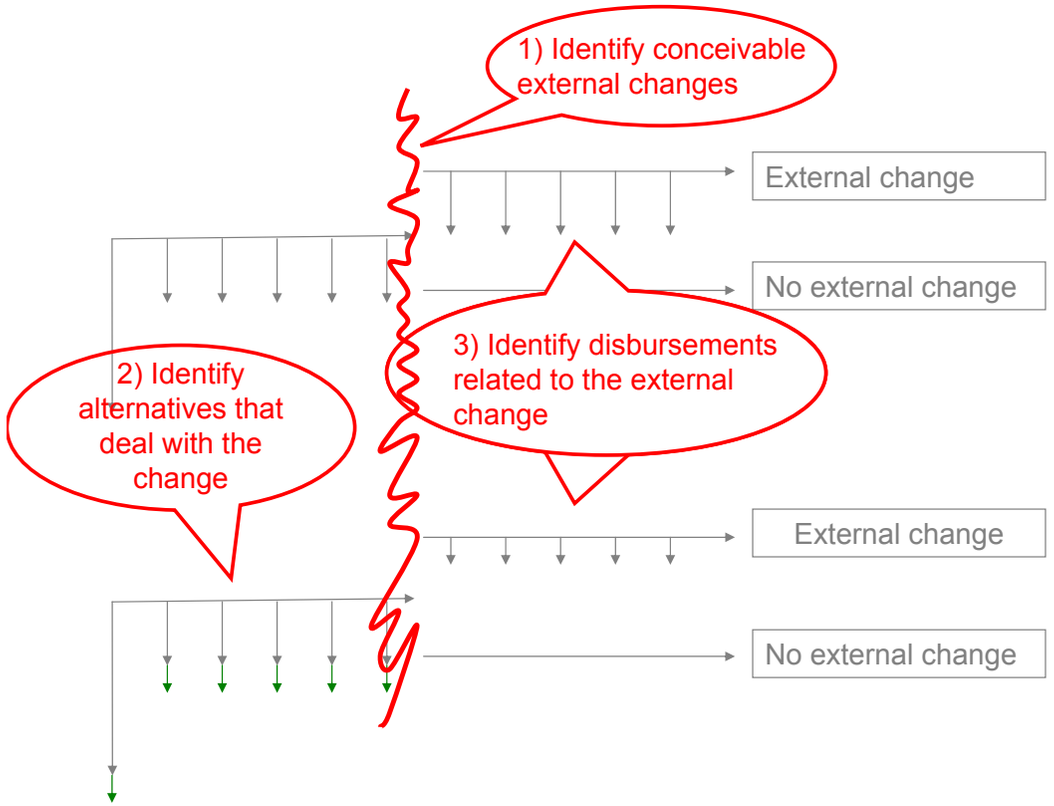
Investments in flexibility
Dealing with an uncertain future

MARIA HEDVALL



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Summary

Within the framework of the Swedish Armed Forces investment in Strategic Research Cores, the Swedish Defence Research Agency has been commissioned to develop a capital budget that takes explicit account of uncertainties. Such capital budgets become particularly interesting in conjunction with decisions regarding large-scale, irreversible investments where there is an underlying risk that external changes could make the investment unusable.

In 2008, the study focused on commencing the development of a capital budget that could be used to evaluate whether investments in flexibility were worthwhile when the Swedish Armed Forces were faced with making a large-scale, irreversible investment. With this purpose in mind, civil, capital-intensive companies and other military authorities were asked about how they appraise investment proposals. An initial conclusion is that military authorities appear to lack the structure and standardisation that characterise the investment processes at the civil companies. A second conclusion is that net present value computations are used – in one case a method is used to take into account the consequential costs generated by integrated systems. A third conclusion is that flexibility appraisals ought to be made for large-scale investments.

It is therefore recommended that the Swedish Armed Forces

- create the methods and processes necessary to make a standardised appraisal of large-scale investments,
- take into account the consequential costs that derive from, among other things, integration with other systems,
- evaluate flexibility, when necessary, in conjunction with investment decisions.

Keywords: capital budget, flexibility, risk, uncertainty, investment process

Contents

1 Summary introduction

1.1 Assignment, purpose and method

Within the framework of the Swedish Armed Forces investment in Strategic Research Cores the Swedish Defence Research Agency has been commissioned to develop a capital budget that takes explicit account of flexibility. Capital budgets for putting a value on flexibility are of particular interest in conjunction with decisions dealing with major irreversible investments, i.e. investments which do not have any alternative use in the event of an external change. This report is a final report and therefore partly overlaps with other reports in the project.

In 2008, the focus of the study – which had been in progress for three years[1] – was on commencing the development of a tool which the Swedish Armed Forces could use in its investment appraisals. To this end, civil, capital-intensive companies and other military authorities were asked how they appraise investment proposals. The civil companies, SL (Stockholm Public Transport) and Vattenfall, were interviewed about decision processes, capital budgets and handling uncertainties. The Danish, Dutch, Norwegian, Swiss and British military authorities were approached through the Swedish Defence attachés. Norway did not reply and Switzerland's reply did not contain anything about investment appraisals. Information from the other military authorities varies but did not go into any great depth and they have therefore been supplemented with literature studies. The project also included involvement in a military authority study to examine the potential for making a flexibility appraisal.

1.2 Recommendations

It would appear that the Swedish Armed Forces – in line with the armed forces in other countries – lack homogeneous methods and processes for appraising investments. It is therefore recommended that the Armed Forces:

- create the methods and processes necessary to make a standardised appraisal of major investments,

[1] The aim of this project has been to develop a capital budget that takes explicit account of uncertainties and to attempt to assess the consequences of uncertainties in the various stages of an investment (sequential investment). In 2006, a study was made of how the value of deferring an investment can be calculated (Hedvall [2006]). In 2007, an examination was made of the real option approach for research and development planning (Henrik Carlsen [2006]) as well as a study of how the value of investing in research and development could be calculated (Hedvall [2007]).

- take into account the consequential costs that derive from, among other things, integration with other systems,
- evaluate flexibility, when necessary, in conjunction with investment decisions.

Alongside the creation of methods and processes for appraising major investments, a system ought to be produced to standardise documentation of the investment proposals presented. One alternative could be the use of a data book. Vattenfall makes use of such a book. Another alternative could be the British MoD's COEIA (Combined Operational Effectiveness and Investment Appraisal). These methods are examined further on pages 24 and 26 of this report. The use of CVA (Cash Value Added, page 23 in this report) can be used to identify and take into account consequential costs that arise in conjunction with, among other things, integration with other systems. Vattenfall makes use of both the data book and a CVA analysis in its investment process. It is also important that those responsible for collating investment data have the requisite financial and technical expertise to generate alternatives and to appraise flexibility.

1.3 Arrangement

The report is arranged in such a way that Chapter 2 provides a background to irreversible investments along with a method for calculating the value of flexibility. In Chapter 3, examples are given of how companies and military authorities prepare capital budgets. In Chapter 4, there is a description of how the Swedish Armed Forces make an investment appraisal and in Chapter 5, conclusions are drawn from previous descriptions and recommendations are made regarding the subsequent work of the Swedish Armed Forces in making investment appraisals.

My sincere thanks to Henrik Andersson, Stockholm School of Economics, who has examined this report and contributed valuable opinions. My special thanks also to Owe Sandin (Asset Manager, Vattenfall) and Helena Sjöberg (Investment Controller, Stockholm Public Transport) who have made this study possible. Owe Sandin and Helena Sjöberg have also examined the sections dealing with Vattenfall and Stockholm Public Transport. At FOI, Anders Almén, Göran Kindvall, Erik Nordstrand, Bo Tarras Wahlberg and Åke Wiss have contributed their views. Peter Sturesson (Air Combat Training School, Air Combat Development Unit) has contributed to and examined an earlier section dealing with ISTAR. Annika Sundholm Parkdal has – as always – been responsible for the layout. Thank you!

2 Capital budgets that appraise flexibility

Capital budgets are used when investors are required to reach decisions that will have long-term cost implications. Normally, a calculation is made to estimate the profitability of an investment. However, capital budgets can also be used more specifically to calculate the value of investing in flexibility, i.e. to invest in further measures to facilitate adaptation of an investment to changes in external conditions. If, for example, a calculation had been made from the outset that the aircraft JAS 39 Gripen – which was developed for invasion defence – would be deployed for operational defence, major redesign costs, including mid-air fuelling – could have been avoided. By avoiding these costs, the Swedish Armed Forces could have freed up resources that perhaps could have been used for further training.

Investing in flexibility becomes particularly interesting if the investment is large-scale, does not have any alternative use – is irreversible – and the future is uncertain (Pindyck [2007]). If the investment has an alternative use there is always a second-hand market on which it can be sold if it can no longer be used for a certain type of operation. As irreversibility and uncertainty (in essence risk) are key concepts in this report, the chapter commences by demonstrating the complexity of these concepts. There then follows a description of how real options – the reason for this project – are used in practice. There then follows a description of the nature of flexibility depending on the type of investment to be made. In the final section of the chapter a more methodological approach is provided for evaluating and choosing between irreversible investments in an uncertain world.

2.1 Irreversibilities, uncertainties and their appraisal

> *This paper offers no easy formulas or solutions for treating uncertainty – to my knowledge, none exist. Instead, I try to clarify the ways in which various kinds of uncertainties will affect optimal policy design, and summarize what we know and don't know about the problem.*
>
> *Pindyck [2007]*

With the above quotation, Pindyck [2007] introduces an article on uncertainties in environmental economics. In a world without uncertainty it is simply a matter of totalling the receipts and disbursements in an investment and discounting the amounts to a net present value. If the result is positive the investment is made and if it is negative the investment is not made. In reality, a whole series of different uncertainties exist that could have an impact on the result of a net present value calculation. These uncertainties could have serious negative implications if an investment is irreversible. Using Pindyck [2007] as a starting point, there is a discussion about what is meant by irreversibility and uncertainty.

