Innovation Systems and European Integration (ISE)

A research project funded by the Targeted Socio-Economic Research (TSER) program of the European Commission (DG XII) under the Fourth Framework Program, European Commission (Contract no. SOE1-CT95-1004, DG XII SOLS), coordinated by Professor Charles Edquist of the Systems of Innovation Research Programme (SIRP) at Linköping University (Sweden).

Sub-Project 3.2.2: Government Technology Procurement as a Policy Instrument

Public technology procurement in the Finnish telecommunications industry

Submitted to the Commission: March, 1998

Christopher Palmberg

VTT Group for technology studies
P.O Box 1002
FIN-02044 VTT
FINLAND
TEL: +358 9 456 4258
FAX: + 358 9 456 7007
E-mail:christopher.palmberg@vtt.fi

Abstract

This paper discusses public technology procurement from the perspective of the PTT's procurement of the DX 200 digital switching system, equipment for the NMT and KAUHA paging network in the Finnish telecommunications industry. The theoretical and conceptual framework draws on a systems of innovation approach using development bloc and technological systems theory, as well as previous research on technology procurement. It is suggested that public technology procurement has generated a set of structural tensions as the main driving force for the evolution of the industry, and Nokia, up until the mid 1980s. These characteristics of the PTT's procurement activities stem from an entrepreneurial mind-set, a decentralised system of operators and the presence of foreign competition on the market, rather than a policy making process. Policy implications thus relate to the role of contextual factors, complementary policies as well as standards during procurement processes.

Keywords

technology procurement, technological systems, Finnish telecommunications industry, structural tensions, standards

CONTENTS

1. INTRODUCTION 4

2. TOWARDS A THEORETICAL AND CONCEPTUAL FRAMEWORK 7

2.1 The 'demand-pull' and 'science and technology-push' debate 7
2.2. Systems of innovation approaches 8
2.2.1. Structural tensions, development blocks and technological systems 9
2.2.2. User producer interaction 13
2.3. User producers interaction and public sector users 15
2.3.1. Organised markets and market structures 16
2.3.2. Public sector user competencies 18
2.3.3. Public sector demand, technological development and the overall 'policy mix' 20
2.3.4. Political factors and 'institutional rivalry' 21

3. THE INSTITUTIONAL FRAMEWORK: THE NATIONAL SYSTEM OF INNOVATION AND FINNISH TELECOMMUNICATIONS POLICY 23

3.1. The main characteristics of the Finnish system of innovation and technology policy 23
3.2. Public technology procurement regulations and norms - past and present 25
3.3. The regulatory structure of telecommunications operators as the buyers and users of telecommunications equipment 28

4. THE KEY ORGANISATIONS INVOLVED, THEIR COMPETENCIES AND OTHER RESOURCES 31

4.1. The evolution, structure and competencies of the Finnish telecommunications equipment producers - the evolution of Nokia 31
4.2. The PTT as a public sector procurer - developing competencies and procurement strategies in a dynamic market 36

5. ORGANISATION AND MANAGEMENT OF THE PROCUREMENT PROCESS 42

5.1. Developing the DX 200 system 42
5.2. Standardisation and procurement - developing NMT cellular systems 53
5.3. Tecnomen and radiosynchronised transmission systems for the KAUHA paging network 69

6. APPRAISAL OF SOCIETAL AND INDUSTRIAL RESULTS AND POLICY IMPLICATIONS 80

6.1. Structural tensions in the Finnish telecommunications industry - the history revisited? 80
6.2. Organisation, management and effectiveness of technology procurement in the Finnish context 86
6.3. Policy implications 94

REFERENCES 98

1. INTRODUCTION

This paper discusses the role of the public sector in the process of technological change from point of view of public technology procurement in the Finnish telecommunications sector. Following Edquist & Homén (1997) public technology procurement is defined as the activity whereby a public sector agency places an order for a product or system which does not exist at the time, but which could (probably) be developed within a reasonable period. Additional or new technological development work is required to fulfil the demands of the buyer.[1] Edquist and Homén (1997) also make a distinction between 'development oriented' and 'adaptive oriented' procurement. Development oriented procurement concerns cases where a product or system is procured which is new to the world. Adaptive oriented procurement concerns cases where a product or system is procured which is not new to the world but still new to the country of procurement.

Broadly speaking, one can distinguish between two streams of underlying theoretical work on the role of the public sector in the process of technological change. On the one hand, the neo-classical market failure theory postulates that firms tend to underinvest in R&D due to involuntary R&D spillovers to competing firms. Within this framework, the role of technology policy is merely to intervene when markets fail and to maintain the sufficient level of basic research through R&D funding and other supply-side technology policy instruments.[2] By contrast, evolutionary economics, and the related systems of innovation approach, stresses the interactions between supply and demand factors. From this perspective there are frequent nodal points and interactions between innovating firms, external institutions and market demand. Hence, governments should not merely support the supply of R&D. Instead policy should focus on the intersections of demand and supply, in order to identify new potentially marketable technologies and to encourage their development and application.

---

[1]It is important to note that this definition does not encompase public procurement of ready made simple products 'off the shelf', which does not involve R&D.

[2]The market failure theory, often associated with Nelson (1959) and Arrow (1962), adopts a linear view on technical change in that more R&D input is assumed to lead to more innovation output as a smooth progression from scientific discovery through applied resarch and development in firms, and further to a stream of new products.

Evolutionary economics, and the systems of innovation approach, postulates a more active role for government policy compared to neo-classical theory. It also extends the range of possible government policy instruments to include more demand oriented instruments, such as public technology procurement involving a public sector authority as a technology procurer. (see e.g. Lemola 1995, Edquist 1996, Edquist & Homén 1997).

Recently the Finnish telecommunications industry has been analysed from a systems of innovation approach following Porter's (1990) theory of the 'competitive diamond' (see Rouvinen 1996), or from the point of view of the corporate management and Nokia (see e.g. Mäkinen 1995, Koivusalo 1995, Lemola & Lovio 1996). It is generally understood that bold managerial decisions as well as the competitive market situation of Finnish telecommunications, along with favourable factor and demand conditions, has been the main reasons for the evident international success of the Finnish telecommunications industry. The role of public sector activities has been less well documented for. This paper analyses the evolution of the Finnish telecommunications from point of view of public technology procurement by the PTT, or Telecom Finland.[3] It is suggested that technology procurement by the Finnish has played a more important role than what has been accounted for so far even though the public policy content of the PTT's procurement decisions has been less relevant than other factors. This proposition is illustrated through in-depth case studies, based on available literature and interviews, of technology procurement of the digital DX 200 switching system, NMT cellular network equipment (MTX switching system, base stations and transmission systems) and radiosynchronized paging network systems (the KAUHA system and the PNU controller).

