APPRAISING INVESTMENTS IN NEW TELECOM TECHNOLOGIES: THE CASE OF SWEDISH TELECOM

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Investment management and investment appraisals of new technologies in Swedish Telecom's network have been investigated in an exploratory manner. Investments in new telecom technologies are difficult to appraise because of, among other things, systems interdependence, technical change and competition. It is argued that investment appraisals need to be more closely integrated with strategy and that it is essential for management to carefully match investment management with different types of investments in order to alleviate measurement problems and to provide the right organizational incentives for investments in new technologies.

Keywords: Investment appraisals, new technology, telecommunications technology, managerial incentives, capital investment strategy, Swedish Telecom.

INTRODUCTION

Problem background and aim

Rapid technological change in telecommunications coupled with market liberalization is opening up new competitive threats and opportunities for equipment suppliers as well as service providers and users, both internationally and domestically.[1] As technological innovations and substitutions have a profound impact on market structure and on firms' competitive positions in terms of long-term market share and profitability,[2] this change places demands on the effectiveness of the investment management of telecommunications service providers. Managing investments becomes crucial, as the investment appraisal, the decision to invest in new technology and the consequent diffusion of new technologies have a profound impact on a firm's technological and competitive position.

At the same time, received theory and methods of investment appraisal seem unsatisfactory in terms of measuring the value of new technologies, technological substitutions and oligopolistic competition. In fact, the concern has increasingly been raised that capital markets and internal managerial evaluation systems induce managers to make myopic

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investments in new technologies.[3] However, any corresponding renewal of theory and methods for investment appraisals to remedy these difficulties have not yet emerged. Rather, the dynamic effects of technological substitutions and diffusion in a competitive environment are still very difficult to capture satisfactorily in an investment appraisal, especially so when there are increasing returns to adoption (for instance from network externalities and critical mass phenomena).[4] Also, despite the fact that advances have been made by game-theoretic modelling of the competitive effects of investments in excess capacity in oligopolistic industries,[5] much remains to be done to make the models operational for business decisions. Lastly, the systems complexity of telecom networks further complicates the investment appraisal for service providers.[6]

Swedish Telecom provides a case in point, as it faces many competitive and technological challenges, despite its well-known efficiency and adherence to received methods of investment appraisal.[7] In fact, there has been a feeling among some managers within Swedish Telecom that the methods used for investment appraisal tend to favour old technologies rather than support radical, offensive investments. For these latter investments it has been argued that competitive and technology strategies should have more weight in the investment appraisal. In fact, this feeling of inadequacy of conventional investment appraisals and conventional management accounting has been shared lately by many researchers and practitioners in different fields.[8] The phenomenon at hand, i.e., widespread discontent with conventional investment appraisal methods, raises several important questions:

1. What is driving the need in Swedish Telecom to develop and change investment management and appraisals, even though the methods arrived at closely correspond to the text-book recommendations?
2. Can the notion that investment appraisals lead to too conservative investments (or more generally, sub-optimal investments) be put in any kind of explanatory framework?
3. What is the role of policies and strategies in the management and appraisal of investments?

These questions could be addressed in several ways. An initial aim of the research project was to develop methods for and perspectives on the appraisal of offensive investments, taking the need for development of investment appraisals for granted. However, as the initial assumption that offensive investments need tailor-made investment appraisals seemed strong, the study was conducted with the following general aims: first, to find problem areas from an exploratory point of view that are related to investment management and investment appraisals of telecom networks; second, to generate theories and hypotheses on the basis of these problem areas; and third, to address paths of improved investment management and appraisals (see also Appendix 1 for definitions of some key concepts). There are obvious limits to such an approach: a broadly

defined aim cannot answer many questions in depth. However, as the questions raised are not trivial but fairly complex and lack both empirical and theoretical consensus, an exploratory study was launched, attempting to tackle the issues from several angles and perspectives.

A note on research method

About 30 interviews were conducted within Swedish Telecom and more than 60 internal documents related to investment appraisals were studied. The interviews were conducted during the winter and spring of 1989/90. They were loosely structured but many questions were recurring (see Appendix 2 for a sample of the most frequently recurring interview questions). Several interviews dealt with investment procedures and appraisals in general in Swedish Telecom, while a large part focused on investment appraisals in four different network areas (with emphasis on the choice between new and old technologies): central offices, inter-office networks, the local-loop and mobile telecom (a few interviews) (see Appendix I for definitions). These latter interviews were mostly centred around specific investment appraisals. The interviewees were chosen so as to reflect a large part of those involved with investment appraisals and investment management, from those preparing investment appraisals in a telecom region to those making actual investment decisions as well as staff at the central departments involved in issuing policies and strategies that serve to influence investments. About two-thirds of the interviews were carried out in local telecom regions and the remaining in the central departments. Four interviews were conducted in the national division Swedish Telecom Radio (responsible for the mobile network).

Many of the results of the study are based on the managers' perceptions (a consequence of the study's broad and exploratory approach). However, the perceptions have been cross-checked for validity, as several managers have read and commented on intermediate reports as well as on the empirical material presented here. The interview-based case research method has been used, since it seemed most conducive to the explorative mode of the study and since one of the aims was to generate theories and hypotheses rather than to verify theory (for the latter, a broader sample would have been needed with preformulated hypotheses).[9]

Outline of the paper

First, the empirical findings are presented. The structure of Swedish Telecom, recent phases in investment management and current procedures for investments are briefly described. Moreover, problem areas relating to appraising new technologies as well as strategies and policies influencing the investment appraisal in Swedish Telecom are presented. An attempt to answer the research questions follows and the paper ends with a summary and some managerial implications.