2.1.1 Irreversibilities – a question of effect or cost

In the broad sense, irreversibility refers to something which once it is done cannot be undone. Pindyck [2007] focuses on environmental economics and speaks about two types of irreversibility: irreversible effect and irreversible investment cost. To exemplify irreversible effects, Pindyck quotes environmental damage, e.g. air and water are polluted in such a way that future generations are denied clean air and clean water for ever. However, the cost of rectifying environmental damage could also be irreversible (the second type of irreversibility), i.e. non-recurring costs to invest in purification facilities and/or ongoing additional costs for more expensive production methods. According to Pindyck, these costs cannot be recouped if in a future society little value is attached to clean air and clean water.

2.1.2 Uncertainty about the effect, benefit and costs generated by an irreversible investment

Putting a value on investments in flexibility (i.e. measures to deal with external changes) is only of interest if an investment is irreversible and made in a state of uncertainty. If an investment is irreversible at the same time that we know for certain what will occur externally, it is simply a case of calculating the net present value of future payment flows in order to determine whether the investment is profitable. If it had been an irrefutable fact that Sweden would have an invasion defence for the next 50 years then the discussion regarding additional costs to redesign the aircraft JAS 39 Gripen for an operational defence would have been superfluous. The basis for making a flexibility calculation would not have existed. Irreversibility only becomes a problem when the future value of the investment is uncertain. If an investment of SEK 1 billion in the future proves to be unusable this is the same as if that investment had made some other activity

impossible. The billion kronor could perhaps have been used for more military training time (as stated above), for improved education, improved health care or for some other purpose.

What forms of uncertainty could thus affect an investment? Pindyck [2007] speaks about uncertainty with regard to effect/benefit in relation to costs and in relation to the discount rate. From now on only the uncertainties regarding effect/benefit and costs will be discussed.

2.1.3 Uncertainty regarding effect/benefit

> *"[…] we never really know what the benefits from reduced environmental damage will be, or even the amount that the environmental damage will be reduced by a particular policy. Worse yet, we can't know with much precision what those benefits will be".*
>
> *Pindyck [2007]*

In the above quotation, Pindyck [2007] refers to the fact that very little is known about the effects of environmental policy on global warming – despite extensive studies. It is not known what impact an environmental policy would have as the true magnitude of greenhouse gases in the future is not known. Nor is it known how quickly the concentration of gases would grow given these emissions, how high concentrations affect global temperatures or how higher temperatures would affect benefit. Furthermore, there is uncertainty about dependencies between underlying physical and ecological processes and how these dependencies, coupled with other uncertainties, affect the benefits. The term 'benefit' thus refers to how changes in climate (through fiscal or production restrictions) affect health, consumer and producer surplus as well as other public goods and production. What complicates uncertainty even further is that the benefit function tends to be non-linear: low pollution levels are not noted but on passing a certain threshold the pollutants could be catastrophic.

2.1.4 Uncertainty regarding costs

> *"[…] we usually don't know what the current and future costs of a policy will be. […] we don't know how consumers and producers will respond, especially over the longer term".*
>
> *Pindyck [2007]*

Generally, more is known about the uncertainties associated with costs – particularly when the time horizons are short – than about the uncertainties associated with benefit. Despite this, it is difficult – particularly in the long-term – to predict how sensitive purchasers are at present and how sensitive they will be when faced with a price increase (caused by tax on fossil fuels). Sensitivity also varies between sectors.

Moreover, the cost function is non-linear: the cost could be low for small reductions in pollutants but would then be extremely high when major pollutants are to be reduced or eliminated.

In addition to the above-mentioned uncertainties in benefits and costs, there are other uncertainties which could affect an environmental decision. Such uncertainties include future demography, changes in income as well as changes in policies and technology. The major uncertainty factor, however, appears to be time. A long time horizon increases uncertainty about what benefits and costs ensue from a particular decision. It is difficult enough to predict the consequences of a decision over the next 5-10 years. The uncertainties are far greater when the time horizon is 50 years.

2.1.5 The impact of irreversibility and uncertainty on defence equipment investments

The above thoughts about irreversibility can to some extent be transferred to the defence sector. As in environmental economics, it is possible in defence economics to talk about two irreversibilities – in benefit/effect and in cost. If no resources are invested in defence, a country could be invaded at no great cost to the hostile nation. The possibility for the invaded country to regain its sovereignty could be lost to future generations (the first type of irreversibility). However, investments in defence capacity could lead to outgoings that do not generate any benefit should the threat change (the second type of irreversibility). Subsequently, alternative investment opportunities are lost. In this project it is mainly the latter type of irreversibility that is of interest.

Pindyck's reasoning regarding uncertainties ought to have a bearing on defence economics. The benefit, the actual effect of the defence equipment investment, is difficult to predict and the benefit function is probably not linear: it is when a threshold is reached that the benefit of the defence investment materialises (in this context defence equipment investment as a deterrent is not taken into account). If we examine the cost, it is mainly the uncertainty about what the defence equipment is to be used for (defending Sweden or a campaign in Africa or Asia?) that is of interest. The equipment acquired for a mission in Africa could

be unusable if the actual initiatives take place in Asia and if that were to be the case other important investments would have been pushed aside. What ought to be emphasised in the final analysis is that uncertainty increases with time – the longer the period of time it is envisaged the defence equipment will be used the greater the uncertainty about how usable it will be. Will a certain type of equipment acquired today be capable of countering a threat in 20 years? Irrespective of upgrades?

These are the similarities but there are also at least two differences. The first difference is that Pindyck's essay is related to environmental economics and this project is related to defence economics. The second is that Pindyck puts forward a social cost-benefit line of argument whilst the discussion here is about defence economics. These differences, however, do not affect the reasoning regarding irreversibility and uncertainty and thus the need to create flexibility.

2.2 Real options and how they have been used

The original aim of this project was to attempt to utilise the option theory approach, which came to be known as real options and which enabled the value of deferring an investment to be calculated. The idea behind the option approach was that it should be possible to deal with the uncertainties related to major irreversible investments. It was thought then that this approach would have a major impact on investment appraisals. This section therefore describes what actually happened.

In 2000, the consultants Bain & Company conducted a survey covering 451 high-ranking managers at more than 30 companies. The managers were asked which of a series of 25 management tools they used. In 2000, real options came bottom of the list. Almost 50 per cent of the North American companies that were asked had experimented with real options but gave up: "Some tools seem to exasperate those who try to use them". One possible explanation for why potential users were irritated with the method was that it was too abstract (Gillies [2000]). When Bain's survey was repeated in 2003, real options had disappeared from the list (Teach [2003]) and has yet to return[2].

In 2000, another survey was published which supported Bain & Company's results from the same year. The survey included "Fortune 1000 Chief Financial Officers" and showed that chief financial officers mainly used net present value

[2] See http://www.bain.com/management_tools/Management_Tools_and_Trends_2007.pdf

calculations as a basis for investment decisions. Real options only appeared as a complementary method and did so in only 11 per cent of the cases (Ryan [2002]).

Real option theory was regarded as revolutionary when it first appeared. A considerable number of academic works have been published which describe the approach and in every standard work on financing there is at least one chapter dealing with real options (BrealeyMyers [2003, Chapter 22]). Why then is option theory not used to a greater extent to calculate the profitability of real investments? According to Teach [2003] the approach was considered to have at least four shortcomings:

1. It is neither transparent nor simple[3],
2. It only works for assets that can be traded in
3. It is too new as a tool
4. It does not take into account how company management teams work.

Teach continues, however, by stating that the real options view also offers benefits, albeit on a fundamental level: in the option approach there is an emphasis on the importance of acquiring further information to improve the basis for making a decision prior to a major irreversible and uncertain investment. This approach concurs with how decision-makers actually think: what could happen and if so how should we react. If it were to emerge that they did not think in that way the usual response, if the approach were to be presented to them, is: "Yes, that's the way you should think" (Teach [2003]). The alternative cost thinking initiated by real option theory has been lacking in traditional net present value calculation.

Real options as a calculation tool has thus not had any great impact (it can be pointed out in this context that it took a number of years before net present value calculation gained acceptance). However, Dixit and Pindyck [1994] also show that net present value calculations can be used to calculate the value of deferring an investment. It is the net present value approach that is used in this study. In the next section – based on Trigeorgis [1996] – different types of investment in flexibility are presented.

[3] A parallel can be drawn with the occurrence of more and more advanced and complicated financial instruments; "Not just heads of Central Banks and supervisory authorities but also the owners and management teams at finance companies and rating institutes have been forced to admit that they do not know the true nature of the risk or how the actual product is designed (Rossander [2008]).

2.3 Investments in flexibility

The external world can thus change in a way that a decision-maker is unable to predict when an investment decision needs to be made. If it emerges that the investment cannot be used other than for the purpose originally envisaged there is a tangible risk that it will become worthless in the event of an external change. This is why decision-makers could be willing to pay for flexibility, i.e. the opportunity to be able to adapt the investment to a drastic change in external conditions.

In which situations could an investor need to invest in flexibility? To highlight when it could be advisable to invest in flexibility, Trigeorgis's [1996, Chapter 1] classifications are used, although in this case applied to military authority investments:

1. The military authority could defer an investment in order to gather more information (option to defer),
2. The military authority could make an investment in stages in order to discontinue the investment should external conditions change (time-to-build option),
3. The military authority invests in such a way that production volume can be changed (option to alter the operating scale, e.g. to expand, contract, shut down and restart),
4. The military authority invests in such a way that the equipment can be sold on the second-hand market (option to abandon for salvage),
5. The military authority invests – in suppliers and production equipment – in such a way that there is the option to change either input or output in the event of a change in external conditions (option to switch),
6. The military authority makes early investments in, for example, research and development in order to be able to make further investments if necessary (corporate growth options).

