IT projects with high business risks. This locates major system upgrade projects that concurrently build a new infrastructure and the identified business applications, in the top right hand cell in Figure 3. In this paper, the challenge is not how to manage such BPR type projects more effectively but to examine how to reposition them towards the simpler, lower risk platform portfolio in the bottom left hand cell. This is done by uncoupling the technical decisions around the IT infrastructure development and the business decisions around commitment to each application.

To ground the above theory development, consider an on-line stockbroking system (see [14]). The IT-savvy Head of Equities described how he decided to undertake a major program of IT-enabled change to support new products and services. First, he upgraded the platform benefits and features until the project clears investment hurdles. The additional features increase the complexity of the project, which becomes harder to achieve. Such stretch goals may motivate teams to produce at high levels of attainment but also increase performance variance and, hence, risk [13].

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To ground the above theory development, consider an on-line stockbroking system (see [14]). The IT-savvy Head of Equities described how he decided to undertake a major program of IT-enabled change to support new products and services. First, he upgraded the platform

![Figure 2. Infrastructure with optional business projects](image1)

![Figure 2. Infrastructure with optional business projects](image2)
releases out over an extended period and gradually train their customers, keeping the site fresh and interesting. This manager made the decision intuitively and without an understanding of the framing that we are discussing here.

<table>
<thead>
<tr>
<th>High BPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tech.</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>Portfo.</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>High</td>
</tr>
</tbody>
</table>

**Figure 3. Typology of major system upgrade projects**

The next three sub-sections discuss the nature of technical complexity and business risks. The goal is to both reduce and explore how to uncouple them, whilst aligning IT with business strategies. Here, we restrict the discussion to the three risks identified by Applegate et al. [15], while recognising the larger body of literature on project risks, which is outside the scope of this paper.

### 2.2. Reducing Technical Complexity

The downside risk of an IT project is a factor of three things [15]:
- Size, and the organisation’s experience in performing projects of this size
- Experience with the technology
- Project structure (task uncertainty and organisational change requirements).

The first two factors directly influence technical complexity. The third contributes to business risk and is discussed in that section below. Increasing the size of IT projects greatly increases their technical complexity. Brooks [16, p88] reports on data from Nanuss and Farr at System Development Corporation. In this example, the effort to write a piece of code is shown to grow at an exponent of 1.5 of the number of lines of code. This is also reflected in the costs of communicating in a large team, with communication requirements rising at the rate of $(n^2 - n) / 2$. In addition, the greater the number of tasks required to complete a project, the greater the probability of failure - simply because there are more tasks that can fail and the outcome is dependent on successful completion of all tasks.

Novel large size projects exacerbate the problem because the organisation has not been exposed to the complexities discussed above and typically is reluctant to accept external warnings because of heuristics (existing anchors) gained in earlier projects [17]. This means that novel large projects are frequently under resourced and have unrealistic targets. The adoption of novel technology, such as found in an infrastructure upgrade, carries an upside risk of reward that motivates its adoption and a downside risk of failure. The outcomes will vary between the best-case desired and failure.

We can reduce technical complexity using modularity, refactoring and standards. Modularity reduces the number of interfaces, allows for modular testing of sub-assemblies [18] and a quicker time to market [19]. A concrete example of this is object oriented programming, which has extended modularity to data [20]. Refactoring reduces complexity inherited from old fragmented systems. This is defined as "a change made to the internal structure of software to make it easier to understand and cheaper to modify without changing its observable behaviour of the software" [21, p54]. These tools and techniques assist in simplifying existing systems to regain their lost elegance.

Standards, such as web services, are being used to simplify interfaces between sub-systems [22]. This permits modules to be removed and replaced with alternative modules and can hide the complexity of an older system in preparation for a major upgrade or in preparation for eCommerce [23].

The above discussion focuses on the first two issues identified by Applegate et al. [15]. It shows that technical risk exhibits itself in large, complex systems that use novel technology. This risk can be managed by using modularity to reduce the number of interfaces, web services to standardise the interfaces, and refactoring to simplify existing application infrastructure.

### 2.3. Reducing Business Risk

Projects are said to be successful if they reach their targets of scope, quality, time and cost, so project risk management focuses on these goals. However, a project may satisfy these goals but fail because business needs change between project conception and implementation.