INVESTMENT MANAGEMENT IN SWEDISH TELECOM

Current organizational structure of Swedish Telecom

Swedish Telecom has been a state agency since the beginning of this century when this legal status was instituted.[10] The parts of Swedish Telecom that will surface in this paper are the telecom regions, the central departments, the headquarters staff and Swedish Telecom Radio (a national division responsible for the mobile network). These units are indicated in Figure 1 together with the rest of the main units in the organizational structure of Swedish Telecom as of 1989.[11]

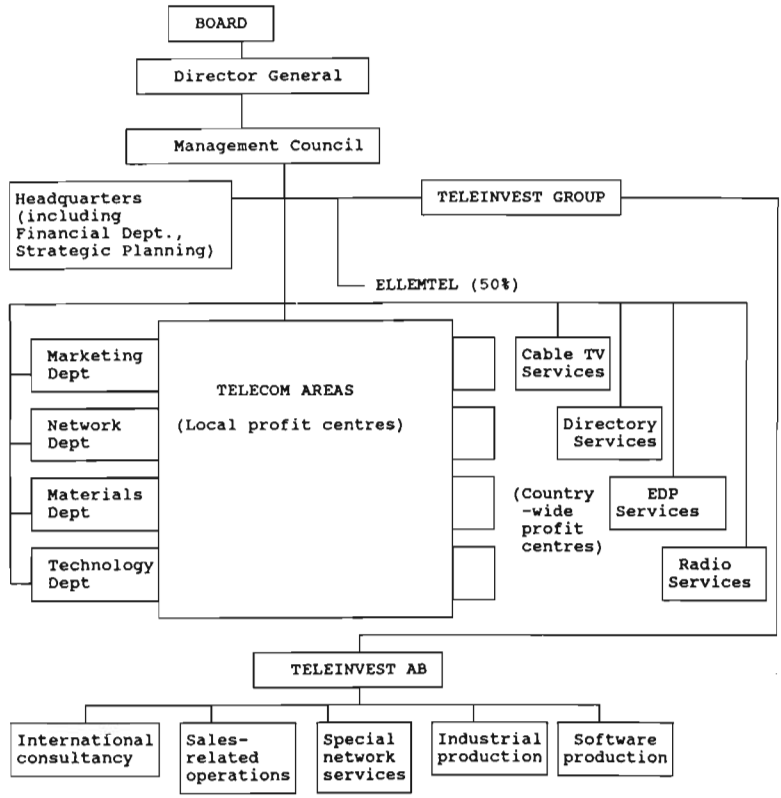
Twenty telecom regions are responsible for the construction, operations and maintenance of the national network within a geographically defined area, as well as for the sale, installation and service of terminals and telecom services. In 1989 the telecom regions accounted for approximately 59 per cent of Swedish Telecom's turnover (i.e., about $US3.5 billion) and employed approximately 72 per cent of Swedish Telecom's staff. The telecom regions are profit centres (revenues accrue from the subscribers within the area), free to make capital investments within certain limits. They are supported by a matrix organization composed of four centralized departments: marketing, materials, technology and network. These departments provide all telecom regions with co-ordination, technical advice and marketing support, and they contribute in different respects to the investment management in the telecom regions.

Within the headquarters, the financial department has the overall responsibility for the budgets and financial statements of Swedish Telecom, and for evaluating investment appraisals that are submitted to the Management Council and the Director General. Strategic planning department is responsible for formulating and communicating the overall strategy of Swedish Telecom and for co-ordinating Swedish Telecom's international policies. The strategic plans of the department aim to help and co-ordinate the strategic planning and investment plans of the telecom regions. The Director General has the operating responsibility for Swedish Telecom and is accountable to the Board. The Management Council consists of the Director General and the heads of the central departments, and it takes part in all major decisions (i.e., large investments).

Recent phases of investment management

Some recent organizational changes have profoundly affected the investment management of Swedish Telecom. Prior to 1975, a considerable part of the investment management was centralized and planned by very large groups of staff at the headquarters. In 1975 a major reorganization was made, whereby the headquarters were significantly scaled down and 20 local telecom regions were established as profit centres. However, gradually it became apparent that many of

FIGURE 1
Organizational structure of Swedish Telecom (1989)



Note: EDP = Electronic Data Processing

the telecom regions had not organized their investment management in the way desired by the top management. The responsibility for taking decisions on capital investments, implementing them and auditing their outcome was unclear in many instances.

Consequently, in the beginning of the 1980s, the top management initiated comprehensive internal studies of the investment management practice within Swedish Telecom. The studies proposed many changes: clear policies on the manner in which major investment decisions were to be prepared (the discounted cash flow model in addition to a penetrating report on various financial aspects of the investment decision), determination of the executive level for decisions on various amounts of expenditure, requirements on careful audits *ex post* and the

establishment of special groups for the purpose of overseeing the implementation of the investment policies.

Recently, the top management has started to allow for greater flexibility when preparing investment appraisals. New ways to evaluate investments financially are encouraged — for instance, methods that explicitly use the investment appraiser's subjective assessment of the risks involved with different technologies. At the same time, there is a movement away from a focus on isolated projects towards a more systematic view of investment programmes. For instance, the interaction of several projects in a geographical area is more often considered.

Table 1 summarizes and simplifies the phases of investment management in Swedish Telecom. It must be noted that even though the phases can be separated in time from a top management perspective, the phases co-exist in other parts of the organization, i.e., a phase may have been initiated but the effects have not penetrated the whole organization.

TABLE 1
Phases of investment management in Swedish Telecom

— 1975	Centralized investment management
1975 — 1982	Decentralization of investment management
1982 — 1988	Decentralized investment management guided by strict rules
1988 —	Decentralized investment management more and more guided by policies

Current investment management procedures

The level of expenditure required for an investment in the network determines in the main who makes the final decision. Investments requiring over $SEK 10 million (Krona), about $US1.5 billion, must be approved by the Management Council. The strategic importance of an investment is a second determining factor for who makes an investment and all 'strategic' investments are made by the Management Council (i.e., all investments in new services or in other respects of importance to the whole).

The investment appraisal is required to follow a predetermined discounted cash flow model consisting of nine major headings (thus the colloquial 'nine-pointer'). The model is a result of one of the major internal studies of investment management conducted in 1986-1987 (for details of the model, see Appendix 3). In order to support the model's implementation, the Management Council and many regional telecom directors have advisory groups that evaluate and check the validity of the investment appraisals.

Most of the current investment appraisals dealing with one object (a new central office, fibre optics along a route) conform to the 'nine-pointer', regardless of whether they are evaluated by the Management Council or by the managing directors of the telecom regions. However, there are also proposals for investment prograrammes, for instance co-ordinated plans for the national long-distance network, for investments in one region or for replacing technologies on a national level. These investment programmes are appraised by using the discounted cash flow method but do not always follow the 'nine-pointer'.