In Hedvall [2007, page 12 ff.] these six categories were regrouped into a) investments in potential, b) investments in flexible equipment/equipment and c) deferral of investments. The idea behind this division is that each of the categories has a calculation to work out whether it is viable to invest in flexibility in order to handle an external change. Investments in potential are characterised, for example, by the fact that know-how should exist should the external situation change markedly; investments in flexible equipment are characterised by the possibility of adapting a certain item of equipment to external changes; deferring an investment could make it possible to gather further information in order to make an improved investment appraisal. The models for calculating whether it is

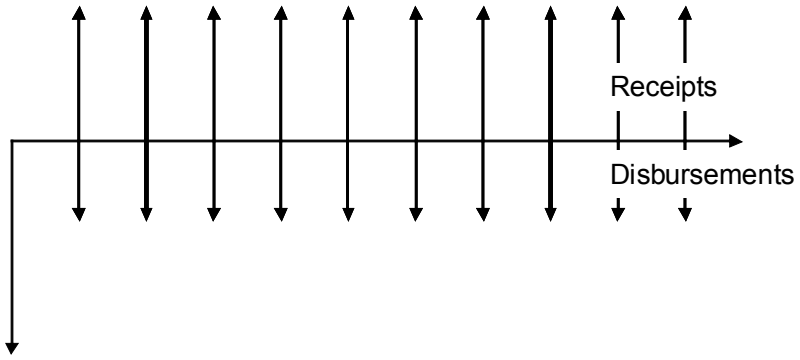
defer an investment or to invest in potential is presented in Hedvall [2006 and 2007]. There follows a description of how the calculations will be made for investment in equipment (alternative b in the above classification).

2.4 Method

How is the value of investing in flexibility calculated when irreversible equipment is procured? How is it possible to calculate whether it is advantageous to make supplementary investments in order to be able to use an item of equipment for purposes other than was originally intended? In simple terms: the difference between all future receipts and disbursements is calculated and discounted for an irreversible investment and compared with the corresponding difference for the flexibility alternative. In the flexibility alternative the original irreversible investment is supplemented by further investments in measures designed to deal with future uncertainties. Let us begin, however, with how the net present value was calculated for a reversible and safe investment and in doing so demonstrate why this calculation could be erroneous when asymmetrical uncertainties occur[4].

In the net present value calculation the difference between all future receipts and disbursements is calculated for an investment, see *Figure 1*. If the difference is positive, the investment should be made. If it is negative the investment should not be made.

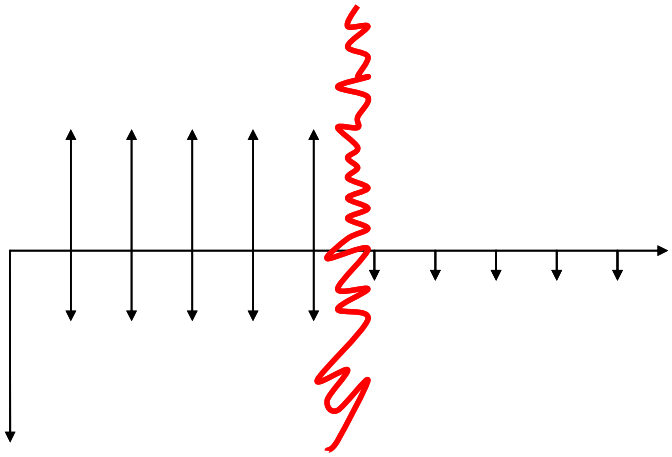
Figure 1: Net present value calculation



[4] Henrik Andersson HHS has pointed out that in effect the common net present value calculation deals with uncertainty by raising the discount rate. This uncertainty, however, is symmetrically arranged around a value. The problem arises when the risk is asymmetrical: something could occur that cannot be corrected.

In this type of net present value calculation no account is taken of the fact that certain investments are tailored to a certain purpose and cannot be used for other purposes. If an external change were to occur, then in effect the payment flows could be as shown in *Figure 2*. The external change is marked using the red 'line'. Compared to *Figure 1*, the company loses receipts for the last five years of the investment – the market has disappeared. A large proportion of the receipts also disappear but it is conceivable that the company has signed a lease agreement for ten years and the costs for this agreement still remain despite the fact that the investment has proved to be worthless. Adding up the receipts shows that the investment represents a loss for the company.

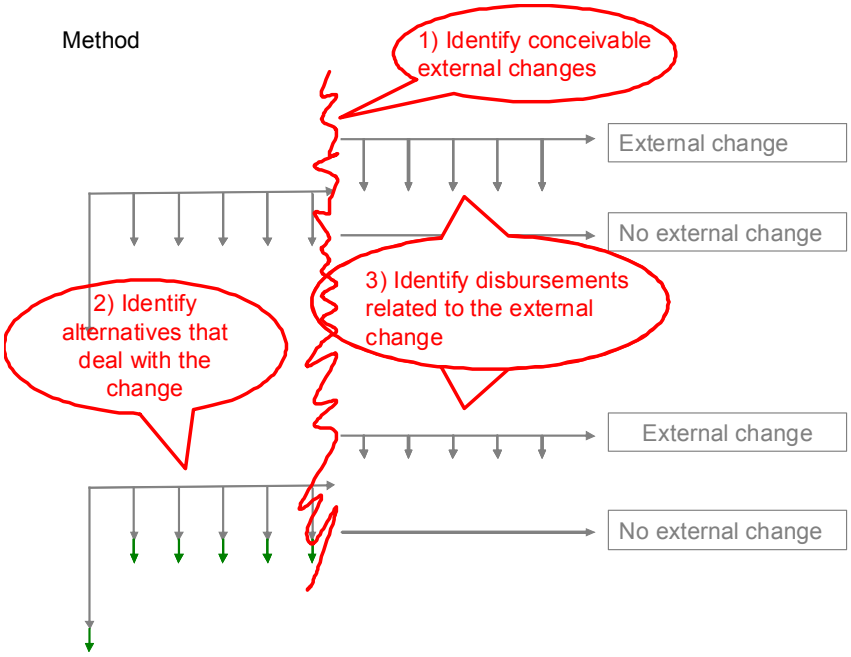
Figure 2: If an external change occurs...



The question that arises is how the decision-maker safeguards against such external changes when faced with making a large-scale, irreversible investment[5]. Is it worth investing in flexibility as an insurance against uncertainty? *Figure 3* shows schematically an approach to calculating whether an investment in flexibility is beneficial.

[5] Here the alternative of making a reversible investment can be taken into account although at the moment we are working on the assumption that the company is faced with a choice between making an irreversible investment without flexibility and an irreversible investment with flexibility.

Figure 3: New calculation method



The calculations are thus made in three stages:

1. Identified possible external changes that could foil the investment (examples of external changes include political actions, threats or other actions),
2. Identify alternatives that could deal with external changes. JAS 39 can be used as an example. JAS 39 was not built for mid-air refuelling but with new assignments it must be capable of flying longer distances and must therefore be upgraded to facilitate mid-air refuelling. What would the savings have been if the alternative of mid-air refuelling had been taken into account from the outset?
3. Identify the payments associated with different external scenarios. The payments are taken into account in two periods[6]. In the first period payments are identified and calculated before an external change. In the second period account is taken of the possibility that an external change could occur. The payments linked to an external change and no external change are identified and evaluated and are then subsequently considered together with the probabilities.

[6] Limiting the time to two periods is a simplification used by Kolstad [1996] in his studies on irreversibility.

In *Figure 3* only the benefits that are derived from supplementary investments in flexibility are shown. Should an external change take place these benefits will be needed. In the upper alternative, however, the cost will be greater than in the lower alternative as no investment in flexibility has been made. For the sake of clarity, only the additional costs for adaptation have been incorporated for an external change and for no external change.

Dixit and Pindyck [1994] examined the value of deferring an investment. The aim of deferral was to acquire more information in order to assess whether the investment would be of benefit. In this project the author has expanded investment in flexibility to include investment in supplementary attributes that an investor makes to safeguard an irreversible investment against possible external changes.

3 Examples of investment appraisals

How is uncertainty handled by commercial companies and other military authorities when they make their investment appraisals? In this chapter we deal with how capital-intensive companies such as SL (Stockholm Public Transport) and Vattenfall make their investment appraisals. The reason for describing SL's and Vattenfall's investment appraisals is that these companies have refined investment processes and investment tools for the purpose of ensuring that the processes and tools are as cost-effective as possible. After the presentations of SL and Vattenfall there is a description of investment appraisals made by military authorities, particularly in the UK but also in Denmark, the Netherlands and Switzerland. In all cases the aim has been for the descriptions to include both the decision-making processes as well as investment appraisals. The reason for attempting to describe the decision-making processes is that an investment calculation/appraisal does not exist in a vacuum: to ensure the best possible basis and for it to be of greatest possible benefit, the investment appraisal must be placed in an organisational context.

3.1 Commercial investment processes – SL and Vattenfall as examples

Characteristic of both SL and Vattenfall is that their operations are very capital-intensive. In this way they are very reminiscent of Swedish Armed Forces' equipment procurement. The section about SL is based on an interview with Helena Söderberg (Investment Controller). The section about Vattenfall is based on interviews with Owe Sandin (Asset Manager) and Jonas Sjölander (Senior Consultant).