Characteristic to all three cases is that the technology procured mainly represented an articulation of the PTT's need to develop a modern functional telecommunications network in Finland to meet anticipated socio-economic needs on the the telecommunications equipment and service market. In the case of the DX 200, adaptive oriented procurement by the PTT was crucial for the continuation of the lengthy digital

---

[3] In 1990 the Finnish PTT was transferred from a state-owned monopoly into a state-controlloed commercial enterprise, and in 1994 into a limited company named Telecom Finland. For the sake of clarity the abbreviation PTT is used throughout this paper. PTT is an abbreviation for the legal entity responsible for the regulation and operation of all public communications services. Note also that the PTT is treated as one coherent entity throughout this paper despite the fact that there have persisted many different viewpoints regarding procurement decision within the PTT.

switching venture, while the DX 200 switching technology that was developed provided a flexible and price-worthy basis for subsequent modernisation of the PTT's networks. The NMT project stemmed from the Nordic PTT's visionary business minded application and refinement of cellular technologies which were disseminated through the Finnish PTT to Nokia (a combination of development and adaptive oriented procurement originating from the Nordic level), while the KAUHA case illustrates what could be called a rather clear-cut example of development oriented procurement of an enabling technology fulfilling a clearly defined socio-economic need. The cases thus provide an interesting illustration of rather successful coupling of public sector user and private sector producer needs in the telecommunications equipment market. Furthermore, while these chosen cases are interesting in their own right, they have also been crucial for the evolution and success of two major Finnish telecommunications firms; Nokia (fixed and mobile network equipment, mobile telephones) and the smaller firm Tecnomen (voice paging network equipment).

The paper is organised as follows. Chapter 2 elaborates on systems of innovation approaches and previous empirical work on public technology procurement, in order to create a theoretical and conceptual framework for studying the role of public technology procurement for the overall development of the Finnish telecommunications industry. In chapter 3 the institutional framework for technology procurement is described, including some main features of the Finnish telecommunication policy. The fourth chapter presents the key organisations involved, as well as the development of their competencies and other resources. Chapter 5 contains a presentation of the cases, while chapter 6 analyses the case studies in light of the theoretical and conceptual framework developed in earlier chapters, and policy conclusions are drawn as the discussion is angled more towards the future viability of using public technology procurement explicitly as a policy instrument.

2. TOWARDS A THEORETICAL AND CONCEPTUAL FRAMEWORK

2.1. The 'demand-pull' and the 'science and technology-push' debate

One central debate within the economics of technical change concerns the relative significance of 'demand-pull' versus 'science and technology push' factors in the process of innovation (Freeman 1994). The science and technology push view very much relies on the simple linear neo-classical model of innovation which assumes a smooth progression from scientific discovery through applied research to technological development and production activities in firms, leading to a stream of new products into the marketplace. In this model the marketplace is merely described as the place where innovations are commercialised, while the consumers play no active role in the process of innovation. In terms of technology policy the prescriptions seem quite clear: more R&D input equals more innovation output. Hence, governments should maintain the sufficient level of basic research through R&D subsidy and other forms of supply-side measures. Indeed, this also seems to be the logic of many technology policy programmes in contemporary economies. (Freeman 1994, Rothwell 1994, Mowery 1995).

The widespread adherence to the linear view of technological change is all the more surprising considering the vast empirical and theoretical work available, in support of a more complex view on technological change. Rothwell (1994) identifies five generations of theoretical models of innovations. In the 1950s and 1960s the above mentioned first generation linear model was the prevalent one. As competition intensified in the 1960s considerably more emphasis was placed on the role of the market and the consumers. This lead to the emergence of the second generation linear need-pull (or market-pull) model of innovation. During the 1970s various detailed empirical studies of innovation (for an critical overview see Mowery & Rosenberg 1979) showed that the 'science and technology push' and 'need demand pull' were overly simplistic and wrongful models of a more general process of *coupling* between science, technology and the marketplace. Hence, the third, fourth and fifth generation models attempted to articulate a more complex view on innovation. Third generation models stressed the various interactive feedback loops at different stages of the innovation process (most notably the Kline & Rosenberg's (1986) 'chain-linked model'), while the fourth generation models highlighted functional overlaps or integration between different phases of the innovation process, whether between units in a firm or between firms, to explain the apparent success Japanese firms in the automobile and electronics industry (see e.g. Imai, Nomaka Takeuchi 1985). The fifth generation models, developed during the late 1980s and early 1990s, extend the analysis to cover networks of innovations, and postulate that the process of innovation has become more of a networking process. (Lemola 1994, Rothwell 1994).

The term 'networks' has been used widely to describe virtually all intra- and inter-firm, or inter-institutional, forms of collaboration. While network theories highlight the need for interaction between actors, and the processes which might shape such interactions, they seldom place networks in their broader institutional and economic context. They do not reveal who might be the central actors, or discuss the boundaries of the networks. Neither do they explicitly discuss the role of public institutions and public policies, such as procurement policies. Such considerations are included in systems of innovation theories of development blocs, industrial clusters, technological systems and national systems of innovation.

2.2. Systems of innovation approaches

Edquist (1997) proposes nine characteristics of the very heterogenous and broad body of literature which could be denoted the systems of innovation approach:

1) They place innovations and learning processes at the centre of focus - learning processes contribute to new knowledge and the recombination of existing knowledge.

2) They adopt a holistic and interdisciplinary perspective with the ambition to encompase in the analysis a wide array of the determinants of innovation, and also allow for the inclusion of broader institutional factors shaping innovations.

3) They employ a historical perspective where emphasis is placed on the co-evolution of technologies and institutions over time. Essentially tehy are concerned with transformation processes in the economic domain.

4) They stress differences between systems rather than the optimality of systems - thay are inherently comparative analytical tools.

5) They emphasise interdependence and non-linearity. Firms almost never innovate in isolation but are interconnected to a broader network subordinated various institutions such as laws, rules, regulations and cultural habits.

6) They encompase product technologies and organisational innovations and thus aply a differentiated concept of innovations.