The investment plans of the different telecom regions are incorporated in the long-term budget plan with a planning horizon of three years, which is revised every year. However, this long-term budget is not prepared independently by the telecom regions but the general budget framework is set by the headquarters (mainly strategic planning department), with the central departments (marketing and network) providing goals and restrictions for the long-term budgets of the various telecom regions. On the basis of the three-year plan, the headquarters' financial department sets goals and restrictions for the yearly budget, the details of which are then worked out by the telecom regions before the Director General's approval is sought.

Within the telecom regions themselves, investment management is organized in largely the same fashion with some variations arising from differences in size. The managing director of the region decides on major investments, while functional managers decide on smaller ones. In some of the large telecom regions there are several groups that carry the responsibility for preparing the investment appraisal, depending on which technological area of the network is involved. The functional managers in these regions meet regularly to co-ordinate investment plans and to prepare investment appraisals that are to be submitted to the Management Council or the regional telecom manager.

Policies and strategies influencing the investment appraisal

There are several policies and strategies for different network areas in Swedish Telecom that in different measures influence the investment appraisal and the rate of investment in new technologies (see Table 2). First, several policies have been aimed at speeding up the rate of investment in technologies. For instance, recommendations have been issued by the network department to the telecom regions regarding the rate of deploying new switches and scrapping the old. Second, the network department made a large study of the feasibility of investing in fibre in the local loop, which encouraged the telecom regions to invest more aggressively. Also, an in-depth study in the mid-1980s, comparing the costs and benefits of microwave and fibre optics for the inter-office network, made a strong recommendation that the telecom regions use fibre.

TABLE 2
Sample of main policies and strategies for different network areas

Network Area	*Central offices*	*Interoffice network*	*Local loop*	*Mobile telecom*[1)]
Nature of Policy				
Rate of new technologies	x	x	x	
Salvage value	x	x	x	
Network performance	x	x	x	
Goal & vision of future network	x	x	x	x
Five-year plans	x	x	x	
'Nine-pointer'	x	x	x	x

1) This network area was not studied in the same depth.

Second, there are several policies that influence the salvage value of new and old technologies in the investment appraisal. Policies on the economic service life formulated by the financial headquarters and also policies on the value of reusable old equipment formulated by the materials department affect the salvage value of new and old equipment at the end of the planning horizon, and hence also the net present value.

Third, there are engineering policies that also affect the rate and direction of investments, for instance, quality standards on the grade of blocking. Related to these are policies that attempt to estimate the value of higher network quality and availability for the inter-office network (from the network department) and the value of new enhanced services made possible by new digital switching (i.e., call forwarding, itemized billing, etc.), a policy formulated by the marketing department.

Fourth, general strategies and plans from the central departments are also used as input to the investment appraisal, as they indirectly influence the decision-maker towards new technologies and new ways to build the network. For instance, the network department and several planning departments within the telecom regions use 'ideal networks' for planning purposes, i.e., network configurations and architectures that create a future vision of the network irrespective of current technological and capital constraints. The 'ideal network' is used to prioritize and direct the planning of investments in the telecom regions' five-year plans, which in turn affects the choice of technologies and investments to be appraised. An early vision in the beginning of the 1970s of wireless communications was furthermore important for Swedish Telecom's early launch of a national mobile telecom network (operational in 1981 with over 400,000 subscribers at the end of 1990, out of a total population of 8.5 million inhabitants).

Lastly, the general rules guiding the methods of investment appraisal (for instance the planning horizon, the discount rate) also have an impact on the rate and direction of investments. For instance, the current discount rate is eight per cent (real rate), which has been raised from

five per cent in response to the heavy investment programmes that were planned in the mid-1980s.

To summarize, several policies and strategies have influenced the appraisal of investments. Some of them have had a direct impact on the investment appraisal itself by manipulating the figures used for the discounted cash flow (e.g., policies on salvage value, service life, revenue potential of AXE, value of network availability). Other policies and strategies are more indirect, as they affect the selection process of technical alternatives and then the investment appraisal (for instance, 'ideal network').

Measurement problems when appraising new technologies

Appraising investments in new telecom technologies is fraught with many uncertainties and difficulties; at least this has been the experience in Swedish Telecom according to many of the interviewees. Table 3 gives a sample of some of the main current problems related to measuring and quantifying the impact of new communications technologies in different network areas.[12]

Referring to Table 3, several points can be made. First, even though there have been policies on the revenue impact of new switching technologies and of increased network availability, these policies have not eliminated all uncertainties in these areas, as the appraiser is allowed some discretion in the choice of the corresponding values. Second, appraising the costs and benefits of increased network integration has proved difficult but important due to technical change. For instance, new ring-based network structures with fibre optics in certain circumstances offer new opportunities for integration between the local loop and the inter-office network. Furthermore, the increasing future integration between the fixed and wireless network, made possible through the emerging wireless personal communications network (PCN), calls for new ways of managing investments, as Swedish Telecom needs to integrate two different organizational cultures — the mobile unit and the traditional wire-oriented network units. Lastly, new technology with synchronous digital hierarchy promises to merge transmission and switching.

Related to increasing integration is the strong systems interdependence of the telecom network. For instance, the replacement of old central offices (COs) by new digital COs has in many cases been difficult to justify financially, taken by itself. However, taking the effects on the total network quality into account and making enlarged sector analyses of larger areas (not just the area of the relevant CO) have made the justification more obvious. Also, increased capacity in the inter-office network has in many cases had positive cross-effects on other inter-office links (sometimes unexpectedly so), as traffic routing has been improved. In the local loop, the benefit of fibre is dependent on the deployment of broadband services, many of which in turn require widespread

deployment of fibre. Lastly, the rapid growth of mobile telecom has necessitated increased investments in the fixed inter-office network. Accounting for all these system effects requires quite complex mathematical programmes with much detailed data.