3.1.1 SL (Stockholm Public Transport)

SL invests around SEK 3 billion each year (one-sixth of the Swedish Armed Forces' equipment budget). The investments normally take the form of replacement investments: vehicles, tracks and depots that need to be replaced when they have become worn out. SL has a matrix-based area structure comprising Technical areas and Types of traffic[7]. The technical areas are Track, Vehicle, Properties (stations etc.), Electro (electrical and signal systems) and IT. Each of

[7] The types of traffic are underground, bus, commuter train and local lines.

these technical areas prepares an investment plan which is then incorporated into an overall investment plan.

Decision-making process

SL's investment requirements arise primarily when infrastructure (tracks, vehicles, station equipment etc.) needs to be replaced. Completely new investment requirements could arise when, for example, new areas are populated. This could generate a need for new bus routes and new land for terminuses. In this case the municipal authority and/or the rail administration initiate new investments.

Let us assume that SL needs to invest in a new commuter train. The process is set in motion by SL's engineers preparing a demand specification to determine the type of commuter train required. As the engineers are in contact with vehicle suppliers, primarily in Europe, they know the types of vehicles that are available and which technology works. When making this type of investment decision the services of external consultants with specialist knowledge (which may be required for the electronics for example) could be employed.

For the demand specification, SL has two points of departure. The first is based on the equipment currently available. In this case this refers to available tracks, depots etc. The other point of departure is needs, such as the demand for toilets for the disabled, speed, timetables, frequency, how much the vehicles will be used and comfort.

SL's board decides on procurement when the board has received a demand specification for the object together with a cost estimate (which could be based on the cost of recent deliveries in Europe). The procurement decision is followed by the tender phase. The department responsible for the investment (Track, Vehicle, Properties, Electro or IT) is also assigned responsibility for the procurement, i.e. evaluating the tenders. The tenders are evaluated by technicians with regard to technical considerations, by the track unit with regard to traffic considerations and by economists with regard to cost. Sometimes evaluations are also made regarding depots.

Investment appraisal

A starting point for SL's investments is to procure tried and tested technology: they should be at the forefront in technology but not the leader. The reinvestment and maintenance required to maintain the standard of the infrastructure is what is prioritised in SL's budget instructions.

An investment calculation covers the cost of vehicles (objects with supplements), as well as a delivery plan (monthly). In certain cases the calculation could also include an option. The fifty-five X60 commuter trains, for example, were procured with an option to order further vehicles within two years. In that case the supplier has the opportunity to use the production equipment that has already been set up. Normally, a few vehicles are delivered during the first year or during the first two years. The vehicles then go into series production. SL therefore has two prices: one for the preliminary series and one for when the vehicles are in series production.

SL's investment calculation is made with the aid of an Excel model. In the calculation, planned disbursements are totalled and discounted. It is when the delivery plans differ between suppliers that net present value calculations have an impact. The former case (early delivery of vehicles) produces a more expensive outcome than an even flow over time. *Table 1* provides an example of what a calculation could contain.

Table 1: Fictitious example of an investment calculation for vehicles

Object		Month 1	Month 2	Month 3	Month 4
Vehicle	Unit price/Preliminary series				
	Unit price/Series				
Supplements	Adaptation for the disabled				
	Wheelchair ramp				
	Special tools/toolboxes				
	Depots				
Total					
Net present value-calculated total					

SL uses this type of calculation to evaluate tenders submitted by different suppliers. The tenders could differ and probably differ with regard to individual components, such as toolboxes. For the comparison to be as impartial as possible, consultants are contacted to evaluate, for example, the toolboxes provided by different suppliers.

The above example is an example of **choice between suppliers**. The choice could, however, be between keeping the existing vehicles and acquiring new vehicles. Although it is not profitable to keep all vehicles that have come to the end of their economic life, a new investment includes more than just replacing an old vehicle. There is a degree of dependence between vehicle, track and other technology that causes a new investment to generate consequential investments – in rails and tracks for example. For climate reasons (to avoid them freezing during the winter) and to make it easier to repair, the technical equipment on SL's new commuter trains is placed on the roof. A consequence of this design is the need for a new depot (which involves an investment costing billions) where the vehicles can be repaired and maintained. Such considerations must be included in the original investment decision as well as the cost implications of using new technology. However, not everything is possible to predict in an investment decision. When the depot was built it emerged that another track was needed to drive the vehicles in and out. The depot was built in such a way that this extra track could be built without any major changes.

Comment

Similar to the Swedish Armed Forces, SL is capital-intensive. Likewise, the investments have a long lifespan, approximately 30 years. On the other hand, SL's investments are not marked by the uncertainty that characterises the investments made by the Swedish Armed Forces: SL's investments are initiated by the need to replace carriages, vehicles and buses that have reached the end of their technical life. Consequently, appraisal of investments and flexibility – in SL's case in potential and equipment – does not appear to be of particular interest as far as SL is concerned.

It is worth observing how investment appraisals are made by a team comprising economists and technical experts (who among other things list demand specifications and take into account both technical and system aspects). Also worth noting is the use of investment calculations (see *Table 1*), which includes a list of the consequential costs of a new investment, such as the need for new depots.

3.1.2 Electricity production, Nordic region – Vattenfall's Nordic division

In 2007, Vattenfall invested over SEK 10 billion in the Nordic region: SEK 7 billion in reinvestment and almost SEK 4 billion in new investments (Vattenfall Annual Report [2007]). In Sweden, Vattenfall invested primarily in upgrades and lifetime extensions of existing production facilities (reinvestment). The following description of an investment process and investment appraisal refers to

Vattenfall's Nordic division, i.e. Electricity Production, Nordic Region. In the future, the term Vattenfall is used synonymously with Electricity Production Nordic Region.

Decision-making process

The starting point for Vattenfall's investment process is the production volume required for Vattenfall to achieve its long-term objectives. To realise this objective, i.e. the production volume, a number of measures are required and it is these measures that will determine Vattenfall's investment strategy for the coming 10 years. Based on a capacity and investment strategy, a dialogue is conducted between the central management (Asset Management) for a production area (e.g. nuclear power) and the production facilities. During the course of these dialogues the investment strategy is broken down to Vattenfall's individual production companies, which make an appraisal of the investments that are to be made. The production companies' investment appraisals are then given to the central unit responsible for investment planning, which makes a collective appraisal and prioritisation of the facilities' investment plans. The dialogue is concluded with Vattenfall's Board of Directors (for the whole Company) reaching a decision on the annual investment programme, which will subsequently form the basis for determining the size of the budget each production company will be allocated. The heads of the production facilities are then responsible for ensuring that the investments are implemented and that they are implemented profitably.

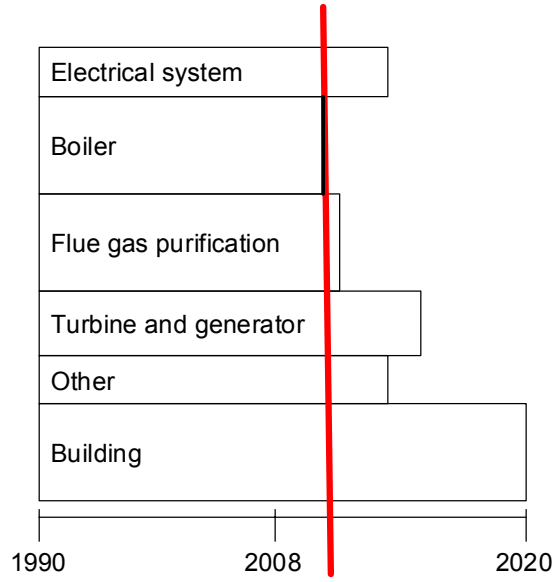
Important elements in this investment process are that the investment appraisals are delegated to the production companies and that the appraisals are conducted uniformly. The investment appraisals are delegated to the production companies as it is the production companies that are familiar with operations and the specific cost-drivers in the various investments. Standardised preparation and presentation of the appraisals is important if the Board of Directors is to be able to reach a decision based on comparable documentation. The underlying documentation for an investment proposal includes a (well-structured) memo and presentation documents in the form of PowerPoint images. The memo should include a description of what is to be done, the profitability of the investment and the recommendations.

Investment appraisal – lifetime limitations and Cash Value Added (CVA)

As costs vary depending on the type of power production, the calculations differ between nuclear power stations, hydro-electric power stations, wind power stations and heating plants. At the nuclear power stations, for example, safety is a cost-driver whilst flue gas purification is the factor above all else that generates costs at a heating plant. The technical lifespan for power facilities is mostly 20 years and it is the mechanical parts that are the limiting factor.

Vattenfall uses Life Cycle Cost as an analytical tool when appraising an investment in a completely new object, such as the purchase of a new power plant. However, many investments are aimed at extending the lifespan of existing operations and in that case it could be that only a certain part needs replacing and not the whole facility. In that case, Cash Value Added is used to determine when part of an existing facility or investment should be replaced. In *Figure 4* a heating plant is taken as a fictitious example.

Figure 4: Basis for a decision to extend the lifespan or not



An investment in a heating plant was made in 1990 with an envisaged lifespan of 30 years. The problem is that the electricity system at the heating plant has one lifespan, the boiler another lifespan, the flue gas purification system a third lifespan, the turbine a fourth and the rest of the system a fifth. In 2008, the investor was faced with making the first decision about whether to extend the life span of the boiler in 2010. To determine whether an investment in a new boiler

was worth making, a calculation must be made of the consequences for the electrical system, flue gas purification system, turbines etc. In this case the investment in a new boiler is set against the alternative of extending the life of the current boiler by renovating worn parts.

By way of conclusion it can be noted that Vattenfall documents its investment appraisals in a 'data book'. A note is made in the data book of all the assumptions that are made. The data book is used primarily to follow the investments, such as how well the forecast concurred with a certain price. The data book can also be used to evaluate new investment objects. The data book documentation also states the cost-drivers and the activities they generate.