A wider definition of risk is variance around an expected outcome, with the project exposed to upside and downside business risk. For example, an on-line stockbroker may be the first to market managed funds and thereby capture significant persistent market share [24]. Alternatively, a bank may suffer a system failure during an upgrade and have hundreds of thousands of transactions worth billions of dollars being held in suspense [25], with a resultant fall in customer confidence. When making these types of strategic bets, managers understand that a range of outcomes are possible.

This paper proposes the use of real options to structure major IS projects to skew the distribution so that negative
NPV projects are avoided and emergent NPV positive projects taken up. This approach to managing business risk aims to maximise the variance at the upside and minimise it on the downside by gathering as much information as possible and delaying the implementation of business applications for as long as necessary. The delay in commitment allows two types of managerial action.

One is the construction of both a valuable portfolio of cascading business options [26] and, at the same time, the capability to select by choosing only those application projects that emerge as having a high positive value as market uncertainty is reduced. This strategy requires rapid execution of the application projects that, in turn, depends on a sound IT infrastructure that flexibly supports future projects. This ensures that the infrastructure is designed and built to remove much of the technical complexity, leaving only the residual business risk to influence the outcome.

The other is that the delay encourages strategic pre-commitment investments that can further shape the business risk in favour of the organisation [1]. Such strategic actions include lobbying, supply solicitation, market intelligence and demand-stimulation campaigns.

A field example of amplification activities is a discount stockbroker who lobbied for permission to sell managed funds and sought out potential suppliers before committing to the business project. With an infrastructure in place that already explicitly supported the flexibility to implement such a function the firm could move quickly to market once permission was given [14].

2.4. Uncoupling the decision-making

In an ideal world, all options would be visible when making a choice. In practice, framing errors frequently limit decision making by using either a technical-only or a business-only frame [27]. By modularising the decision-making, the many options available in each world can be considered in their own space, while the options-valuation process keeps them aligned.

This alignment comes from an infrastructure upgrade that meets the required future flexibility. These requirements can be captured from a high level analysis that enumerates the options to be supported and any cascading dependencies. Indicative prices are produced of the cost to develop the option on an envisaged newly refreshed infrastructure. The infrastructure development costs are not included. Managers then rank the options and negotiate for the right to an optional implementation at an agreed price, valid for a certain period.

The result is a minimum of two projects – first a technical project to deliver flexible infrastructure and second, the business project. In practice, the latter is likely to be a portfolio of business projects. The size of these projects is much smaller than an equivalent complete system re-engineering, reducing the technical complexity.

The uncoupling also allows managers to focus and specialise. Organisational change is made easier by reducing the capability gap between the desired and current states. The infrastructure renewal project also begins the process of unfreezing.

3. Reframing the Investment Decision

Justification for infrastructural renewal can be made on a number of bases, including the cost of staying in business. Some organisations use benchmarks where a percentage of sales or assets is expended each year or use last year’s infrastructure budget. The dominant financial technique is Net Present Value (NPV), within which infrastructure investments are often justified by the costs avoided in averting an infrastructure failure. Alternatively, the infrastructure costs may be included in those projects that have a strong NPV-positive case.

A variant of NPV, active NPV, accounts for risky outcomes by including the probability of the future cash flows in a decision tree [12, 28]. However, the weakness of any NPV technique is that it does not easily tolerate ambiguity. For example, it needs a defined finish date. The user renounces flexibility in order to perform an NPV [12]. These techniques also have a central point tendency in that they base future expenditure on the whole-company cost of capital and past experience. They fail to include the value of options, which leaves options and their associated flexibility underexploited in the management of IT [29].

In addition, as uncertainty in the environment increases, the value of flexibility increases along with the need for an alternative infrastructure upgrade decision-making process which models that flexibility. The real options pricing model captures the value of these options. Here, we argue for its theoretical and practical use in framing the infrastructure upgrade decision.

There are six input “levers” to this model. The levers are: period of validity for the option (at some point the options expire), variance of the cash flows, present value of the expected cash flows, value lost over the duration, present value of the fixed costs to exercise the option and the yield of a riskless security [30-32]. The period of validity and variance of the cash flows offer the most insight to frame the decision.

The longer the period of validity, the greater the value of the option [31]. In an IT infrastructure decision, this means that the longer the commitment to implement a project can be delayed, the greater the value of the option. As explained above, the length of this delay is not only affected by external limits on when the application is required but also on how long it takes to execute the option. A short implementation time increases the value to the business of the option.
The variance of the cash flows also positively impacts the value of the option [31]. This means that the greater the uncertainty over the cash flows, the more value there is in having an option over those cash flows. Taudes [33] provides an example of this in a case study where the company had to choose between upgrading to SAP R/3 or staying with R/2. R/3 provided optional modules to exploit eCommerce. These features modules were not NPV positive at the time of making the decision but would have had value if eCommerce proved commercially viable. The variance of the cash flows was large, increasing the value of the option. The decision was made to upgrade to capture the options excluded from the NPV analysis.

