The Real-Options-Based Approach to Management of Defence R&D Investments: An Exploratory Study

ABSTRACT

The real options methodology has been widely used in investment models. Many researchers have also proposed modelling R&D investments as real options since they present the right - but not the obligation - to commercialise the R&D product. This idea is particularly powerful when applied in defence R&D where the objective of strategic investments in R&D is to develop technological capability. While the real options methodology has been used in the evaluation of defence acquisitions, the models for defence capital investments may not be suited for investments in defence R&D. Literature on real options modelling for R&D investments has also not offered in-depth suggestions on how to characterise defence R&D investments for modelling as real options. This paper will examine the issues that need to be considered in using real options to model defence R&D investments and improve the management of defence R&D investments.

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INTRODUCTION

Socio-political developments since the end of the Cold War order have presented fresh security challenges. In place of the clearly defined camps and balanced power structure of the Cold War era, the worldwide security landscape is now shrouded by rapid and uncertain developments. Globalisation and terrorism has brought the battleground to areas once removed from the regions of conflict. Hence, defence forces of today need to be prepared for evolving challenges in an uncertain future.

STRATEGIC OBJECTIVES FOR DEFENCE R&D

Singapore relies on technology as "a key enabler" for building its new generation of defence forces (Singapore Minister for Defence, 2006). It invests in defence R&D to deliver solutions to meet "requirements that are specific to... [its] needs, environment and fighting concepts" as "[not] all the required technological solutions are available because of commercial and proprietary reasons" and "[the] ability to customise and improve elements of its weapon systems also gives... [it] an edge over similar systems which have not been so improved". Another aim is to allow the creation of "surprises on the battlefield and to come up with quick fix solutions should the need arise" (Singapore Minister for Defence, 2006).

Our indigenous defence R&D could provide us the innovation leverage to gain a competitive advantage over our potential adversaries. There is a need to better manage our defence R&D portfolio to deliver greater returns on investments and greater opportunities in the strategic technology options created.

CURRENT LIMITATIONS

An integrated R&D investment approach is needed to create greater value for strategic investments in the uncertain future. The portfolio management must be supported by tools such as technology valuation methods, which consider the systemic relations in the investment framework. However, current methods in portfolio management and technology valuation are inadequate in modelling defence R&D systems.

Traditional technology valuation methods, including the Discounted Cash Flow methodology, are useful when there is little uncertainty in both the project and the estimate for the cash flow. R&D investments, however, are highly volatile and uncertain. They could be highly risky while offering opportunities for great returns. R&D projects may span over a long period of time and the know-how developed in a project may create options to pursue development downstream. R&D success may also depend on the success of interdependent developments. Hence, a mere factoring of risks in the traditional valuation methods is inadequate to model R&D ventures. Since portfolio management approaches are frequently built on similar theoretical foundations as valuation methods, traditional portfolio management approaches must also be enhanced to account for the uncertainties and opportunities offered by a portfolio of R&D investments.

MODELLING R&D INVESTMENTS AS REAL OPTIONS

The real options methodology has been advocated by researchers for use in R&D valuations as R&D investments are akin to real options since they present the right - but not the obligation - to commercialise the products of R&D investments. Real options could be viewed as growth options or flexibility options. The former gives a firm the ability to increase its future business. Examples include R&D, brand development, mergers and acquisitions, leasing or developing land, and launching a technology initiative. The latter gives a company the ability to change its plans in the future. Real options better model the returns

of R&D investments under uncertainty as the model takes the value of flexibility and opportunities into consideration.

Real options valuation (ROV) has been widely adopted by practitioners in modelling R&D investments. Many major companies in the pharmaceutical and health care industries, including Merck and Eli Lilly, have used ROV for their R&D decisions (Boer, 2002). Reiss (1998) also reported many cases of ROV applications in R&D investments.

APPLICATIONS OF REAL OPTIONS IN DEFENCE BUSINESS

In recent years, there has been widespread interest in applying real options in defence business management. Housel (2003) suggested that defence activities are comparable to capital market activities and proposed a real options analysis model to evaluate investments in joint forces planning. A framework to manage uncertainty in defence acquisition was proposed by Ceylan and Ford (2002). Glaros (2003) proposed the use of the ROV method in evaluating defence businesses. More recently, Setter and Tishler (2005) proposed using the real options concept for investment policies in defence R&D programmes.