Risk assessment

Vattenfall's Annual Report [2007 pages 70-73] contains a presentation of 11 different risks: political, operational, environmental, electricity price, facility, fuel price, investment, volume, price area, credit and currency risk. The investment risk refers to the risk of a loss if an investment falls in value due to a change in electricity prices or delays. Consequently, a risk analysis is made for each investment decision: the outcome is simulated for different changes in price, cost, delays, cost of capital and so on. Even if the human race will not cease to require electricity within the foreseeable future, Vattenfall makes assessments of how future electricity consumption will develop: how consumption will change as a result of improvements in energy efficiency (decrease), increased use of computers (increase), a reduction in the size of basic industry (decrease) etc. Vattenfall's assessment of future electricity consumption is reflected in its assessment of the electricity price trend on a deregulated market. As a result of changes in demand for electricity, Vattenfall is looking for new areas of use for electricity in households and in industry.

Managing the role of being a small player on a large international provider market

There are, however, more markets than the sales market i.e. the market where a company disposes of a product, which in Vattenfall's case is electricity. Vattenfall also procures resources. This is the market that will be dealt with in this section.

The growth in population and GNP will lead to demand for electricity outstripping the supply of electricity. This trend, combined with the fact that Vattenfall is a relatively small player on the international market, will have implications for Vattenfall's investments. Vattenfall's relatively small size creates problems for the simple reason that the major producers that invest regularly are more attractive to suppliers than small producers that seldom make investments.

Vattenfall invests, for example, in upgrading existing nuclear power stations. The suppliers of this type of equipment also receive orders for new nuclear power stations – in China for example. The Chinese market, for obvious reasons, offers far greater potential than the Swedish market. For a nuclear power station supplier it is therefore of more interest to supply turbines continuously to a large growing market instead of individual turbines to a market that only needs to renew its power stations. It is therefore important for the marginal purchaser to create incentives for the supplier other than continuous procurement. One way of doing so could be to offer know-how that is of interest to the supplier and which provides the supplier with good references on other markets.

Comment

Similar to SL and the Swedish Armed Forces, Vattenfall is capital-intensive with investments that need to last for decades. Particularly with regard to SL, but also with regard to Vattenfall, the investments are characterised by safety: the people of Stockholm will need transport and the population generally will need electricity. A situation where transport and power stations are superfluous is unlikely. This is where both SL and Vattenfall differ from the Swedish Armed Forces, whose investments could be unusable depending on the threat that arises and where it arises (the potential deterrent effect of an investment is not taken into account here). This does not prevent SL and Vattenfall from encountering other uncertainties, such as rules and regulations, which could give rise to unforeseen costs.

Similar to SL – and as opposed to the Swedish Armed Forces – Vattenfall's investment process can be characterised as decentralised: the investment appraisals are made at the production facilities, which are considered to have the experts required to make the appraisals. Vattenfall – like SL – has standard procedures for producing comparable investment proposals.

Similar to SL, Vattenfall analyses whether a replacement investment is profitable or not. Vattenfall uses the analytical tool Cash Value Added to calculate the cost implications a replacement investment could have on other parts of the system.

3.2 Investment appraisals by the British, Danish and Dutch Armed Forces

The purpose of this section is to present how other countries' armed forces reach decisions regarding irreversible investments – the way they take risk into account and what calculations form the basis for investment decisions. To obtain these accounts, the armed forces attachés for the United Kingdom, Denmark, the

Netherlands, Norway and Switzerland were contacted. Norway did not reply. The Swiss authorities regretted that they were unable to make any major contribution but referred to the fact that 'Investment under uncertainty' was handled within the framework of Concept Development and Experimentation[8]. The basis for a description of the British process was obtained following communication with Professor Keith Hartley (Department of Economics and Related Studies, University of York). The description of the investment appraisal made by the Netherlands is based on material from Lt Gen Anders Waldén.

United Kingdom[9]

Decision processes

In the British armed forces an investment need arises when an analysis has been made that indicates that there could be a deficiency or failing. There then follows a concept phase in which a demand specification is formulated by a team made up of the areas concerned at the Ministry of Defence and experts from major industrial suppliers. It is the central planning staff at the Ministry of Defence that examines individual investment proposals and decides whether the various proposals and investment plans concur with each other. The total budget and consideration of investment decisions are dealt with by the Defence Management Board.

Investment appraisal

The tool used by the Ministry of Defence to appraise investments in defence equipment is **COEIA** (the Combined Operational Effectiveness and Investment Appraisal procedure). COEIA comprises four parts:

1. Production of analytical concepts that form the basis for
2. Assessment of operational effectiveness and an
3. Investment appraisal. The appraisal of operational effectiveness and the investment appraisal result in
4. How the results are to be presented to the decision-makers.

[8] Concept Development and Experimentation is intended to be a forward-thinking process to develop and evaluate new concepts before a decision is reached regarding large-scale investments. In Concept Development and Experimentation a best solution should be identified from a technical point of view and in the light of doctrine, training and equipment in order to achieve significant advantages in future operations.

[9] This section is based on Hambleton et al. [2005, Chapters 2, 4 and 8].

When it **has been decided which analytical concepts** (the first part of COEIA) are to be used, effect and investment appraisals are made in parallel but by different teams to limit unnecessary dissemination of military and commercial intelligence. In the second part, **effect appraisal**, a measure of military effectiveness is chosen, the time period is decided, military and financial dependencies on other ongoing or envisaged projects are identified (these should include the benchmarking alternative 'no capacity change'). In the third part – the investment appraisal – an assessment is made of the financial side of the investment alternatives. In the fourth and final part, recommendations are made for how the results of the effectiveness and investment appraisal are to be presented.

The basis for the actual **investment appraisal** (the third part of COEIA) is the British Treasury's guidelines on how financially large investments are to be appraised. Sunk cost – payments already made – should for instance be excluded. Future payment flows are discounted in such a way that all imaginary costs (depreciation and return on capital) are excluded. Finally, no macroeconomic effects should be taken into account.

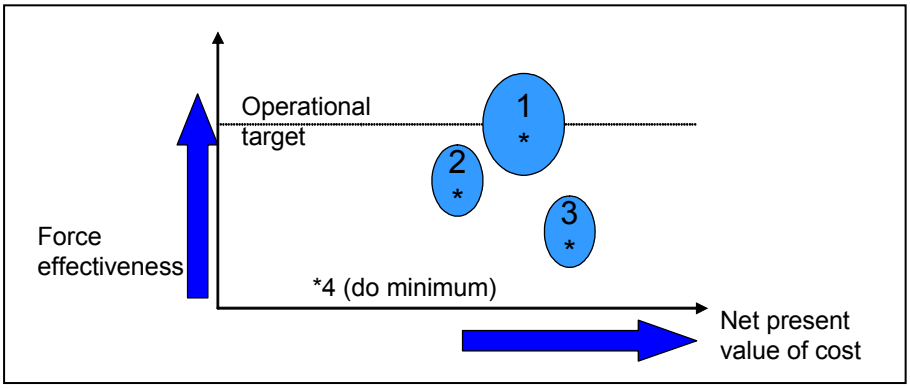
The Treasury's investment appraisal is a structured process of gathering and analysing all the costs, benefits and risks associated with planned projects:

1. Define the timeframe for the project that is to be evaluated.
2. Identify and specify a list of alternatives.
3. Forecast the future payment flows for each alternative. In each investment appraisal it is important to identify all payment implications for a certain alternative. This also includes the costs generated by winding up the investment.
4. Use the (Treasury's) discount rate to discount the payment flows.
5. Calculate the net present value, i.e. the discounted value of all future payment flows.
6. For a potential Swedish Armed Forces procurement, net present value should be seen as a quantitative measure of the financial burden generated by the project.
7. Examine how net present value is affected by risks and uncertainties. Risks and uncertainties are estimated with, among other things, the aid of probabilities.
8. A sensitivity analysis: how is net present value affected by possible variations in input in the investment evaluation.

All the above points are important although in Hambleton [2005] it is stated that the third point represents the greatest challenge. The most important aspect of an investment appraisal – and the factor that is lacking in the majority of investment guides – is identifying the nature of the costs that a certain investment generates. Tracing the major costs in an investment is fundamental – particularly if irreversibility and uncertainty are to be evaluated.

In the fourth part of COEIA – presentation of results – it is proposed that when a decision is to be reached the results from the generation of alternatives should be presented as shown in *Figure 5*. The axes represent the effectiveness of the alternatives in war and the net present value of the payments associated with the different alternatives.

Figure 5: How force effectiveness of four alternative options relates to cost



Source: Hambleton et al. [2005, page 170]

Finally, it can be noted that in Hambleton [Chapter 5, section 3] a decision-making tree is recommended in order to handle uncertainties in investment appraisals.

3.2.1 Denmark and the Netherlands

The British investment process – which is described in Hambleton [2005] – is presented separately as the British documentation is relatively comprehensive. Denmark and the Netherlands, however, are presented jointly due to the absence of more detailed descriptions.

Decision-making processes

The Danish response does not indicate how equipment procurement decisions are made. However, it does state the tools they intend to use. These tools include calculations of life-cycle costs and risk control, both of which are in the process of being developed. With effect from 2008, analyses of life-cycle costs will be made on a broad front with the aid of both in-house personnel and external experts. In addition to life-cycle costs and risk control, the Danish armed forces will use a project management method[10] and a project control module[11]. In time the aim is that a project management method, project control module, life-cycle costs, risk control and project follow-up will be dealt with on an integrated basis.