TABLE 3
Sample of the main measurement problems

Network area	*Central offices*	*Interoffice network*	*Local loop*	*Mobile telecom*[1)]
Nature of measurement problems				
Revenue impact	x	x	x	
Network integration	x	x	x	x
Systems interdependence	x	x	x	x
Diffusion costs	x	x	x	
Enhanced quality & availability	x	x	x	
Competition	x	x	x	
Lock-in	x	x	x	

1) This network area was not studied in the same depth.

A fourth factor that is difficult to appraise concerns the effects of diffusion of new technologies (both inter-firm and intra-firm diffusion). Diffusion of new technologies, for instance, fibre optics in the local loop, has an expected impact on maintenance costs. However, it has been the experience in Swedish Telecom (with new digital central offices) that the savings in maintenance costs do not materialize until a large proportion of the old technology has been replaced. Another aspect of diffusion is the revenue impact of enhanced services, which materializes when the installed base of digital switching is sufficiently large. The revenue impact of these services is currently starting to be significant for Swedish Telecom, but the take-off phase has not been particularly short. There needed to be a critical mass of users that could use or be reached before marketing efforts were effective. A related issue is the justification of broadband in the local loop, as the net present value is highly dependent on optimistic scenarios as to the revenue impact of broadband-based new services, only to be realized when the installed base of broadband has become significant and has diffused to the appropriate market segments. Furthermore, rapid diffusion of new technologies in the whole industry reduces costs and prices from the suppliers (due to learning effects and process innovations), which in turn allows even more rapid diffusion (compare the cost reductions in fibre optics). Thus, the diffusion process is extremely interdependent and complex.

A fifth area of difficulty is the effects of new performance and quality improvements in the network. Quality enhancement affects the

performance of the network but it is not always obvious how to transform performance changes into a positive cash flow in the appraisal. For instance, (irrespective of any systemic positive effects) how should better hearing quality due to digital switching be valued? Furthermore, in the inter-office network new ring-based network structures are installed in Swedish Telecom with increased redundancy and hence, increased network availability. However, there has been much discussion about and different approaches to measuring the benefits to the customer with as yet no final solution.

The emerging and increasing competition for telecom services in Sweden is another area which is difficult to incorporate into the actual investment appraisal.[13] Ideally, the opportunity cost of not investing should be incorporated into the appraisal (where the players' interdependent competitive moves could be modelled along the lines of game theory) but this is seldom, if ever, done in Swedish Telecom. Increasing quality competition further compounds the problem. There are of course several uncertainties involved when making estimations of opportunity losses that an appraiser must come to grips with. Nevertheless, several interviewees still felt that the appraisals needed to be refined in this dimension, as the 'nine-pointer' does not provide a financial analysis of the effects of competition.

A final area relates to the difficulties of measuring the financial effects of inflexibility (lock-in effects) and of flexible technical solutions.[14] Sunk costs, the existing network and existing network competence have added inertia to the implementation of new technologies and new ways of building the network in Swedish Telecom. For instance, the implementation of fibre in the local-loop has been made more difficult by Swedish Telecom's commitment to support some old terminals and certain alarm services. Furthermore, building networks with digital technology instead of analogue technology creates new opportunities for optimizing the inter-office network (quality of sound being less sensitive to distance), which are in certain instances difficult to reap due to lock-in effects of existing structures. When appraising the future network to be constructed, it is a very complex operation to disentangle the costs associated with inflexibility of current technologies and also those associated with the potential flexibility of the new technical solutions (for instance, the new ISDN-system can be reused if ISDN does not diffuse). All in all, different degrees of technical flexibility have similarities with financial options and it should be possible to value these similarly. However, Swedish Telecom has not developed many operational methods for valuation of real capital options.[15]

Managerial incentives

The investment procedures and processes also affect the investment appraisal and the manager's incentives to take investment decisions in new technologies over and above measurement problems discussed above.

Several managers within Swedish Telecom claimed that current procedures had an impact on the degree of conservatism (or carefulness) applied when deciding and appraising new technologies.

First, the telecom regions have been evaluated on the basis of the book ROCE (Return on Capital Employed) and recently the book ROE (Return on Equity),[16] together with quality measurements of the network (mean grade of blocking, etc.). Since the book ROCE has become increasingly important when assessing the performance of the telecom region and its managing director, the impact of the planned investment levels of new technologies on the book ROCE is studied carefully on an aggregate level in the telecom regions. This is so as new capital affects the size of depreciation as well as the size of capital, both having a negative influence on the book ROCE (or ROE), all else equal.[17] Second, being evaluated by the book ROCE with higher and higher target levels forces the manager to appraise not only investment plans with greater scrutiny but also individual investment projects.

A second factor that is claimed to contribute towards a conservative approach is the emphasis on the use of the 'nine-pointer' in the investment appraisal. When the 'nine-pointer' was implemented, special groups were formed at the headquarters and in the larger telecom regions for the purpose of evaluating the incoming investment appraisals and briefing the decision-maker. Some managers felt that these groups focused too much on form and on deviations from the 'nine-pointer', which in turn forced the appraisers to closely align themselves with the prescribed form. Furthermore, since the investment appraisals had shown, over and over again, that it was difficult to justify investments in new technologies at the same time as there was a gut feeling that these investments were needed, there was a desire among managers to find new and perhaps more fruitful ways to appraise the investments, which was not possible at the time. (However, very recently new methods of appraising investments have been encouraged and allowed, but this new attitude has not as yet penetrated the organization — see also above.) In this way the 'nine-pointer' tended to make managers more conservative.

Empirical summary

The investment management and appraisals in the telecom regions in Swedish Telecom are influenced by guidelines from several central departments and by corporate strategies as well as local strategies and policies. The investment management has evolved in several phases, from being centrally administered (before 1975) to being decentralized to the point where top management needed to interfere through imposing strict rules and guidelines (starting about 1982), as telecom regions differed widely in the way large capital investments were managed and appraised. The investment management has recently become more flexible, not only focusing on a single object but allowing analysis of groups of

investments. However, there is still a heavy emphasis on each investment appraisal following a structured presentation (the 'nine-pointer') and that the net present value should be calculated. The basic investment procedures are also intact: limits on expenditure determine who has the right to make investment decisions, and the investment appraisal is reviewed by several groups (the number depending on which hierarchical level makes the decision).