MODELLING DEFENCE R&D INVESTMENTS AS REAL OPTIONS

Current literature on real options modelling for R&D investments and defence business management generally does not offer suggestions on characterising defence R&D investments for modelling as real options. Rouse and Boff (2004) made an important exception. They suggested that defence R&D investments can be modelled as real options and proposed using the real options methodology to put a value on these investments. As ROV requires quantification of returns and "defence investments do not

yield profits for the public that invests in these capabilities", they argued that the "investments yield desired military capabilities and effects" and proposed "[t]aking these desires as requirements or "givens"" to "characterise the returns on investing in a new technology in terms of potential cost savings in meeting given requirements within this technology".

The modelling of real options as cost savings obtained by deferring the decision for acquisition is useful in the valuation of investments in hardware assets. The direct application of this approach in R&D valuation, however, ignores some important elements of R&D investments. In addition to the value of an R&D investment to create the option to commercialise the R&D product, the R&D investment also creates the option to pursue further technological development, hence creating the option to create more options. This latter value can be modelled using American sequential options (Lee and Paxson, 2003).

Another important omission in the ROV method proposed by Rouse and Boff is the strategic considerations in defence R&D investments. As discussed earlier, strategic considerations are of particular importance in defence R&D investments by small countries. In addition to delivering short-term operational payoffs, their investments frequently aim to develop indigenous capabilities and create human capital to mitigate risks in technology sourcing and gain a competitive advantage

	Discounted Cash Flow	Real Options Approach
Strengths	• Widely accepted • Simple to use	• Considers the flexibility and opportunity in uncertain R&D investments • Models the options offered by technology and intellectual capital created
Weaknesses	• Ignores the flexibility and opportunity in uncertain R&D investments	• Not widely adopted across all industries • Computation often seen as a "black box"

Figure 1. Comparison of the Discounted Cash Flow and Real Options methods

over their competitors. R&D investments not only help to develop technological knowledge, they also assist in developing the organisation's technological capability. This capability resides in the human capital created and generates the option to create more technology options. The human capital option could allow small countries to gain a competitive advantage over larger resource-rich competitors through technological innovation in the uncertain future. This is also a compound option with the option for innovation embedded in the human capital option.

COMPARISON OF DIFFERENT VALUATION TOOLS FOR DEFENCE R&D INVESTMENTS

Figure 1 summarises some of the strengths and weaknesses for the Discounted Cash Flow and Real Options methods.

Real options modelling has been proposed as a better model for uncertainty in R&D investments. It has also gained support for application in defence business management. While there is a lack of literature characterising the unique elements of defence R&D investments for modelling as real options, we believe that the real options methodology could be extended to offer a holistic valuation for defence R&D investments. More importantly, a real-options-based approach would be a more holistic approach to defence R&D management since it considers the uncertainties and opportunities in the strategic investments in defence R&D. The rest of this paper attempts to propose a preliminary framework for a real-options-based approach to defence R&D management.

A PRELIMINARY FRAMEWORK

Objectives of the framework

The framework aims to support the strategic objectives of defence R&D investments to meet our specific requirements and fighting concepts. The investments also aim to develop the capability to customise and improve elements of our weapons systems to give our forces an edge (Singapore Minister of Defence, 2006). These objectives would require investments to develop capability for hardware assets and strategic development in the organisational capability and human capital. The investment strategy must also consider the varying level of uncertainty and expected payoffs of the R&D investments.

The simple framework in Figure 2 illustrates the possible influence from integrating two of the many dimensions of R&D investment strategy. The dimensions are the investment objective and uncertainty in R&D investments.

The current defence R&D management framework based on traditional valuation and management tools does not consider the systemic relationship adequately. A systemic and real-options-based approach is required to integrate the multiple dimensions and consider the expected payoffs and opportunities offered by the uncertain R&D investments.

Valuation

The definition of the currency for defence R&D management is crucial in the construction of the real options model. Measurement of the returns is essential to test the effectiveness of the real-options-based approach in maximising operational payoffs. Since the ultimate objective of technological options is to generate operational payoffs, the returns for real options could be based on an estimate of operational payoffs.

For example, Housel (2003) proposed estimating the returns by the number of targets killed.

The real options model also needs to consider the multiple objectives of the defence R&D investment including the delivery of operational payoffs through technologically improved military capabilities embedded in the hardware assets as well as the development of strategic technological capabilities embedded in intellectual capital. From the life cycle perspective of research, development and deployment, the knowledge developed through R&D is embodied in technological options and in the people. The technological options can be exercised to improve military capabilities in the hardware assets. The human capital created provides the option to create more technological options subsequently. These are compound options with options embedded in every research scientist and engineer trained through strategic R&D investments.