In the Netherlands, the document 'Defence Materiel Process' governs how the basis for an investment can be formulated for a possible investment in defence equipment. The 'Defence Materiel Process' is applied to all investments in excess of €5 million. Investment decisions are delegated to the civil servant level or are reached by the Minister for Defence. In effect, the decisions are always made on the civil servant level for investments of between €5 billion and €25 million and commonly between €25 million and €100 million. Decisions regarding investments in excess of €100 million are made by the Minister for Defence. Whether or not an investment decision should be delegated to the civil servant level also depends on the complexity of the investment/procurement, political sensitivity and international considerations.

The Dutch 'Defence Materiel Process' is divided into four phases, i.e. a) needs specification, b) preliminary study, c) main study and d) procurement preparation. These phases follow on from each other. The results from each phase are documented in a report which provides a basis for deciding whether the next phase is to continue or not. In each phase needs are documented, a consequence analysis is made, a procurement strategy is formulated, a time and cost framework is estimated and the consequences of planning and risks are estimated.

Investment appraisals

In Denmark, as mentioned previously, a life cycle cost analysis is made for all large-scale investment projects before a decision is reached to invest in certain equipment. The calculation of the life cycle cost is based on the procurement cost

[10] The project management method is PRINCE 2 (PRojects IN Controlled Environments) and it is said to focus on business justification, to have a defined organisational structure, to adopt a product-based planning approach and to emphasise the division of the project into manageable and controllable phases. It is also said to be sufficiently flexible to be used adequately for projects.

[11] The project management module SAP is an organisational form specific to a project and which is shared by all the departments involved.

of the equipment and the cost of upgrading (Mid Life Update). Historically however, only a few of these analyses have been made, i.e. for new transport aircraft and for helicopters. In both cases the calculations were made at a very early stage in the investment process and were based mainly on the supplier's calculations. The analyses were made primarily by Danish Armed Forces personnel and only with limited use of external consultants.

According to the Dutch Defence Materiel Process it is mainly in the preliminary study and main study that investment appraisals should be made. In a preliminary study needs are translated into functions and when possible into the technical performance required for the investment to satisfy the needs. A market overview is made of the alternatives available and the risks associated with these alternatives. When alternatives have been compared, an initial selection of the alternatives is made. Each alternative included in the list is investigated to decide to what extent the alternative satisfies the criteria discussed as well as needs. This investigation of alternatives could result in a change in needs. At the same time an evaluation is made of the life-cycle cost for each alternative. The life-cycle cost includes cost estimates for the actual procurement, use (including the need for maintenance) and phasing out. The life-cycle costs could, together with quantitative and qualitative benefits, be used for different points in the Defence Materiel Process to evaluate alternatives. External experts can also be used to make an evaluation. In addition, social cost-benefit analyses can be made. In the main study, the requirements in the preliminary study are formulated in more detail and a shortlist of the most interesting alternatives is drawn up. A decision is made at the end of the main study.

Risk assessments

In order to identify critical change-over points in an equipment project when external conditions change, the Danish armed forces have decided to make risk analyses for all large-scale investment projects. In order to make a subsequent evaluation of the alternative investments, the aim is to use external consultants to clarify and deal with the risks facing an investment during the procurement phase. It is considered important for Denmark to decide on necessary adjustments as early as possible, regardless of whether these are the result of internal or external factors.

In the Dutch document 'Defence Materiel Process' it is emphasised that risks and the means of controlling these risks should be the ongoing focus of attention although without specifying in more detail how this should be done.

3.3 Summary

The aim of the comparisons made in this chapter was to investigate – both on a civilian and military level – how investment decisions are made and what form the appraisals that make up the basis for these decisions might take. By way of introduction, it can be stated that whilst SL and Vattenfall, like the Swedish Armed Forces, are very capital-intensive, they can, in contrast to the Swedish Armed Forces, be regarded as having relatively safe use of their investments. The question is whether there are other capital-intensive organisations to compare with where the production equipment has a lifespan of some 30 years and whose future is uncertain (which to a certain extent was made through attempts to describe the armed forces in other countries). If such organisations exist, this does not necessarily mean that these organisations have good investment processes. It is perhaps of greater interest to study organisations with efficient investment routines rather than study investment processes in organisations that are identical to the Swedish Armed Forces.

Decision-making process

SL and Vattenfall delegate the investment appraisal to operational experts and decisions are made by the Board of Directors. In the Netherlands it is the cost framework that determines whether the decision is made by the Minister for Defence or civil servants. In the United Kingdom an investment is initiated centrally, the proposal is processed by an integrated product team and a final investment decision is then reached, also centrally. It is not possible to determine from the responses by the different armed forces how they make use of the technical and financial expertise required to produce the best possible basis for making an investment decision.

Investment appraisals

In all cases it can be said that use is made of life-cycle cost calculations[12]. However, the answers do not show what these calculations cover. According to Fabrycky and Blanchard [1991, Chapter 1]) a life-cycle cost calculation should encompass all costs that arise from an investment over time (including phasing-out costs). The costs refer to the actual product and its use, to the production process and to its maintenance system. The armed forces include phasing-out costs but otherwise appear to limit the cost calculations to the investment object

[12] In Hambleton [2005, pages 41 and 124] it is not life-cycle cost that is spoken about but rather Through-Life-Cost. In Through-Life-Cost it is not just costs for development and procurement that are identified and predicted but also the procurement costs for operations, service (support) and phasing out.

and the necessary replacement parts. No account is taken of other costs generated by an investment.

Vattenfall uses life-cycle costs for investments that are independent of the company's existing capital structure (the facilities and the equipment that exist). For investments that affect the existing structure, a method is used that analyses consequential costs. This method could be worth bearing in mind in the light of how integrated the armed forces are: an investment in equipment has implications for other investments in both equipment and management systems.

Risk and uncertainties

The starting point for this project was how changes in a threat to a nation could make investments unusable. The uncertainty/risk, which is discussed by Dixit and Pindyck in particular [1994], take the form of uncertainties about the price that can be charged for a product. It is also prices (not changes in demand) that Vattenfall refers to when talking about uncertainty. There is thus reason to clarify exactly which uncertainty is being referred to: even if demand is 'certain', other uncertainties – about the supplier markets for example – could arise.

4 Investment appraisals in the Swedish Armed Forces

How do the Swedish Armed Forces reach a decision to invest in an irreversible asset? What takes place before an investment is registered – as ordered or planned – in the Swedish Armed Forces' long-term equipment plan?[13] By way of introduction, a presentation is made of the various forms that investment appraisals take within the Swedish Armed Forces. This description is based on information from Erik Nordstrand at the Swedish Defence Research Agency. This is then followed by a more detailed description of how a basis for an investment that takes into account uncertainties and irreversibilities could be produced in a study.

4.1 Production of a basis for investment

The idea behind *Figure 6* is to attempt to describe how the Swedish Armed Forces decide on large-scale, irreversible investments. However, it should be noted in the first instance that *Figure 6* describes a rational process. In reality, large-scale investments, such as the procurement of the aircraft JAS 39 Gripen, are decided mostly on the basis of political considerations. Secondly, it must be emphasised that *Figure 6* is primarily an expression of the long-term orientation of defence operations in the perspective studies. In transforming the Swedish Armed Forces from an invasion defence to an operational defence the emphasis has been shifted from long-term planning of investments to the ability to make rapid investments.

A prerequisite in *Figure 6* therefore is that large-scale investment decisions are prepared in Swedish Armed Forces' perspective studies in which an investigation is made of which armed forces structures could resolve the tasks that need to be addressed should a threat arise within 10 years[14]. However, investment proposals are also produced in other studies, such as the ISTAR study. The formal decision is then reached by the head of the Swedish Armed Forces production process (HKV ArbO, [2007, Appendix 2, page 7]).

[13] The (long-term) equipment plan for the Swedish Armed Forces is a specification of the investments ordered or planned by the Swedish Armed Forces over the next 10 years.

[14] In the perspective studies a balance is struck between different Swedish Armed Forces structures with the purpose of ensuring that payments fall within a framework.

Figure 6: Investment process

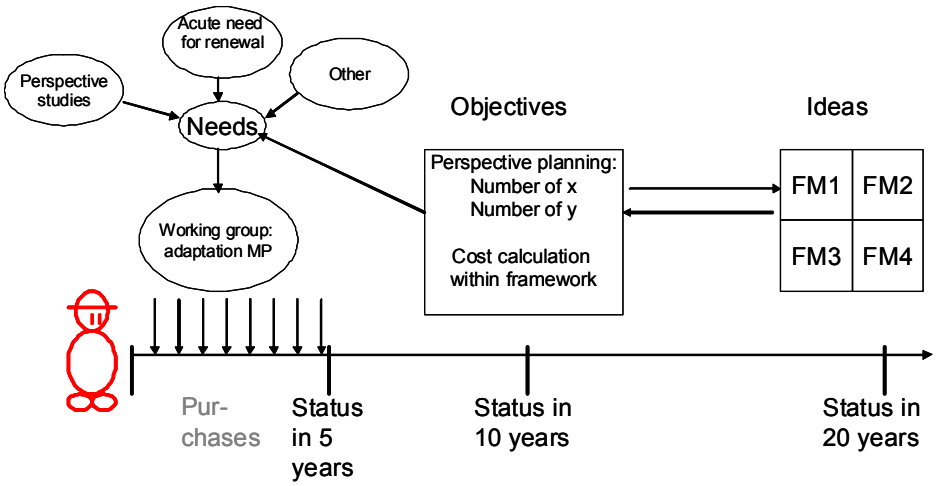


Figure 6 is also intended to illustrate how different time horizons affect an investment decision concurrently. The red man in the figure represents the person or persons who choose the basis for a decision at the point in time 0. At this point in time an investment decision is affected by an existing short-term equipment plan and by the Swedish Armed Forces targets for the next 10 years and – more indirectly – the Swedish Armed Forces ideas for the next 20 years.