There are a number of problems relating to measuring the costs and benefits of new communications technologies, mainly arising from the complexity and systemic nature of the telecom network, from uncertainties about market demand and from technical change. Furthermore, the current mode of investment procedures and appraisals in Swedish Telecom has a two-fold impact on managerial incentives when investing in new technologies. First, evaluation of a telecom region's performance based on the book ROI tends to make managers more inclined to be conservative, and second, the strong emphasis on following a prescribed method for appraisals reduces the incentives to find new approaches to investment appraisals.

DISCUSSION

Introduction

In this section some answers are sought to the initial research questions. First of all, what is driving the need in Swedish Telecom (and supposedly, among telecom service providers generally) to develop and change investment management and appraisals, even though the methods arrived at closely correspond to the text-book recommendations? Second, can the notion that investment appraisals lead to too conservative investments (or more generally suboptimal decisions) be put in any kind of explanatory framework? Third, what is the role of strategies and policies in the management and appraisal of investments?

Drivers of new investment appraisals

In the empirical material above, several problem areas associated with measuring investments in new technologies were enumerated. The measurement problems could be interpreted as indicators of the real drivers of the perceived misfit of the current methods of investment appraisal. It is then important to find more aggregate dimensions of the measurement problems enumerated in Table 3 and to see how these throw light on the drivers of new investment appraisals.

Stated in more general terms, the problem areas in Table 3 can be further classified into uncertainty and complexity, where both variables affect all the problem areas to different degrees. Uncertainty here refers to the lack of knowledge of the state of the world (present and future). Complexity then refers to difficulties of knowing and processing all the

complex interactions of a knowledgeable world. Problems of managing complexity ultimately derive from bounds of rationality — with unlimited processing abilities, complexity will disappear.

Returning to Table 3, uncertainty and bounds of rationality do not come separately but interact and are contingent upon one another. In each problem area there is both complexity and uncertainty. For instance, measuring diffusion effects is not only operationally difficult because of analytical complexity and diverse sets of data but there is a great deal of uncertainty regarding the state of the relevant variables. Likewise, the effects of competition are also difficult to appraise, as it is not clear how to develop operational methods for the assessment in conjunction with uncertainty regarding the actions of the competitors. Furthermore, a fair analysis of network integration and systems interdependence is made more difficult by complexity as well as uncertainty. In fact, the very definition of uncertainty is closely connected with complexity.[18]

However, why are complexity/uncertainty important for Swedish Telecom at this time, as these, admittedly, have been a part of investments in earlier days? The answer seems to be that it has become increasingly important to manage uncertainty in the emerging competition in order to obtain a competitive advantage and to reach better business decisions. A more exact knowledge of, for instance, the dynamic effects of diffusion would make the optimal timing of investments in new technologies easier and hence confer a competitive advantage. Also, a better knowledge of the economic life-cycle of different generations of technologies would increase the probability of having a technology mix that closely corresponds to what the market demands. Furthermore, competition increases uncertainty, as there is not only uncertainty about states but also about the various players' actions and their collective impact on the market place.

Second, managing complexity is also increasingly important in a competitive environment. New technologies have new and complex systemic impacts that require a new analysis and appraisal, at the same time as a correct rate and direction of investments in new technologies have a decisive influence on the competitive outcome.[19] Old telecom technologies certainly also have systemic impacts but new technologies do not only have new forms of systemic impacts but also often involve new performance, compounding the difficulties. For instance, investments in new ring-based networks with fibre are difficult to appraise because of network integration (between the local loop and the inter-office network) and increased performance (new availability). Also, investments in new digital switching have a new systemic impact on the total network quality as well as enhancing network quality to the subscriber connected to the particular exchange. All these factors are complex to evaluate but increasingly important.

As a consequence, to resolve uncertainty and system complexity, a top-down perspective is needed in the investment appraisal. Integration of strategies and investments is needed, as the competitive threats and

increased importance of technical changes require a perspective of the whole in order to be managed effectively. The perceived difficulties associated with project oriented investment appraisals of managing uncertainties and complexities call for a broader approach, where business goals and strategies come to the fore. For instance, project-oriented investment appraisals of central offices do not, to a large extent, take account of the competitive advantage and the benefit to the network as a whole.

In sum, three drivers of new appraisals have been emphasized. First, in the face of emerging competition it is increasingly important to reduce and manage uncertainty in order to create a competitive advantage through new technologies. Second, as new technologies have new systemic impacts and new performance, it is more and more important to manage complexity and to economize on bounds of rationality. Third, as a consequence, the importance of strategic orientation of investments and of integration between strategy/investment appraisals has increased, which has led to a demand for changes in the appraisal and management of investments.

The case of investment conservatism

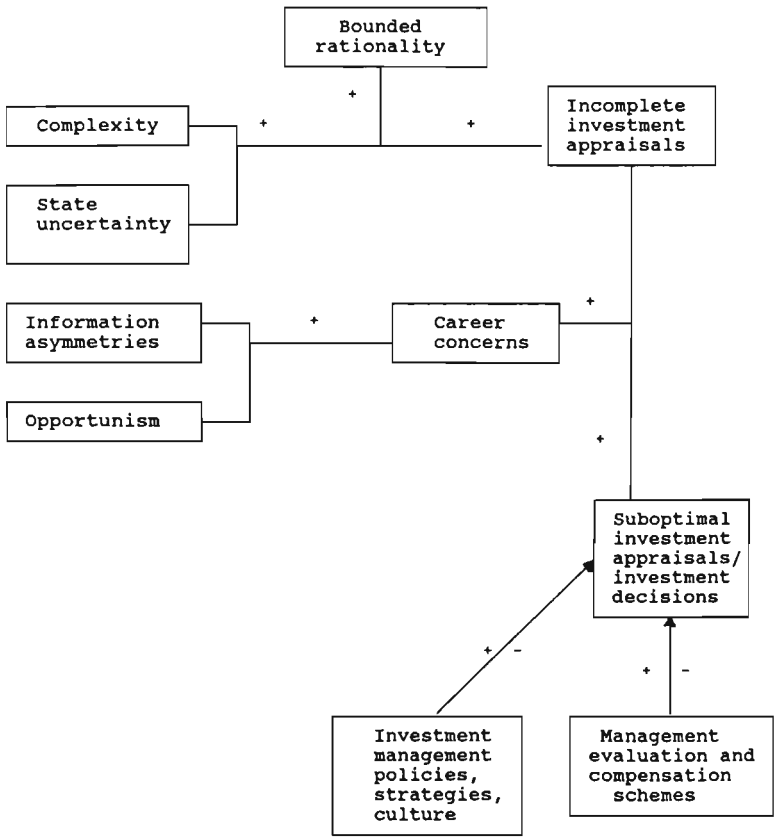
In the empirical section, the notion was put forward that current methods of appraising investments seem to favour old technologies rather than new ones, i.e., that they are technology conserving. This section aims to conceptualize in a general way the circumstances in which suboptimal investment appraisals occur (i.e., not only too conservative but also too risky investments),[20] assuming that the top management know the optimal investment path.