7) They emphasise the central role of institutions in the broader meaning of the term (for a discussion see Johnson 1992).

8) They are still conceptually diffuse and unprecise.

9) They are conceptual frameworks rather than formal theories.

Even though there are several theoretical contributions which might bear close resemblance with a systems of innovations approach to technological change, the most prominent include the concept of national systems of innovation, put forward by Freeman (1987), Lundvall (1992a) and Nelson (1993), Porter's (1990) concept of industrial clusters and the competitive diamond and Dahmén's (1950 & 1989) and Carlsson's (1991 & 1994) concept of development blocks or technological systems. Here we will stick to development block and technological systems theory, as these tend to deal with the sectorial (industry or technology) clustering of activities, and primarily are geared towards explaining industrial *transformation* over time rather than the factors shaping the competitiveness of firms, industries and nations. For the purpose of this paper it seems that a development block and technological systems approach best interprets the role of public technology procurement for the evolution of the Finnish telecommunications industry.

2.2.1. Structural tensions, development blocs and technological systems

Dahmén stresses the Schumpeterian disequilibrium nature of economic development, resulting in continually changing relationships or structural tensions between economic agents, or entrepreneurs, at different levels of aggregation (for example between users and producers within a firm, between different firms, or between firms and other external institutions in their broader socio-economic environment). Structural tensions arise as part of entrepreneurial activities, as 'new' things are introduced which lead to a process of creative destruction as 'old' things are outcompeted. It is these structural tensions, or the conflict between 'new' things and 'old' things, which are the driving forces of industrial transformation. Examples of positive transformation include the introduction of new methods of production and marketing, the appearance of new marketable products and services, the opening up of new markets, the exploitation of new sources of raw materials and energy, and so on, while negative transformation is brought about through the scrapping of old methods of producing and marketing products and services, the disappearance of old products and services, the decline and fall of old markets, and the closing of old sources of raw material and energy.

In Dahménian terms, industrial transformation thus occurs in a sequence of structural tensions. Resources will cluster around certain industries, or technologies, in the form of a development blocs, once there are sufficient and competent entrepreneurs to seize the opportunities which are generated through the structural tensions. The other crucial factor is the existence of suitable institutional environment, such as groups of people with vested interests, favourable market structures, government regulations and a suitable legal framework. The same factors are important, when structural tensions lead to negative transformation, as development blocs risk losing their development power. (Dahmén 1989).

The concept of technological systems is an extension of the development bloc approach, but Carlsson is more specific in dealing with the factors which lead to the clustering of resources, in this case around certain key industries or core technologies. Carlsson is also more specific concerning policy implications. A technological systems might be defined as:

"...a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilisation of technology. Technological systems are defined in terms of knowledge/competence flows rather than flows of ordinary goods and services. They consists of dynamic knowledge and competence networks. In the presence of an entrepreneur and sufficient critical mass, such networks can be transformed into development blocks, i.e. synergistic cluster of firms and technologies within an industry or a group of industries". (Carlsson & Stankiewics 1991, 26).

There are three central elements, or concepts, inherent in the technological systems approach; namely the institutional infrastructure, knowledge/competence networks and economic competencies.

1) The institutional infrastructure of a technological system consist of a set of institutional arrangements which directly or indirectly support, stimulate and regulate the process of innovation and diffusion of technology. Carlsson & Stankewics make a distinction between basic economic institutions, such as the political system and educational system, patents legislation, institutions regulating labour, factor, capital and fiscal markets, which might be common to many technological systems, and the system of production and distribution of knowledge (the R&D system) which might be specific and different for each technological system. Institutions of the latter kind are essentially related to F&U within industry, academic infrastructure and other public sector research institutions or 'bridging institutions', and sector specific policies such as subsidies or procurement policies. It is argued that these institutions contribute to the creation of technological variety, or the pool of technological opportunities in the system, as well as to the selection of technologies through their effects on market competition and structure.

2) Knowledge/competence networks - or relations between different actors - forms the second important element. As opposed to traditional market signals, such as price and cost signals, the essential function of networks is the exchange of information. Information exchange reduces the uncertainties of investment decisions, generates knowledge and diffuses knowledge. Carlsson & Stankewics stress the importance of trust between the actors, and the importance of the economic competencies of the actors involved.

3) The concept of economic competencies is at the core of technological systems. While the institutional infrastructure, and networks form the basis for a technological systems, the role of entrepreneurs and entrepreneurial activity is pivotal in order for a technological system to come into being. Characteristic for such kind of entrepreneurial activity is the economic competence of the actors involved. Economic competence is defined along four dimensions; selective capabilities, organisational capabilities, technical capabilities and learning abilities (see Carlsson & Eliasson 1994). The *selective capabilities* of actors include the ability to make innovative choices of markets, products, technologies and overall organisational structure; to

engage in entrepreneurial activity; and especially to select key personnel and acquire key resources, including new competencies. *Organisational capabilities* refers to the abilities to organise business units in such a way that there is greater value in the corporate entity as a whole than in the sum of it's parts. *Technical abilities* refers to various function within organisations, such as production, marketing engineering, R&D e.t.c, and *learning abilities* refer to the shaping of organisational culture which encourages continual change in response to changes in the environment. Economic competence must be present in sufficient quantity and quality ("critical mass") on the part of all relevant agents, including users as well as producers and other private/public sector agents.

As the above presented 'Dahménian' approach puts such concepts as changing relationships and structural tensions between actors, the co-evolution of technologies, markets and institutions, and the importance of economic competence at the centre of analysis, as opposed to Porterian competitive factors, the role of public policies becomes more evident. As such a Dahménian approach also constitutes a promising framework for analysing public technology procurement. According to Carlsson (1994) public policy, should be targeted to the specific problems in each specific area, whereby the necessity, means and magnitude of public intervention will vary from one area to another. Public policies might be designed to increase the institutional adaptiveness towards technical change in a certain field (for example through regulatory reform and organisational change, through the founding of bridging institutions and research collaboration). They might have a system-building function, enhancing the connectedness of various agents and entities within a network - or the 'critical mass' of networks (for example through the founding of bridging institutions and research collaboration) - they might aim at fostering the economic competencies of agents (for example through educational measures and funding of basic research, or through monitoring technological advances abroad and aiding in their diffusion). On the basis of studies in Sweden, Carlsson (1994) especially highlight the crucial role of competent buyers, or users, and close long-term collaboration between users and producers These users are often private firms but may also be public agencies. From this perspective public technology procurement might provide resources for system building. (Carlsson 1994).