Managers are intuitively aware of the input levers and the IT options to maximise the value. According to Benaroch [28], these options include deferral, staging, experimentation, scaling up or down, abandonment, outsourcing, leasing, growth and combinations of these options. The manager of the broking business described earlier referred to all of these options in his explanation of his behaviour [14].

For IT projects, the option to defer a business application is obvious. Staging options also helps to reduce risk by removing dependences and hence improving project performance [4]. Experimenting to determine the value of future technology has consistently been a problem to justify and companies resort to allocating budgets to the CIO and CEO for discretionary expenditure. This should be thought through in a more structured manner and may be justified within a real options frame due to the many options created. The options to scale up or down and outsource are self-evident as is the abandonment option.

In summary then, uncoupling the decisions allows the technology infrastructure to flexibly deliver future applications using techniques such as modularity, refactoring and standards to technically simplify and prepare to support future business applications. The business then has options that permit deferral, scaling, exploration, abandonment, outsourcing and leasing.

4. Maximising the Value of the Upgrade

Separating the infrastructure and business application decisions with an options-value link simplifies the former and adds value to the latter while supporting business-IT alignment. A second-order effect is that real options theory also provides insights into how to maximise the business value [1]. Here, we begin to explore how to do so for major corporate information systems upgrades.

From a value perspective, such projects are composed of the costs of upgrading the infrastructure, the costs of building applications and the business benefits that flow from them. Once the infrastructure is built, there are variances around the application costs and the business benefits. When designing and building the infrastructure, management should focus on the boundaries of the largest anticipated variances. The objective is to increase business benefit variance and/or suppress the application cost variance as shown in Table 2. The value of the investment is a negative function of cost variances and a positive function of the business variances [1].

### Table 2. Influence of business and application variances on investment value

<table>
<thead>
<tr>
<th>Variance</th>
<th>Recommendations for options holders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Benefit</td>
<td>Amplify the variance. Infrastructure should support reach, richness and scale. For example, bandwidth, Rapid Application Development, multiple vendors. Modularise infrastructure.</td>
</tr>
<tr>
<td>Cash Flows</td>
<td></td>
</tr>
<tr>
<td>Application</td>
<td>Suppress the variance. Acquire infrastructure knowledge, standardise infrastructure, refactor existing systems, web service wrappers. Outsource application development.</td>
</tr>
<tr>
<td>Project Cost</td>
<td></td>
</tr>
</tbody>
</table>

Uncoupling the infrastructure decisions from the business application decisions reduces cost variances in comparison with a BPR-style project. In that case, the variance with the largest impact on the investment value would be the variance of the cash flows from the business benefits. Information Systems can drive up the variances around the business benefits by offering support for high levels of reach, richness and scale. Any pre-commitment infrastructure investments to support best-case business scenarios help to increase the value of the optional business application. Examples include server capacity, network bandwidth, rapid application development methodologies and multi-vendor sourcing.

While business benefits variance increases the value of the option, application development variance reduces the value. The goal is therefore to lower the upper boundaries of these costs. One way to do this is to upgrade the infrastructure in such a way that it lowers complexity and, therefore, reduces the size of the application project. Examples include refactoring and modularising systems that may require change, enforcing standard operating environments, cleansing databases, practising release procedures, validating configuration management tools, developing change management methodologies and checking test scripts so that interaction effects can be reliably tested. Ensuring that the infrastructure is very well understood is more important than having a modern infrastructure.

5. Discussion

The dominant decision framework for major IT systems upgrades aggregates across the NPVs for the business projects to justify the infrastructure investment.
A major change program is then designed in which the infrastructure and the business projects are delivered concurrently with both high technical complexity and high business risk. This paper examines an alternative decision framework and IT strategy. The infrastructure and business projects are uncoupled within a real options pricing framework. The infrastructure is implemented first, as a platform on which the business projects are delivered within a staged flexible strategy. In this discussion, the issue of alignment is revisited and the limitations are considered. Then future implications are briefly explored.