Figure 2 summarizes the argument. Starting from the top of the Figure, incomplete investment appraisals arise, as agents have bounded rationality and face a complex and uncertain world (uncertainty arising from unknown future states of the world). However, incomplete investment appraisals are not necessarily biased in any certain direction, as the impact of complexity and uncertainty could either reduce or increase the probability of technological inertia depending on the case at hand, and in the long run, random deviations can be expected to average out any bias. However, career concerns may affect the incentives for managers to supply top management with suboptimal investment appraisals and/or, in a decentralized fashion, to decide on suboptimal investments (i.e., too conservative/risky). The recommendation in the investment appraisal and the investment decision signal perceived ability which in turn affects the agent's future position and pay.

Career concerns arise when opportunism and behavioural uncertainty are joined. The latter has been emphasized in the literature on the principal-agent relationship[21] and appears when players have different information sets (which seems to be a very plausible assumption of the world as we know it). With the addition of opportunism the information

asymmetries are used strategically (i.e., with the intent to affect the other player's behaviour). The agent (in this case the sub-manager) has private information regarding, for instance, the stock of available investment projects, the effort made to make the investment project a success, his personal ability of managing business operations, etc. The output of the investment projected (and output related to the investments, i.e., the telecom region's profit) is however observable to top management who use this information to assess the ability of the manager (his ability to choose the right projects, his industriousness, his management ability, etc.).

FIGURE 2
Factors affecting the optimality of investment appraisals



The agent's strategic use of private information is furthermore affected by the way the agent is evaluated and the compensation he receives. If, for instance, the manager's responsibilities are evaluated predominantly on the basis of the current book ROI, this will negatively affect the incentives to make large investments with future pay-off. On the other hand, if the manager is evaluated on a more long-term basis, this evaluation scheme induces other incentives. The investment appraisal is furthermore affected by central guidelines, policies and strategies on investment management. For instance, there may be policies that affect various parameters of the investment appraisal (limits on capital spending, the discount rate, estimates of economic life-cycle, etc.). Also, there may be more general guidelines for the choice of technologies, and finally there may be guidelines for the appraisal method as such. Regarding the latter, the guidelines may be such that they tend to increase the private information of the agent, all else equal, as the method may prohibit or reduce the probability that certain information sets are included. For instance, in Swedish Telecom it was claimed that the implementation of the 'nine-pointer' did not encourage evaluation and discussion of qualitative information. A corporate culture conducive to informal discussion (i.e., to more communication than provided by the formal investment appraisal) may alleviate these potential problems.

To summarize, suboptimality of investment appraisals (where an optimality criterion is assumed to exist) arises when an agent (e.g., a manager) has private information and when the top management evaluate the agent based on an outcome that is contingent on the investment decision. The agent's incentives to use the investment for career purposes can be influenced by the top management by the use of evaluation and compensation schemes as well as by investment management policies in general.

Selective intervention in investment management

In the empirical material presented above, investment appraisals were supported and influenced by various forms of policies and strategies. A fundamental question is why these interventions exist in a decentralized firm, or, put differently, why does a firm exist at all? The very existence of firms implies some form of economic comparative advantage compared with a decentralized market organization.

Despite the fact that the questions at first glance may seem trivial, solid and in-depth answers to these questions are not easy to formulate.[22] In the preceding discussion, two factors surfaced. First, management of telecom networks may be so complex and interrelated that centralized strategies and policies are advantageous compared with decentralized investment appraisals. With increased competition, greater emphasis is placed on strategic orientation in order to effectively manage new technologies. Second, investment policies are important to align sub-managers' incentives with the firm's orientation or to otherwise correct the investment appraisal.

A further reason for not letting investments operate in a completely decentralized environment is the inseparability of the technological assets of the telecom network. Separating the different assets into marginal market values for the investment appraisal involves an expensive search and also costly negotiations between the different units of a firm. Instead, the investment appraisal considers only some of the benefits and some of the costs associated with an investment (for instance, in the case of Swedish Telecom, only the costs of investing in transmission are considered, not the revenues).

Non-separability of assets thus creates a need for other management systems to emphasize the whole and to complement an investment appraisal of a single object. The co-existence of several management systems (strategy systems, policy systems, investment appraisal systems) provides different perspectives and foci of analysis. Some management systems emphasize the whole (top-down systems — strategies), while other systems emphasize parts of the whole (bottom-up systems — investment appraisals), and the different systems interact in a complex way.

One of the initial questions of the research project — why conventional investment appraisals do not seem to deal fairly with new technologies — can then be given an additional, tentative answer. The decision to go ahead with some investments needs to be complemented by, influenced by and integrated with other management systems. Investments that would tend to need such support are investments whose overall benefits are new (breaking away from *status quo)* and apparent only from a top-down perspective.

In sum, selective intervention embodied in investment policies and strategies arises as a response to the complexity of telecom networks, managerial incentives and the non-separability of the assets in the telecom network. An optimal mechanism of selective intervention uses several management systems in a complementary fashion to further the goal of the firm.