2.2.2. User-producer interaction

The interactions between users and producers of technology constitutes a key element in most systems of innovation approaches - the micro theoretical foundation so to say - even though there exists few detailed studies of the actual dynamics of such relationships. This is especially the case concerning public sector users. Concepts such as structural tensions, and economic competencies might illustrate the forces which motivate users to interact with producers, and vice versa, in the context of the broader economic and institutional environment. In the following the notion of user producer interaction is approached from the point of view of contributions by Burenstam-Linder (1962), Lundvall (1992) and von Hippel (1988).

Burenstam-Linder (1962) was among the first to discuss the importance of users for innovation. Burenstam-Linder links the existence of qualitative home market demand, with successful exports. Burenstam-Linders so called home-market theory of export specialisation has subsequently been modified and incorporated into various trade theories. It has also been drawn upon to call for infant-industry policies, whereby domestic firms are sheltered from international competition at the early stages of the industry life-cycle.

More recently user producer interaction have been discussed in more detail by Lundvall. Through his theory of user producer interaction he shifts the focus from allocation and commodity exchange, guided by price signals, towards innovation, guided by non-price signals. As innovation by definition involves uncertainties, users and producers cannot co-operate anonymously through price signals. Instead Lundvall puts forward the notion of organised markets in which reciprocal information flows between users and producers are crucial to successful innovation. These observations might come as no great surprise to entrepreneurs and to students of the innovation management literature. However, the main thrust of Lundvalls arguments is that markets are organised differently in different 'national (or why not regional or sectorial) systems of innovation', as the behaviour of agents belonging to different systems are governed by different institutional configurations, rules and norms, or different institutional set-ups.

Lundvall highlights problems of organising co-ordination and exchange of information when the innovating producer and the potential user belong to two different organisations, separated by a market. Such organisational aspects might be related to arranging the mode of qualitative information flows and direct co-operation, in the face of different kinds of technological change.They might be related to hierarchical forms, reflecting the power distribution of the relationship by means of financial power or superior scientific and technical competence (market position and structure). They might also be related to aspects of mutual trust and codes of conduct. Lundvall then uses these different aspects of user producer interaction to discuss the prospects and problems of organised markets.

The main line of Lundvall's argument is that the technical competence of the users, or the quality of demand, is crucial. Technologically weak users might lead the innovation process astray. Closely related are considerations of the market structure of the users as well as the producers. If the user side of the market is dominated by one technically and financially strong and well organised user (monopsony) this user will have greater potential to influence the direction of technological change. Likewise, being dependant upon a diverse set of competing users with very unspecified needs (oligopsony or polyopsony) might make it difficult for the producer to accumulate experience and to exploit economies of scale. In other situations, when user producer relationships are dominated by strong dominance of producers (monopoly or oligopoly) user needs might deviate considerably from the actual goods produced. Finally, considering elements of hierarchy and trustworthiness, Lundvall acknowledges that too rigid and established user producer relationships might lead to opportunistic behaviour in the long run and eventually slow down the rate of innovation. This situation might occur, for example if suppliers are tempted to substitute low price for quality while users might favour national suppliers, or 'national champions'. According to Lundvall, the rigidity of user-producer relationships might be especially harmful in the face of radical change, manifest as a mismatch between the co-evolution of organised markets and technologies. (Lundvall 1992).

The von Hippel study (1988) is more empirically oriented. His main enquiry was to determine how an innovating firm goes about acquiring an accurate understanding of user needs, through very detailed case studies of process equipment used by the electronics industry. He concludes that the innovation process for the most part is "user dominated", where the user: 1) Perceives the need for the innovative industrial good; 2) Conceives a solution; 3) Builds a prototype device and 4) Proves the value of this prototype by using it. Only at the stages of redesign, production, diffusion and commercialisation will the role of the producer become more important and dominate the innovation process. Thus, von Hippel proposes a theory of the "functional sources of innovation", which predicts that markets will be divided into different user-groups on the basis of very specific functional requirements of the users. In this way he also very much underlines the importance of user competence for successful innovation. From the point of view of the producer, the main task then becomes to identify such competent users whose functional requirements correspond to needs that will be general in a market place some months or years in the future, and which are positioned to benefit significantly by obtaining a solution to their needs. Von Hippel calls such users lead users. (von Hippel 1988).

2.3. User producer interaction and public sector users

Conventional wisdom generally considers market demand in the realm of the private sector, while public technology procurement per definition takes place in public goods markets, or at least in markets where the public sector is one important buyer among other private sector buyers. Interest in the use of public technology procurement as an instrument for promoting industrial innovation has partly been inspired by the above mentioned theoretical considerations of the importance of demand-pull factors in the process of technological change, as well as by various systems of innovation theories of the user producer kind.[4]

For the most part research on public technology procurement has been carried out using case study methodology. The case studies covering technology procurement have mainly focused on organisational aspects, with the aim of providing some guidelines for the efficient management and use of public technology procurement in order to stimulate industrial innovation. The studies thus function as a conceptual framework for designing the 'optimal interface' between public sector users and private sector producers in the above proposed Lundvallian sense. The main results of the various case studies have been reviewed by Rothwell & Zegweld (1982), Geroski (1991), Dalpé (1994) and partly also by Rothwell (1994). In general these reviews discuss cases for and against

[4]Authors frequently refer to Mowery & Rosenberg (1979), von Hippel (1988), and to Lundvall (1992).

the use of procurement policies, in relation to four main topics which seem to have been assigned special importance; namely market structures, public sector user competence, the different stages of development of the technology life-cycle as anticipated by Kline & Rosenberg (1986), the institutional set-up and the overall 'policy mix' of public sector involvement. The reviews are summarised below under these four main topics, even though there obviously will exist several overlaps.

2.3.1. Organised markets and market structures

As Lundvall points out, hierarchial forms reflecting power distributions in organised market, will affect the nature of user producer interactions. In the case of public sector involvement in certain industrial sectors there might be built in power distributions depending on the specific sector (i.e. public goods or not public goods) and depending on the economic and political heritage of different countries. Overall, the role of market structures for innovation is a fundamental and disputed question, especially in relation to the market structure of buyers, or producers (see e.g. Kamien & Schwarz 1975). Rothwell & Zegweld (1982) use the theoretical distinction between monopsony, oligopsony and polypsony to discuss the relevance of market structure on the demand (procurement) side.