5.1. Alignment and Limitations

Building infrastructure ahead of the business needs removes the infrastructure lag and thereby improves alignment. Furthermore, by designing the infrastructure to support specific business options, the basic alignment is improved to create a tight fit between IT and the business, which also improves performance [34]. In addition, by uncoupling the infrastructure and business application decisions, the demand on the business managers to understand IT and on the IT managers to understand the business is reduced. These demands are focused on and limited to the design and requirements of the business applications. The design and build of the infrastructure is essentially a technical issue once the portfolio of potential business applications has been agreed.

While building the infrastructure early solves a number of problems, it raises a number of other issues. The first components upgraded could be dated by the time they are used because IT changes so quickly. This constrains the period of validity of the options and puts upper limits on the values of the options.

Successful alignment is also dependent on business managers being able to elucidate their requirements in such a way that the IT infrastructure team can understand. With these communication skills still in short supply, business analysts will be needed to interpret and communicate the requirements. In addition, with infrastructure decisions contributing directly to business options, the IT governance structure would need to be extended to approve and monitor these decisions.

In addition, the value of options is a function of the context. When the environment is stable, variance around the outcomes is low and, therefore, the value of an option is low. In that context, a pre-determined strategy would have lower overall costs and faster delivery. Finally, in infrastructure upgrades where the NPV is clearly positive or negative, a real options approach is of little use, as managers will be unable to exercise or reject the optional applications [29]. In contrast, when the environment is turbulent, rapid timely execution of focused business projects may be the basis of a strong market driving strategy.

Finally, none of this reduces the importance of the application projects being delivered on time, to budget and to scope. In addition, the higher the level of project performance and the lower the variance around that performance, the more valuable the underlying options become. Many are working to improve project management either within the project (for example, the Project Management Institute [35]) or to structure the environment around the project (for example, Office of Government Commerce’s PRINCE2 [36]). Successful project management would significantly increase the value of the business application by reducing the cost variances.

5.2. Future Implications

The discussion above on maximising the business value by using real options theory is only the first step in using this reframing. Options to move in the marketplace are valuable and yet subject to complex interaction effects with competitors [37]. The explanation above has been limited to improving the effectiveness of IT decision making and improving internal alignment. The next step is to set this analysis within a competitive framework.

Options are also most valuable where there is uncertainty and IT-based business strategies have high levels of uncertainty [38]. The critical insight here is that the value of the portfolio of options is maximised by reducing the cost variances of the business applications or maximising the variance of the business cash flows. Reducing the cost variances would primarily be a technical issue but maximising the business variances offers a new challenge for strategic collaboration between IT and the business.

Finally, the explicit link between infrastructure and application projects would help software designers to concretise the use of options in their designs and further enhance business value at a micro level. Software engineers that restructure existing systems organise code into modules and hide data to reduce complexity and improve flexibility. The choice of modules and data hiding determines how flexibly the code copes with future changes. Informing these designers of possible scenarios will help to localise those anticipated changes and improve future project performance [18].
6. Conclusion

This paper begins by identifying the emergent strategy [39] of building the infrastructure ahead of business projects as illustrated by a case study of a broking business. Real options pricing is then adopted to model this process formally. This generates a series of insights beginning with how to uncouple the infrastructure and business project decisions while aligning them to improve performance. A key implication is how real option pricing focuses analysis on opportunities to increase the value of IT investments by reducing the variances in the cost of the business projects and/or increasing the variances in the business cash flows. This reframing of infrastructure and IT business project decisions has major implications for both technical inputs and innovative performance opportunities of collaboration between IT and the business.

7. References


8. Author Note

Alan Thorogood is researching theoretical frameworks to assist management thinking with regard to IT flexibility, outsourcing and project management. In the research he draws on nearly two decades of wide-ranging global industry experience. He is a PhD candidate in Professor Philip Yetton's Fujitsu Centre for Managing Information Technology, a lecturer on the AGSM’s Executive MBA and tutor on the full time programme. His AGSM MBA was awarded in 2003 with the Australian Business Limited Prize for excellence and the BCG Prize in Strategy.

Philip W. Yetton is the Commonwealth Bank Professor of Management at the AGSM. He is a graduate of Cambridge, Liverpool and Carnegie-Mellon Universities. His major research interests are in leadership style, decision making, and information technology. He has extensive consulting experience in Australia, Europe, the UK and the USA in areas as diverse as computer, chemical, textile and banking industries, and in health, prison services and the military.

He is co-author of the leading text book “Management in Australia”, has written numerous research papers, and is co-author with Professor Victor Vroom of the internationally acclaimed text “Leadership and Decision Making”. Philip has been General Editor of the Australian Journal of Management.