SUMMARY AND CONCLUSIONS

Investment management in Swedish Telecom is influenced by guidelines and strategies from central departments as well as by local strategies. Investment management has evolved in several phases from being centrally administered to being decentralized, followed by renewed centralization. Coupled with the renewed centralization, a conceptual model was implemented (the 'nine-pointer') to structure investment appraisals and to ensure that net present values were calculated. The model continues to be the standard one even though other types of investment appraisals have been attempted recently.

Investment in new technologies in different parts of the network (transmission, switching, mobile telecom) is, however, difficult to appraise because of, among other things, systems interdependence,

network integration, diffusion effects, new performance of new technologies, and competition. Furthermore, there is a need to develop investment appraisals in order to manage uncertainty and complexity more effectively in an increasingly competitive environment, and also to achieve greater integration between the investment appraisal and the competitive strategy. Moreover, suboptimality of investment appraisals is contingent on the impact of informational asymmetries within the firm and on the evaluation of management and the compensation schemes used. Also, the design of investment management policies may reduce deviations from the desired investment path.

Several implications for management stand out (with corresponding research needs). First, increasing technological network integration must be followed by organizational integration. Investments in different parts of the network that hitherto have been managed and appraised separately need to be integrated and analyzed interdependently. Second, as complexity and the overall importance of correctly planned and executed investments have increased, investment appraisals need to be more closely connected with strategies. To make integration with strategies possible, investments must be appraised on a more aggregate level (i.e., investment programmes, investment plans) than solely on a project-by-project basis. Furthermore, management must seek to develop a contingency approach for different types of investments, where various management systems and policies are utilized and emphasized in a complementary fashion, depending on the case at hand.

Moving specifically to the cases of radical technological substitutions *versus* more evolutionary technical change, it is in the former case advisable to have centralized investment management. Centralized investment management determines the technologies to be invested in, controls the aggregate rate of investments in the new technologies and the exiting process of old technologies, and likewise monitors the aggregate investment levels of mature technologies. This seems reasonable as investment appraisals in periods of technological transitions become strongly contingent on technological and business expectations, on the expected investment decisions (in the firm, in the industry, among suppliers and buyers), and on the consequent intra-firm and inter-firm diffusion, which in turn often induces technological change and cost reductions ('learning by using', 'learning by producing'). Expectations may tip the interacting process in one direction or the other with the consequence that an *ex post* suboptimal technology is chosen. Co-ordinated investment may be called for when there is an incidence of volatile (or sensitive) expectations or when positive systemic benefits are involved and a critical mass is needed in order to start the investment process (a marked feature of telecom networks). However, with more mature stages of technological change it is advisable to decentralize the investment decision to local profit centres, as the diffusion process is already under way, as well as to provide managers with productive incentives and responsibilities.

APPENDIX 1: CONCEPTS AND KEY TERMS

Several concepts related to investments need to be clarified. *Investments* are defined in accordance with Massé:[23]

> it [investment] constitutes the sacrifice of an immediate and certain satisfaction in exchange for a future expectation whose security lies in the capital invested.

Offensive investments refers to such investments that principally aim to create technical or market leadership in at least one dimension of a competitive advantage. *Investment management* refers to the policies, organization (for instance, responsibility and decision levels) and evaluation systems that are intended to influence capital investment decisions. A part of investment management consists of *investment appraisals,* which are here defined as methods for computing the economic value of the investment, the intended way of screening available alternatives and the final actual document intended to guide the decision by management. *Policies* refer to guidelines for repetitive decision-making, whereas *strategy* emphasizes guidelines used for decision-making in a competitive environment.

Central offices (COs) refer to the switching system used for public telecommunications systems, and the *inter-office network* refers to the transmission links connecting various COs. The inter-office network discussed here is mostly regional, but it is possible to integrate the inter-office network with the national network. The *local loop* refers to the circuit connecting a subscriber to the local central office. *Mobile telecom* refers to the telephone system with portable or transportable telephones accessing the public network by radio frequencies instead of using wires. The radio signal is transmitted to base stations which are connected to the fixed network. The traffic flow from the base stations is switched to the controlling mobile telephone exchange which redirects the calls.

APPENDIX 2: EXAMPLES OF INTERVIEW QUESTIONS ON INVESTMENT MANAGEMENT AND APPRAISALS

Investment management in general

How has investment management evolved and what were critical incidents in the evolution? What were the problems involved in each phase? Why did it evolve as it did?

Investment appraisals

What determines the selection of the competing technologies in the investment appraisal?
What technological alternatives are considered (old, new, hybrid, next-new)?

How have qualitative (non-financial) factors been treated in investment appraisals? Have such factors justified a heavier investment at any time?
Are there any categories of expenditures and revenues that are particularly sensitive to change?
Which inputs to the investment appraisal are particularly uncertain?
Are any aspects of investments left out of the investment appraisal? Which? Why?

APPENDIX 3: THE MODEL FOR INVESTMENT APPRAISAL (THE 'NINE-POINTER')

The 'nine-pointer' consists of nine steps to be addressed for every investment appraisal in Swedish Telecom. The following points should be included:

1. Background and description of the problem at hand.
2. Assumptions made (i.e., discount rate, estimated life-cycle of the technologies, salvage values, planning horizon, prognosis of the growth in the area, etc.).
3. Presentation of the actual alternatives (i.e., the alternative of continuing the operations with the current mode and realistic competing alternatives).
4. Net present value of continuing with the current mode (i.e., continued operation with technologies currently used with no change in methods or equipment).
5. Net present values of competing alternatives.
6. Sensitivity analysis (i.e., evaluating the better alternatives along dimensions where changes may influence the order between the alternatives).
7. Effects on the budgets for the coming years (i.e., how do the different alternatives affect the budget within the next couple of years?).
8. Other consequences of the investment (i.e., how do the alternatives affect dimensions that are not easy to financially quantify? What is the technological and strategic 'fit' of the alternatives?).
9. Explicit recommendation as to the best alternative.

The main aim of the model is to provide the decision-maker with a structure that makes the analysis and assessment of the investment appraisal easy. The model is also intended to give the decision-maker an overview, a sense of the whole, and not to overload him with details. One of the main criticisms of the way in which the model has been implemented is that point eight (qualitative consequences of the investment) has not been used enough, and when it has been used, it has not carried enough weight for the decision to invest.