The Swedish Armed Forces short-term equipment plan generally determines which equipment the Swedish Armed forces will invest in over the next five years. The short-term investment decisions originate on many occasions from previous perspective studies. In time, investments decided on will contribute to the Swedish Armed Forces focusing on its targets. In the targets for how the Swedish Armed Forces will be in 10 years, considerations are made within a cost framework. This does not apply, however, to the ideas for the next 20 years, for which no cost estimates are made. In addition to investments already decided, the Swedish Armed Forces must take into account the acute need for renewal.

In the perspective studies different armed forces structures are weighed up against each other and form a basis for deciding which investments are made and to what extent. The perspective studies – with regard to investments in equipment – are in turn based on studies made at different levels in the Swedish Armed Forces. These studies could be common to the Swedish Armed Forces or are made within the framework of a particular branch. The ISTAR study was conducted, for example, by the Air Force. One question that is examined in this type of study is "How can we use certain equipment". If it emerges that equip-

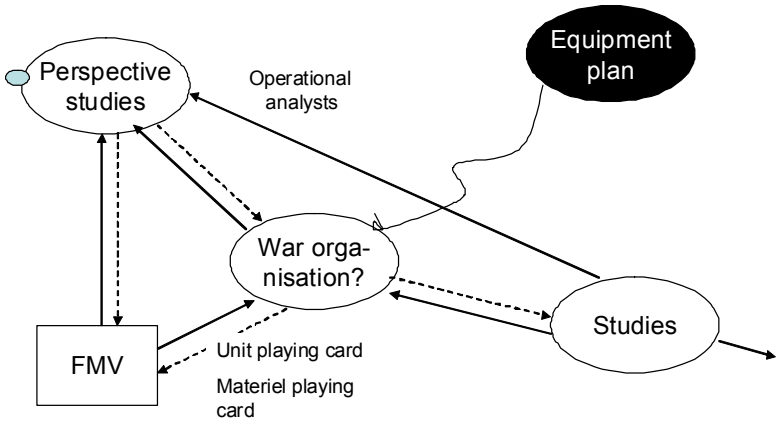
ment is unusable, the results of the study (playing card) serve as input in the perspective studies.

By way of conclusion it ought to be mentioned that an investment process or investment appraisal is affected by the time available for producing a basis. When there is ample time, a working group (within the framework of the Swedish Armed Forces study programme) can be appointed to investigate what equipment is needed and at what cost. If the situation is acute, the Swedish Armed Forces can conduct a fast-track investigation into the costs an investment could entail.

4.1.1 Estimate of costs – collation of information

Both with regard to 'normal' studies and perspective studies cost estimates are made or will be made. The way this information is gathered is presented in *Figure 7*.

Figure 7: Collation of information



In the figure the broken lines show the request made by the perspective studies for information from different parties and the unbroken lines show the provision of information by these parties. In the perspective studies, the department affected at Supreme Headquarters must provide cost estimates for certain equipment. In this case the department can receive help from other study work. If the department is unable to provide information, information can be requested from the Swedish Defence Materiel Administration. The blue-grey marking in the perspective studies circle indicates that sometimes expert help must be sought externally, i.e. outside the perspective study.

4.2 Investment decision and investment documentation for a new radar (ISTAR)

In the earlier text a general account was presented of how the Swedish Armed Forces make investment decisions. The idea behind this section is to reflect more specifically on how irreversibility and uncertainty could be taken into account in a study dealing with procurement of equipment, namely the study *'ISTAR i luftarenan LUFT 070801S'*. The name ISTAR (*Intelligence, Surveillance, Target Acquisition, and Reconnaissance*) represents an improved flow of information and thus a better basis for operational decisions.

4.2.1 Purpose of the study

One of the aims of the ISTAR study is to investigate and propose a future 'sensor package' for the JAS 39 Gripen fighter plane and to choose from possible alternatives the system that is most cost-effective. The timeframe is 10-20 years into the future. As a cost-effect analysis for the alternatives analysed must be included, a method for cost-effect analysis should also be developed (F17 21 120:30299, dated 25-06-2007). An alternative future sensor could be a nose radar of the AESA (Active Electronically Scanned Array) type. The AESA alternative is used here to discuss how in an investment appraisal, risk and irreversibility could be taken into account when making cost assessments for a sensor package and consequently how flexibility could be evaluated.

4.2.2 An investment appraisal that includes risk and irreversibility

The term 'risk' means the probability of an investment becoming unusable within a certain area of operations. This is *per se* not a problem if the investment is reversible, i.e. that it has an alternative use and can be sold on the second-hand market. The problem arises when the investment does not have any alternative use, i.e. it is irreversible. The nose radar for a fighter plane cannot be used for anything other than as a nose radar for a fighter plane; it cannot be sold on the civilian market and it has no alternative use for land or sea attack forces. In other words, the investment in a nose radar is irreversible. Risk entails the probability that the AESA radar would become unusable: a new countermeasure could be developed that would nullify its functions; the manufacturer ceases to produce replacement parts or discontinues the upgrading programme. What becomes interesting then is estimating how much it could be worth for a decision-maker – in this case the Swedish Armed Forces – to safeguard itself against this risk, i.e.

to invest in flexibility. The iterative steps in estimating the value of flexibility are (cf. section 2.4 of this report):

1. Identify external changes that could make AESA worthless (new jamming technology, change in the threat scenario),
2. Identify alternatives that create flexibility, i.e. can deal with external changes, such as new jamming technology and a change in the threat scenario,
3. Calculate whether the investment in flexibility is worthwhile.

The value of flexibility can be described as being linked to the possibility of being able to modify an AESA in such a way that it can be adapted to future situations, for example being able to identify an enemy UAV (Unmanned aerial vehicle) so that it could be rapidly shot down. An adaptation of AESA to this situation could mean that the Swedish Armed Forces pay industry for 1) ensuring that the capacity of the processor is sufficient for the necessary upgrading; 2) development of a function (producing the algorithms required for identification of UAV) and 3) translating algorithms into code so that these can be applied. In addition, there are extra costs for integrating the development/modification of the AESA with the parts that the AESA is to work with, such as the JAS 39 Gripen aircraft itself but also the weapon systems the aircraft is to be fitted as well as the Swedish Armed Forces command system. In addition to these computations, the value of deferring an investment in an AESA must be calculated. If the investment is deferred – which is a further aspect of flexibility – for a number of years new information could be gathered that provides a better basis for reaching a decision about whether to invest in a radar.

In *Table 2* an overview is presented of how the value of investing in a flexible AESA could be calculated[15]. External changes have already been identified which could make the AESA unusable. In this case the external change could be handled as a change in the central computer (activity). This activity makes use of a number of resources: personnel, equipment and, for example, consultants (others) whose costs should preferably be estimated separately. However, no such division of resources has been made. If the Swedish Armed Forces choose to initially, in phase 1, make changes in the central computer (flexibility) this entails an extra cost of SEK 1 million. In addition, there is a minor adjustment in phase 2 if the external change occurs, which would cost SEK 0.1 million. If the Swedish Armed Forces do not invest in flexibility and something happens (phase 2) the central unit will be forced to respond to this threat. The probability of this happening is valued at SEK 0.5 million. An adaptation in phase 2 costs SEK 2 million. The reason why the price is much higher than in phase 1 is the fact that

[15] An investment calculation is being developed within the ISTAR project.

competition to have the units reprogrammed has increased significantly as a result of the new threat. Likewise, there is a demand for shorter delivery times – something which also forces prices up.

Table 2: Costs in SEK million for investing or not investing in flexibility

Alternative	**Phase 1: Costs before a possible external change**			**Phase 2: Costs after a possible external change**			**Total**
Activity	Change in a central computer			Change in a central computer			
Type of cost	Pers.	Equip.	Misc.	Pers.	Equip.	Misc.	
(1) AESA without flexibility				0.5 x 2 = 1			- 1
(2) AESA with flexibility	1			0.5 x 0.1 = 0.05			- 1.05
Difference (2)-(1)							- 0.05

As this example has been designed it is cheaper for the Swedish Armed Forces to refrain from investing in flexibility.

4.2.3 Benefit and effect[16] – a deviation

Very often the terms benefit and effect are regarded as being synonymous (see, for example, Swedish Road Administration [2006:127]). Health economist Jönsson [1992] distinguishes between effect and benefit in such a way that the former is a one-dimensional measurement (for example days without problems or an increased lifespan) and benefit is a composite measurement (for example, a combination of increased survival **and** quality of life).

Section 2.1 of this report contains a presentation of Pindyck's thoughts on the problem of measuring the benefit of making an environmental investment. Pindyck [2007] makes an interesting distinction between effect and benefit. An environmental investment could result in reduced air pollution – this refers to an effect. Reduced acidification could in time lead to improved health – and in that

[16] In the Swedish discussion about 'income' the term 'need' also rises, which can be regarded as the capacity necessary given a certain scenario.

case improved health is also an expression of increased benefit. We thus have two 'income concepts' – benefit and effect – to set off against the cost of an investment[17].

If Pindyck's distinction between effect and benefit are translated into effect/benefit in a defence investment, effect is described as the performance of an investment: in the case of the AESA it could be identification of an object, the time taken for identification as well as the sending back of information etc. But this is an effect, i.e. what the AESA is capable of doing (or, using Pindyck's example, the reduced air pollution that could be the result of an environmental investment). This means that the benefit[18] of an AESA first emerges in the war or defence situation (or, using Pindyck' example, the improved health of the individual that is the result of a reduction in air pollution). A cost-effect analysis thus says very little about the benefit of an investment. Hypothetically, the benefit of a less cost-effective investment could be greater than for a more cost-effective investment in a special use situation.