The capabilities embedded in hardware assets generate operational payoffs. These payoffs are direct and explicit and the investment can be modelled using a Margrabe exchange option. The strategic capability development of human capital is more indirect and tacit. This investment requires the characterisation of uncertainty, time horizon and payoff for modelling in a more complex American sequential option.

Intellectual and human capital

The relative value of assets is changing in the new knowledge-enabled economy. The capital market appears to value intangible assets like intellectual capital more than traditional hardware assets in the new economy. Approximately 83% of the collective market value of all publicly traded companies in the Standard & Poor's (S&P) 500 index is now attributable to intangible assets. As the defence forces transform to compete in the new

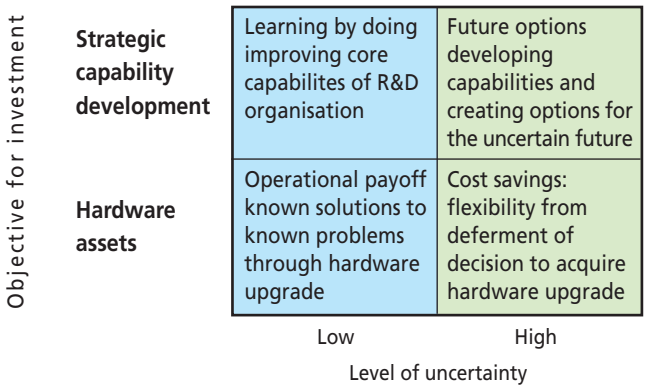

Figure 2. Possible influence of investment objectives and uncertainties in R&D investments on R&D investment strategies

economy, intellectual capital could also become the key lever to derive competitive advantage for the defence forces.

While the capability options created by a commercial firm would form the firm's capabilities, the capabilities options created by defence R&D form the defence capability of the defence force. Kogut and Kulatilaka (2001) argue that the firm's capabilities reside in core competencies and prepare the firm for market uncertainties. Similarly, the human capital created through defence R&D improves the core capabilities of the R&D organisation with which the organisation can capitalise to generate more technological options. Hence, this capability to create is a compound option. Miller and Morris (1999) argue that this capability is crucial for exploring unknown possibilities and latent needs of the future. The defence R&D human capital would offer us a competitive advantage as they can provide leverage for technological innovations for the defence forces in a competitive and uncertain future.

Portfolio management

Defence R&D investments do not exist in isolation. The portfolio of investments creates a portfolio of technological and capability options. An R&D investment can be modelled as a technology option and the investment portfolio as a portfolio of technology options. This approach is more than just a different method of putting a value on R&D projects. It encompasses adopting a new Options Thinking (Brown and Olmsted, 2003) strategy in managing a portfolio of R&D projects to optimise the portfolio value.

The defence R&D investment portfolio of options is characterised by different time horizons, returns and uncertainties. The systemic relationship among the options also varies in complexity and interdependence. Hence, the portfolio option must be managed holistically to achieve:

1. Optimal return for investments
2. Balanced portfolio of investments in short-term and low-risk projects and long-term and high-risk projects.
3. Alignment of portfolio to strategic defence interests.

NEXT STEPS

The real options approach is theoretically more attractive than traditional valuation methods in modelling and managing the efficiency of defence R&D investments. Despite its theoretical appeal, however, real options valuation has yet to take root in practice. Implementation challenges include the efficacy of the assumptions underlying the standard model. Additionally, the estimation of several of the input parameters that are needed in the model is a less than trivial exercise. Real options valuation has also been criticised as being inferior to traditional methods like decision tree analysis. There are also gaps in the body of knowledge of real options theory (Tong and Reuer, 2007). These implementation challenges must be resolved ahead of developing a real-options-based framework to improve the strategic management of public R&D investments.

CONCLUSION

Optimal returns for defence R&D investments necessitate portfolio management based on an accurate model for the investments. We propose a preliminary framework for a systems and real-options-based approach. This approach integrates the strategic considerations and better models the defence R&D investments especially the opportunities generated in the technology options and the compound options generated in the human capital created through the R&D technological capability development. The enhanced framework would improve the management of defence R&D investments to achieve more efficient strategic investments and gain a competitive advantage through innovation in the uncertain future.

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