In the case of monopsony a public sector authority is the sole buyer in a market. Such markets generally produce public goods, such as military goods, telecommunications, transportation. Rothwell & Zegweld argues that the potential for an innovation oriented procurement policy is greatest in the case of a monopsonistic market, given the significant market power of the public sector. Dalpé (1994) concludes that in general the increased value of orders is often assured by a greater concentration of demand, which in turn influences the suppliers to more closely satisfy the requirements of the buyer. In such cases procurement orders are of a sufficient value to allow companies to offset R&D costs and reduce risks. Similarly even a smaller 'first-mover' order might stimulate R&D, if the sole public sector buyer can guarantee follow-up contracts. Further, the allocation of orders to a fairly wide range of firms could ensure that elements of competition are established on the market. These kind of observations are usually based on studies of large scale European and American defence sector procurement programmes, in such fields as early computers, semiconductors and aeronautics where the defence authorities had a natural monopoly position. (Dalpé 1994, Geroski 1991).

On the other hand there is also abundant evidence that monopsonistic buyers market might have retarding effect on innovation. Frequently quoted examples include 'national champions policies', which typically have been employed in the European telecommunications sectors. Hence, a monopsonistic buyers market might lead to a situation were user producer interactions become too routinized, or even internalised through the forming of a state-owned company. The situation appears similar to Lundvalls notion of rigid user producer relationships, where producers are tempted to substitute low price for quality and thus slow down learning and technical change.

In an oligopsonistic market a number of other large buyers besides the government are in the market, either in the private or public sector. A situation where the market consists of government authorities and semi-governmental authorities can also be described as oligopsonistic, depending the degree of autonomy of the semi-governmental authorities vis-a-vis the state. In this context, Rothwell & Zegweld (1982) refer to cases which illustrate the role that one oligopsonist can play as a 'quality leader', in much the same way as the behaviour of the 'price leader', in industrial organisations theory of oligopoly. The quality leader might set de facto standards and influence the decision of the other oligopsonists and in this way influence technical innovation in the supplying firms. Another aspect of oligopsony is that more co-operative agreements might be concluded between single oligopsonists and the various suppliers, if the the market structure of the supplier is more diverse.

In the case of polypsony, the government is only one of many buyers and its share of the market is relatively small. This is the usual position of the government, if we are not dealing with pure public goods markets. According to Rothwell & Zegweld (1982) a government can still pursue an active procurement policy aimed at innovation, but the effect will in principle be limited to that small share of the market, while the innovative effects on the producer side will be small.

When turning to the effects of the market structure of the suppliers, it seems obvious that this side of the market will be less relevant in the context of public technology procurement as defined in this paper. However, Rothwell & Zegweld (1982) list a number of problems which might arise in this context. In the case of monopoly with only one supplier, there is considerable danger that a similar kind of 'national champion' policy situation might arise as was discussed above, as a close and rigid relationship might develop between the supplier and the government. Again this would retard competition, and slow down technological development as the suppliers substitutes price considerations for R&D strategy. Concerning more decentralised markets Rothwell & Zegweld point out that they might also be important in generating variety through parallel and competitive developments of different technological approaches to a certain problem in a procurement process.

In conclusion then, it seems as though the effects of public technology procurement on industrial innovation is closely related with the market power, or the concentration of demand, of the respective governmental authorities. The market power in turn affects to what degree the buyer get the suppliers to satisfy their requirements. On the supplier side the situation might be the opposite. Less concentrated markets might generate diversity, while a situation of monopoly might lead to national champions policies. Overall, however, the role of the market structure seems to be a highly unresolved question, especially in relation to public technology procurement. It is too early to draw the conclusion that governments should always try to centralise procurement as much as possible. For the most part observations rely on such big procurement programs as those of the defence sectors in Europe and USA during the 1950 and 1960. Furthermore, eventual conclusion are subject to other characteristics of procurement processes. Some of these will be discussed further below.

2.3.2. Public sector user competencies

User competence is a central theme in the Dahménian systems of innovation approaches presented above, as well as in the Burenstam-Linder, Lundvall, and von Hippel framework of user producer interaction. It is also a central theme in most of the reviews of technology procurement case studies.

Dalpé (1994) proclaims that the most obvious factor that distinguishes governmental organisations that buy new products from those that purchase standardised goods is their technological capacity. Governmental authorities are often themselves users of the technology procured and monitor technological advances through their own in house R&D laboratories, and through close contacts with state-owned research institutions. As such they might function as a 'lead user' in the von Hippel sense. They might also have better prerequisites to second guess future technological needs than private sector end-consumers (Geroski 1991). Hence, suppliers closely connected to governmental authorities have an advantage, particularly when the development of a new generation of technology is at stake. (Dalpé 1994). The same point was emphasised by Grandstand & Sigurdson (1985) in their study of technology procurement in the Nordic countries. The users with the highest technological capacity seemingly have had the most impact on suppliers' innovation.

The importance of government user competence is closely related to market structure considerations. Above it was suggested that a certain degree of government market power in a technology-intensive sector might be a necessary, but not a sufficient condition, for successful public technology procurement. In this context the importance of the competence of governmental authorities becomes crucial, since the dangers of poorly articulated demand correlates with the size of procurement orders. An additional requirement is that competencies are successfully transferred to the suppliers. Essentially this boils down to the expression of clear and satisfiable user needs, and functional requirements. When procurement contracts and standards are stipulated closely in line with the functional needs of the respective government authorities, the user will be in a better position to evaluate the various technologies and to choose the most adequate one. And if the user owes high technical competence, the innovator has a better chance of finding other markets for the product or the system. The policy implications might then be, that the various technical specifications should be formulated directly by the user rather than through centralised administrations or other organisations and departments. This also implies that the government sector user must play an active role in the procurement process, during the different stages of innovation. (Dalpé 1994, Faucher & Fitzgibbons 1993).

2.3.3. Public sector demand, technological development and the overall 'policy mix'

Above public technology procurement was discussed under different market conditions, as well as the closely related importance of user competence. A second important aspect concerns the role of technology procurement under different stages of the innovation process.