How then are the benefit and effect of investments in flexibility defined? When the flexibility represents deferring an investment in new equipment (cf. Hedvall [2006]) both alternatives differ with regard to effect. Deferring an investment means no effect during the period the investment has been deferred. There could thus be a difference in effect between the alternative of investing now or deferring the investment. A similar line of reasoning can be pursued for development investments (cf. Hedvall [2007]) and for the type of investment in flexibility touched on in this report.

4.3 Summary

In this chapter a general presentation is made of the Swedish Armed Forces' investment process with the aim of indicating where in the process the appraisal of flexibility can be costed. As the Swedish Armed Forces investment process has been described, the perspective studies, together with other more equipment-specific studies, ought to generate investments which the Swedish Armed Forces ought to make and which should therefore be included in the (long-term) investment plan.

[17] In the British armed forces instrument COEIA (see section 3.2 in this report) the operative efficiency is highlighted in preference to acquiring a measure of how cost-effective investments are in different items of defence equipment.

[18] The effect and benefit could coincide if the investment in defence equipment has a deterring effect on a possible enemy.

Of the studies, the cost estimates should be acquired and this collation of information is done by the heads of equipment systems in the Swedish Armed Forces war organisation and particular by the Swedish Defence Materiel Administration. The heads of equipment systems and the Swedish Defence Equipment Administration in turn often acquire their cost estimates from the defence industry and the information industry provides is information which the Swedish Armed Forces could need to pay for a specific defence equipment system and for the spare parts for that system. Consequently, no analysis is made of what the Swedish Armed Forces will need to pay to operate the system and/or payment consequences for integrating the system into the Swedish Armed Forces operations. Nor is an analysis made of the value of investing in flexibility to deal with an external change. The ISTAR study has been used as an example – although without making computations – to indicate how the value of investing in flexibility can be calculated:

1. Identify external changes that could make the investment worthless (new technology, change in the threat scenario),
2. Identify alternatives that create flexibility, i.e. could deal with external changes,
3. Calculate whether the investment in flexibility is worthwhile.

5 Conclusions and recommendations

This chapter contains the conclusions which are drawn from the previous chapters and an indication of what the Swedish Armed Forces can do to benefit from these conclusions (recommendations). In a concluding section a summary is presented of the issues that have arisen during the course of the project.

5.1 Conclusions

SL and Vattenfall are capital-intensive companies and in that respect the companies' operations are similar to the Swedish Armed Forces operations. However, SL and Vattenfall differ from the Swedish Armed Forces with regard to the reasons for making investments. The need to invest at both SL and Vattenfall is initiated primarily when equipment needs to be replaced. In this way, these companies differ from military operations, where investments assume the nature of 'something new that is needed in order to counteract a threat'. In all cases, however, it is a matter of investments that are required in order to adapt to a system.

5.1.1 Decision processes – the significance of the involvement of experts and a standardised basis for making decisions

The need to replace equipment is thus the initiating factor behind the process of reaching an investment decision at SL and Vattenfall. At both companies the task of formulating investment calculations is delegated to experts. At both companies – albeit in different ways – investment appraisals are standardised in order to enable an unbiased comparison to be made before they are presented to the Board of Directors for a decision.

In the British armed forces an investment decision is initiated by a predicted future shortage. The demand specification for a potential investment is formulated by a team comprising the parties concerned at the Ministry of Defence and experts from major industrial suppliers. The parties involved in this process differ from SL and Vattenfall in the fact that external parties (major industrial suppliers) are included. In the Dutch armed forces, the Minister for Defence decides on investments in excess of €100 million whilst decisions regarding investments below this amount are normally reached on the civil servant level. It is, however, uncertain who produces the demand specification and cost docu-

mentation. The Danish and Swiss armed forces made no comment whatsoever regarding the parties involved in the decision-making process.

The above descriptions highlight the significance of experts – including financial experts – being included in the teams that produce the basis for an investment. The descriptions of the investment processes at SL and Vattenfall also illustrate the importance of having a standardised investment basis in order to enable unbiased comparisons to be made between investments.

5.1.2 Investment appraisal – net present value calculation, consequential investments and flexibility

Characteristic of SL, Vattenfall and military authorities are that they are capital-intensive. From the information received it can be seen that the investment appraisals made are based – or should be based – on a net present value calculation. Future payment flows should be discounted to a net present value. Future payment flows refer to all payment consequences of an investment, including disposal or phasing out. Vattenfall uses a method to calculate whether or not a reinvestment in a certain item of equipment in a major facility is worthwhile. The aim of this method is to analyse which consequential costs will arise for other parts of the facility (which have other technical lifespans). It ought to be mentioned that the calculations made by Vattenfall are documented for different reasons, one being to act as a basis for future investment appraisals.

5.1.3 Uncertainty and the value of flexibility

We know so little about the future that mental arithmetic is sufficient.

Hans Werthén (Electrolux)

The aim of this project is to produce a calculation to appraise investments in flexibility designed to adapt an irreversible investment to possible unforeseen external changes. Neither SL and Vattenfall nor the military authorities reported appear to make such calculations. The reason why SL and Vattenfall do not make such calculations is that that uncertainties for these companies are different and therefore cannot be taken into account in any way other than by explicitly valuing flexibility. As stated previously, Vattenfall's appraisal of future electricity production reflects their assessment of the electricity price trend on a deregulated market. In section 2.4, a distinction was made between symmetrical and asymmetrical risks, where the uncertainties encountered by Vattenfall, for example, are more symmetrical (the consumption of electricity can both increase

and decrease), whilst investments made by the Swedish Armed Forces meet an asymmetrical risk, namely an impending risk that equipment procured becomes unusable. There are therefore good reasons to attempt – with the aid of scenarios – to assess the value of investing in flexibility when investments are major and irreversible.

If the model in section 4.2 were to be used, a calculation for estimating the value of investing in flexibility could be as shown in *Table 3*. Given that an analysis has been made of the change in the threat that could occur, an analysis is made of the adaptation measures in the equipment required to counter the threat (external change). The value of implementing the adaptation measures (investing in flexibility) or not is then calculated and compared.

Table 3: Model for calculating the value of investing in flexibility

Alternatives	**Phase 1: Costs before a possible external change**			**Phase 2: Costs after a possible external change**			**Total**
Adaptation measure							
Type of cost	Pers.	Equip.	Misc.	Pers.	Equip.	Misc.	
(1) Investment without flexibility							
(2) Investment with flexibility							
Difference (2)-(1)							

By way of conclusion it is interesting to note that – in the academic literature – it is often maintained that the pay-off method has shortcomings compared with the net present value method (Baumol [1972], BrealeyMyers [2003]). In the pay-off method a calculation is made of how long it takes before an investment pays for itself. The shortcoming is to be found in the fact that the pay-off method does not take into account the (large) payments that could arise after an investment has paid for itself and that the value of the investment is therefore underestimated. However, the pay-off method can undeniably be regarded as a way for companies to reduce uncertainty: the longer it takes for an investment before it generates a profit, the more uncertain it is that the investment will ever generate a profit. The quicker the profit phase is reached, the safer the investment. This supports the notion that in appraisals of uncertain investments the principle

should be to minimise the lifespan of the investment. An alternative is to extend the lifespan of existing equipment in order to be able to defer large-scale investments in new equipment. Uncertainty in new technology, increased costs for new equipment etc. can thus be pushed ahead – to allow technology to be developed or to be tested by others for example.

5.2 Recommendations

In the light of what has been written previously, it is considered important that the Swedish Armed Forces make a number of changes to contribute to an efficient investment process. The following sections contain proposals for measures that could be taken by the Swedish Armed Forces.

5.2.1 Decision-making process

- Create a process where experts (in studies) are responsible for formulating investment calculations.
- Formulate investment calculations in a standardised way so that the bases are comparable when the head of the Swedish Armed Forces production process is required to make a decision regarding which investments are to be made.

5.2.2 The investment appraisal

- A net present value calculation of large-scale equipment investments that also analyses the consequential costs for other parts of the armed forces.
- Documentation of investment appraisals as a basis for future investment appraisals (build-up of a bank of experience).

5.2.3 Valuation of flexibility

- Calculate the value of flexibility in conjunction with larges-scale, irreversible investments.
- Make cost-benefit comparisons between investments with different lifespans.

5.3 Future issues

The purpose of this project has been to develop an investment calculation that makes an explicit evaluation of flexibility. Such a development presupposes that there are processes to produce investment appraisals and to produce a standardised means of making such assessments. This highlights the urgency within

the Swedish Armed Forces to produce such processes and routines and in conjunction with this – for large-scale, irreversible investments – calculate the value of investing in flexibility.

As part of this project, other armed forces have been asked about their routines for making investment appraisals. No detailed responses were provided, probably due to the complexity of the issue. The armed forces also appear to be tentative with regard to how investments are to be appraised. This supports the notion that the Swedish Armed Forces should, rather than study other armed forces, co-operate with capital-intensive organisations that have developed processes and routines for making investment appraisals.

The nature of investments has changed over time: from being autonomous (independent of the rest of the system) to becoming integrated. One consequence of this is that an investment made today results in consequential costs in other parts of the system. Bearing in mind the significance of integrated systems, it is of some urgency to produce methods to trace consequential costs and to formulate cost-benefit alternatives.

This report has touched slightly on how benefit should be evaluated – and in this context benefit has been discussed when a threat comes to the fore. The benefit of having a deterrent defence has not been discussed. Furthermore, the benefit of an investment varies depending on whether the investment is designed to deal with a threat or to act as a deterrent. It is therefore important to clarify the benefit of investment.

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