NOTES AND REFERENCES

1. See for instance R.W. Crandall and K. Flamm, *Changing the Rules: Technological Change, International Competition and Regulation in Communications,* The Brookings Institution, Washington, DC, 1989.
2. A substantial body of empirical evidence supports the Schumpeterian propositions on the impact of technological competition (see for instance, A. Cooper and D. Schendel, 'Strategic responses to technological threats', *Business Horizons,* 19, 1976; and M.I. Kamien and N.I. Schwartz, *Market Structure and Innovation,* Cambridge University Press, 1982.
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4. J.S. Metcalfe, 'On diffusion, investment and the process of technological change', in E. Deiaco, E. Hornell, and G. Vickers (eds), *Technology and Investment,* Pinter Publishers, 1991; W.B. Arthur, 'Competing technologies increasing returns and lock-in by historical events', *Economic Journal,* 99, March 1989, pp. 116-31; P.A. David, and S. Greenstein, *The Economics of Compatibility Standards: An Introduction to Recent Research,* CEPR Publications No. 207, Center for Economic Policy Research, Stanford University, 1990; C. Antonelli, 'Investment and adoption in the international diffusion of advanced telecommunications', paper presented at the *17th Conference of the European Association of Research on Industrial Economics,* 1990, Lisboa; and 0. Granstrand, 'Temporal diffusion and population dynamics: a systems model', in A. Grübler and N. Nakicenovic (eds), *Rat Race Dynamics and Crazy Companies: The Diffusion of Technologies and Social Behavior,* Springer-Verlag, Berlin, 1990.
5. See A. Dixit, 'The role of investment in entry deterrence', *Economic Journal,* 90, 1981, pp. 95-106; R.J. Gilbert, 'Mobility barriers and the value of incumbency', in R. Schmalensee and R.D. Willig (eds), *Handbook of Industrial Organization,* 1, Elsevier, 1989.
6. See R.A. Skoog, 'The design and cost characteristics of telecommunications networks', Bell Telephone Laboratories, 1980.
7. For a detailed description of competitive threats and opportunities facing Swedish Telecom, see E. Bohlin and 0. Granstrand, 'Strategic options for national monopolies in transition: the case of Swedish Telecom', *Telecommunications Policy,* 15, 5, October 1991, pp. 453-76.
8. See for instance H.T. Johnson and R.S. Kaplan, *Relevance Lost — The Rise and Fall of Management Accounting,* Harvard Business School Press, 1987; H.R. Parsaei, T.L. Ward and W. Karwowski (eds), *Justification Methods for Computer Integrated Manufacturing Systems,* Elsevier, 1990.
9. The use of case studies to generate theory has increasingly become an accepted research approach, especially since Glaser and Strauss in 1967 pointed out the need in research for theory generation rather than solely theory verification. The generality of a case study then lies in its ability to generate theory and hypotheses with wider applicability than the case at hand. The methods used in case studies have also been expanded from being ethnographically based, as initially in Glaser and Strauss, to constituting a general approach for qualitative research in the social sciences. See B.G. Glaser and A.L. Strauss, *The Discovery of Grounded Theory: Strategies for Qualitative Research,* Aldine de Gruyter, 1967; K.R. Yin, *Case Study Research: Design and Methods,* Sage Publications, Beverly Hills, 1984; and K.M. Eisenhardt, 'Building theories from case study research', *Academy of Management Review,* 14, 4, 1989, pp. 532-50.
10. In December 1990, the Board of Swedish Telecom proposed to the government that it be organized as a corporation. This change will take place in January 1993 but Swedish Telecom will not yet be privatized at this stage.

11. The rest of the units are of secondary importance for our purposes. They are first three national divisions — cable TV services, directory services and electronic data processing services. Second, TELEINVEST is a fully owned subsidiary that in turn owns companies that are engaged in international telecom consulting, value-added services, software and industrial production. Finally, ELLEMTEL is a joint venture with Ericsson for the development of the AXE switching system.
12. For a detailed treatment, see E. Bohlin, 'Techno-economic management of investments: offensive investments', (Licentiate Dissertation, Chalmers University of Technology, 1990).
13. For a detailed description of competitive threats and opportunities facing Swedish Telecom, see E. Bohlin and 0. Granstrand, *op. cit.*
14. For a general theory of lock-in effects, see Arthur, *op. cit.*
15. Of late there have appeared several theoretical papers that attempt to value real as opposed to financial options, building on the option pricing model, see, for instance, P. Bjerksund and S. Ekern, *Managing Investment Opportunities Under Price Uncertainty: From "Last Chance" to "Wait and See" Strategies,* Norwegian School of Economics and Business Administration, 1989. However, most of these models are not suitable for practical applications.
16. The telecom regions are not legally separated as companies but debts and equity have been allocated to the different regions.
17. In fact, it can be shown that the higher the growth, the lower the book ROI (Return on Investment) compared to the true economic return. This is due to linear depreciation which is not based on changes in the market value of assets from one period to another. See R. Brealey and S. Myers, *Principles of Corporate Finance,* 3rd ed., Prentice-Hall, 1989, ch. 12.
18. O.E. Williamson, *The Economic Organizations of Capitalism,* Free Press, 1985.
19. See E. Bohlin and O. Granstrand, *op.cit.*
20. For the ensuing arguments I have benefited much from discussions with Alain de Fontenay, Bellcore. However, any errors remain mine. Important references for the argument are 0. Hart and B. Holmström, 'The theory of contracts', in T.F. Bewley (ed.), *Advances in Economic Theory,* Cambridge University Press, 1987; and B. Holmström, 'Agency costs and innovation', *Journal of Economic Behavior and Organization,* 12, 1989, pp. 305-27.
21. For an accessible survey, see D. Levinthal, 'A survey of agency models of organizations', *Journal of Economic Behavior and Organization,* 9, 1988, pp. 153-85.
22. For in-depth discussions, see Williamson, *op. cit.;* and B. Holmström and J. Tirole, 'The theory of the firm', in R. Schmalensee and R.D. Willig (eds), *Handbook of Industrial Organization,* Elsevier, 1989.
23. P. Masse, *Optimal Investment Decisions,* Prentice-Hall, 1962, p. 1.