It is generally understood that the impact of public technology procurement is most significant at the early stages of a typical innovation process, as technological and commercial possibilities are difficult to evaluate while development costs are high. At later stages producers become less receptive to users demands (Faucher & Fitzginbbons 1993, Dalpé 1994, Geroski 1991, Rothwell 1994). These observations lie very close to Burenstam-Linders hypothesis of demand induced exports, and could be drawn upon to justify infant industry arguments where the government procurement authorities act as providers of a first market for an innovation which is later sold to other public and private markets, and finally for exports. Likewise, they lend support to von Hippel's conclusion of the user dominated stages of the innovation process. But while the review articles point out that procurement policies become more effective when properly co-ordinated with other policy instruments, they shed little light on the role of such other instruments. Neither do they discuss the role of government sector users at later stages of the innovation process, as the innovation process might become more producer dominated.

Geroski (1991) and Rothwell (1994) stress that procurement policies must indicate a long-term credible commitment by governmental authorities, which suggest that government sector users also should engage themselves for a longer period of time. Rothwell (1994) provides a more thorough analysis of such longer term commitment on the basis of a wide variety of examples from Europe, the USA and Japan. At the same time he takes a broader view of government technology procurement, where governments not only act as users, but can also act as proxies for users through the establishing of various regulations and standards, more in line with Carlsson's technological systems approach. Furthermore governments can influence the user-producer interface by bringing the two into contact during technological development. On the basis of his findings, Rothwell proposes a 'technology activity' approach to study the role of governments at the different stages of the innovation process. His model could be labelled a 'public goods market' alternation of the chain-linked model, which analyses innovations more in the realm of private sector users.

The technology activity approach distinguishes between three main stages of technological development. During the early, or pre-paradigmatic, research stage, producers determine technological development possibilities and establish early technological and design trajectories. At this stage government user impact will be most effective, but might also involve user involvement in pre-competitive research consortia. At the design and development stages, where producers monitor more precise user specifications and solve specific technical problems, government users might establish standards and regulations. At the design and development stage, Rothwell also suggests that government sector users can take more directly part in the innovation process, for example through the establishment of government labs and technology clubs, where users and producers together develop the specific product or system, or through supply-side policies such as R&D subsidy. Turning to the post-launch commercialisation and diffusion stage, where producers finalise an innovation for specific customers or market segments, the role of governments is mainly to act as a an early and risk accepting user and in this way influence diffusion and marketing. At this stage government sector users can also provide important feedback concerning performance characteristics. Hence, even though public technology procurement might be most effective at the early stages of the innovation process, they must indicate a long-term credible commitment by governmental purchasing agents. As such they must not only be limited to single-instance demand of a certain product or system. Instead they should span over a longer period of time.

2.3.4. Political factors and 'institutional rivalry'

The public sector is composed of several different institutions whose sometimes rival behaviour fulfil a variety of functions. Hence procurement decisions in the public sector result from a variety of economic as well as political and other non-economic factors. Surprisingly however, a discussion of the role of such factors seems to be the most neglected in the various reviewed case studies. Dalpé (1994) concludes that political and institutional factors are essential for the understanding of technology procurement policies, and then goes on to discuss these on the basis of the reviewed cases.

Generally speaking the most important political factors are connected to governments considerations of national security and electoral support. Such objectives might relegate cost considerations to a secondary role, as product or system performance is the primary selection criteria. Even though a higher price might be an indicator for inefficiencies and lack of competition, such procurement policies will have greater potential to fulfil socio-economic goals in society. Defence sector initiated procurement policies is a typical example of such dynamics, where national security considerations often are the highest. But the same situation might prevail in other sectors, i.e. such as health, energy, communications. (Dalpé 1994). Furthermore, Edquist (1996) suggests that national security and socio-economic aspects also make the use of technology procurement by governments politically attractive and widely accepted by the general public, by large segments of industry and trade unions, and by most political parties.

On the other hand, there seems to be more evidence to suggest that political factors in fact might retard the effects of public technology procurement on industrial innovation. Given the political nature of state intervention, other considerations can take priority over innovativeness. Above problems of national champion policies were discussed from point of view of monoposonistic and monopolistic market structures. While market structures might generate such policies, or are themselves the result of such policies, they will ultimately rely on political decisions. Furthermore, political decisions will be subject to lobbying from part of the supplier firms and other agents, where such issues as market shares considerations, regional distribution of activity and employment might be interwoven with the distribution of procurement contracts. Elected officials might attempt to maximise electoral support, and prefer to invest in risky short-term projects even though they appear less innovative. In some situations lobbying might also take the form of nepotism and outright corruption. (Dalpé 1994).

Given that the public sector is composed of various different institutions, all with different and complex objectives, it might be difficult to formulate technology procurement policies which serves one objective only. Similarly, it might be difficult to co-ordinate and regulate various public sector activities in a coherent way, in order to design a relevant policy mix with a focused aim, for example following the logic of Rothwell's (1994) technology activity approach. (Rothwell & Zegweld 1982, Dalpé 1994).

3. THE INSTITUTIONAL FRAMEWORK: THE NATIONAL SYSTEM OF INNOVATION AND FINNISH TELE-COMMUNICATIONS POLICY

3.1. The main characteristics of the Finnish system of innovation and technology policy

Adhering to a very crude division of technology-push and demand pull policy instruments, it seems fair to say that Finnish technology policy has been predominated by a science and technology-push view on technological change. In contrast with many other industrialised countries the role of more demand oriented instruments, such as public technology procurement, has been negible and there has not been any major conscious initiatives to set up goal-oriented technology procurement schemes in order to stimulate innovative activities. Even though technology policy makers have not necessarily been aware of the theoretical dimensions, technology policy has essentially been pursued along the lines of the market failure theory rather than evolutionary or systems of innovation theory (Lemola 1994). All-in-all there does not exist a national model of public technology procurement in Finland of the kind that Edquist & Homén identify in Sweden, the US and Japan (see Edquist & Homén 1997).

Following international trends, the history of Finnish technology policy can be traced back to the late 1960s as the development needs of industry began to assume a more important position in the priorities of technology policy in general. (see e.g. OECD 1980, Rothwell & Zegweld 1982). Up to the 1960s, technical colleges, universities and the Technical Research Centre (VTT) - established in 1941 - were the main informal agents of technology policy. Characterising these early days was the lack of selective target setting as well as specific instruments to guide firms research activities. Sweden, Japan and the OECD have been the main sources of the models and ideas regulating the design of the technology policy machinery in Finland. The foundations for a separate technology policy institutional infrastructure were created through the establishment of a technology policy unit at the Ministry of Trade and Industry and the Finnish National Fund for Research and Development (SITRA) during the late 1960s. Following this, such traditional policy instruments as R&D loans, subsidies and support for applied research in research institutes and universities were introduced. Instead of selectivity, a quantitative increase of input resources was the explicit target. (Vuori & Vuorinen 1994, Lemola 1994).

Starting from the early 1970s, as the basic infrastructure was in place, the remainder of the decade was dedicated to the further quantitative development of the system. Public sector R&D expenditure grew much faster than average R&D expenditure, and during the latter half of the 1970s it became apparent that more attention had to be paid to the selective allocation of resources. In the early 1980s it was proposed that major projects should be initiated in the key areas of technological developments, which subsequently lead to the introduction of a technology programme procedure. In order to increase goal-orientation and co-ordination, the Technology Development Centre of Finland (Tekes) was established in 1983 with the first urgent task to implement national technology programmes in various technology fields. (Lemola 1994). Around the same time a comparative fact-finding study was undertaken by SITRA with the purpose of introducing technology procurement as a complementary innovation enhancing policy instrument. The final report proclaimed the viability of technology procurement and envisioned that TEKES could be assigned the role of the co-ordinator, while financial resources could be secured through a special provision in the federal budget. (Insinööriuutiset 1983, Mäkinen 1984). In retrospect it is clear that these suggestions have not been followed.

The main overall aim of Finnish technology policy has been to support industrial renewal and competitiveness of exports. While the forestry industry traditionally has played an important role, the main thrust of the national technology programmes has been to support the emerging electronics and information technology industry. Another feature has been the organisation of the programmes, in the form of close co-operation between universities, research institutes and companies, even formally motivating the creation of user-producer networks. The latest trend is towards internationalisation and the increasing importance of the role played by EU policy promotion. (Vuori & Vuorinen 1993).

While the 1980s and 1990s has witnessed a continuation of the quantitative upgrading of the R&D system, the degree of state intervention in the process of technological change has been quite marginal and does not seem to be increasing - the share of private sector R&D has grown steadily from around 50% in 1969 to over 60% in 1989, and the share of state funding in corporate R&D averaged to around 5% during the 1980s. Rather, the demand of firms have focused the attention of public financiers. Other national features of technology policy are the absolute and relative shortage of resources, the relative insignificance of the defence sector and military research and other fields of big science, as well as the limited size of the home market. (Lemola 1994). Apparently these features might also, to some extent, explain the lack of more widespread use of technology procurement as a conscious technology policy instrument. Traditionally procurement schemes originate from the defence sector (se e.g. Rothwell 1994), and perhaps the absence of this tradition in Finland feeds back on technology policy options and the non-existence of a national model of technology procurement. Furthermore Mäkinen (1984) suggests that the procuring organisations might have problems to provide the suppliers with a big enough market to make risky R&D viable.

3.2. Public technology procurement regulations and norms - past and present

From point of view of industrial policy, the main policy rationale for procurement policies in Finland has been, on the one hand, to increase the domestic content of procurement orders as substitutes to imports, and thus attribute to job job creation and protection of national industries rather than technological development. On the other hand, there has been a general tendency to closely adhere to various external free trade and competition obligations stipulated by e.g. GATT (WTO), EU and other international organisations. While practice sometimes has proven otherwise, various regulations and norms governing procurement reflect these conflicting priorities. (Mäkinen 1984).

The regulations governing procurement have traditionally been prepared by the Ministry of Trade and Industry, or the Ministry of Finance, for approval by the Council of State. External agreements have been concluded directly by the Council of State. It has then been the responsibility of the individual ministries concerned to supervise compliance to these regulations. Starting from the early 20th century, it was stipulated that *"...decisions concerning public sector procurement should be guided by national interests, and procurement orders should be placed domestically..."*. (Valtioneuvoston päätös 136/1930, translation). For this purpose special domestic content indicators (a certain percentage of domestic value added of a product or system) were developed in order to assure compliance to these principles. These framework conditions also applied even though domestic goods were more expensive than foreign goods. Alongside these regulations there has also existed various institutions and norms which have shaped policy. A centralised procurement agency has been established in order to co-ordinate public sector procurement of products 'bought off the shelf', and up until the mid 1980s a special delegation had been assigned the duty to supervise that bigger procurement orders were given to domestic suppliers. While the delegation evidently did not intervene to any significant extent, it does illustrate the role that higher-instance government authorities sought to play in influencing the domestic content of orders. On the other hand the regulations did promote competition amongst domestic suppliers, as it was stipulated that procurement orders *"...should be distributed amongst a sufficient number of reliable and competent suppliers..."* (Asetus valtion tavarahankinnoista 714/1965, translation). At least 4 competent suppliers have to be given a fair chance to take part in the bid for tenders. (Mäkinen 1984, Interviews 1996).

Starting from 1970 a more innovation enhancing stance was taken as the regulations from 1965 (Asetus valtion tavarahankinnoista 714/1965) were complemented with paragraphs which allowed for preferential procurement in cases where the procurer and supplier had concluded an R&D collaboration agreement. Prior to Finnish accession to the GATT agreement in 1980, regulations were again amended (Kauppa ja teollisuusministeriön päätös valtion hankinnoista 1071/1979). Apart from the normal procedure involving a minimum requirement of four competitors for each procurement order, these amended regulations allows for two alternative modes of procurement in special cases. In situations where there is a lack of competition, or the product or system to be procured is technically especially sophisticated and new to the world, the procuring organisation has the right to initiate negotiations concerning the details of the contract with suppliers. In the case of preferential procurement, R&D collaboration is defined more strictly, and preferential procurement is allowed in cases where the procuring organisation places a prototype order for a product or system which explicitly aims at test-field trials prior to more widespread deployment. For follow-up orders normal procedures involving open tenders have to be adopted. While these amended regulation largely complies with GATT and EFTA rules, the above mentioned delegation was still left intact. (Mäkinen 1984).

The next changes in Finnish procurement regulations were prompted by closer integration with the EU. These present regulations (Laki julkisista hankinnoista 1505/1992) came into force 1.1. 1994, and incorporated amendments in accordance with the EEA treaty (the European Economic Area free trade agreement between the EEC and EFTA). The main change was the introduction of threshold levels for European-wide bid for tenders. Procurement orders valued over 200 000 ECU's are subject to open competition and have to be published in the Official Journal of the EU, whereas orders valued below the threshold still are subject to the national regulatory framework which was left largely intact. In addition, new EEA regulations stipulated higher 600 000 ECU competition thresholds for procuring public organisations active in the field of water, transport, energy and telecommunications. In other major parts the national regulations originating from 1979 remained unaltered. Meanwhile, during the late 1980s, nationalistic norms well as the delegation supervising bigger procurement orders were dismantled. As the EEA agreement also incorporated EU regulations governing procurement, Finnish membership in the EU did not affect national regulations to any significant extent. The most recent trend is the incorporation of new WTO rules on procurement, but these changes will be carried through at the EU level. (KTM:n työryhmä- ja toimikuntaraportteja 13/1996).

Hence, it seems fair to conclude that the regulations and norms governing procurement have not created optimal conditions to actively pursue technology procurement policies. Higher-instance government authorities have played a rather strong regulatory and supervisory role, up until EEA association and EU membership, but the aim has primarily been to motivate 'off the shelf' procurement of ready made products and systems rather than to create more goal oriented policy schemes. The domestic content of orders has been more important than innovativness.

It seems that the primary examples of public technology procurement in Finland can be found within the telecommunications and railway sector, and in the field of small-scale military equipment. On the other hand, procurement regulations have fostered competition between, and from this point of view the new EU regulations concerning public sector procurement have not changed the situation to any significant degree. Rather Finnish suppliers are set to benefit from the opening up of sheltered European markets.

3.3. The regulatory structure of telecommunications operators as the buyers and users of telecommunications equipment

Apart from the above discussed 'basic institutional infrastructure' (to use Carlsson's concept), which have set the general framework conditions for harnessing technology procurement for explicit policy objectives, the regulatory structure of the telecommunications operators, or buyers, provides the second set of rules and norms which have affected the PTT's technology procurement strategies as well as technological development in the field more generally.

As opposed to the public monopoly situation that has prevailed in most other European countries, the telecommunications operators are organised on a decentralised basis. The first legislation concerning telephony was adopted in the form of the Imperial Telephone Decree, which was enacted as late as in 1886 at the time when Finland was an Russian Grand Duchy. The decree authorised the Finnish senate the right to grant licences for private sector telephone operators as the Russian Tsar favoured the telegraphic network for military purposes.

The first private local telephone company (telco for short), the Helsinki telco, was established in 1882. In 1917, when Finland became independent, the state entered telecommunications operations through the founding of the PTT, in order to build trunk networks and local networks in scarcely populated rural areas neglected by the telcos operations. Meanwhile the number of telcos started to grow rapidly, and in 1921 the Association for Private Telephone Companies (the Finnet group) was founded in order to co-ordinate the activities of the telcos in certain administrative matters, and in matters related to procurement and modernising the networks. (Mäenpää & Luukkainen 1994, Telecommunications Statistics 1989/96).

The market share of the telcos, and Finnet, on the fixed network reached it's height during the early 1930s, while frequent nationalisation initiatives and associated acquisitions by the PTT during the late 1930s gradually increased the market shares of the PTT. Since late 1970s, the market share of the PTT has remained constant at around 30% of all subscriber lines, while the telcos and the Finnet association account for the remaining 70%. The PTT is the biggest single operator, with a monopoly over fixed trunk networks (long-distance and international calls), some local networks, and a near-monopoly over the mobile networks (monopoly in NMT and 90% of all subscribers on the GSM market). Of the remaining 45 telcos the peerless leaders are the Helsinki telco, the Tampere telco and the Turku telco, operating the biggest cities, while the remaining telcos are significantly smaller and typically operate small local networks with a limited number of subscribers. In terms of the market structure of the users, this decentralised set-up has lead to fragmented buyer's market for telecommunications equipment for the fixed networks, while the PTT has exercised a monopsonits' market power in the field mobile telecommunications up until the early 1990s as Finnish telephony was liberalised further. (Ministry of Transport and Communication 1996, Telecommunications statistics 1989/96).

Subordinated the Council of State, the main regulatory bodies are the Ministry of Transport and Communications and the Telecommunications Administrations Centre, while the Ministry of Finance and the Ministry of Trade and Industry (since 1983 Tekes) have affected the development of the telecommunications industry through more general industrial- and technology policy measures (e.g. subsidy, technology programmes e.t.c).

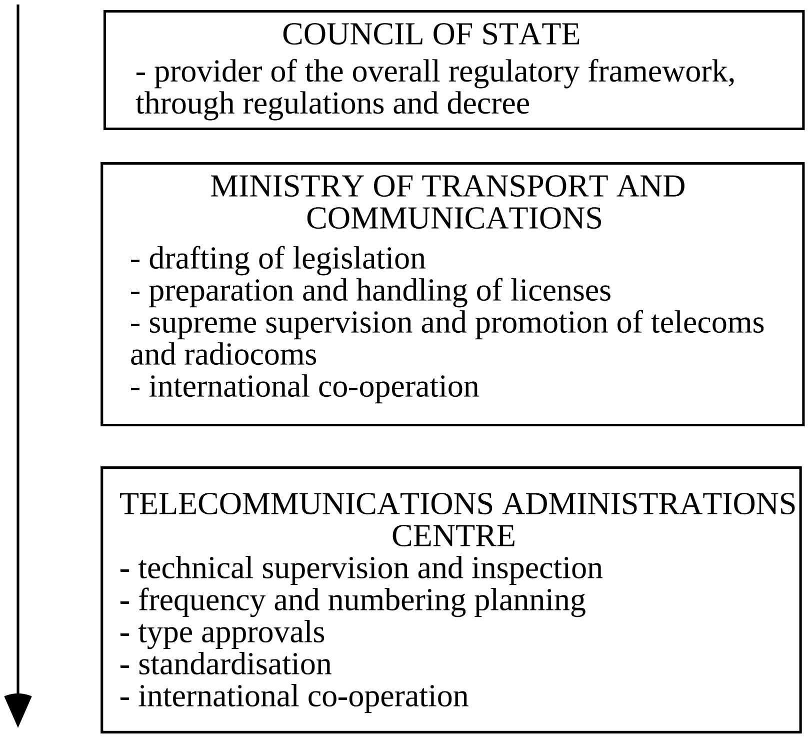

Figure 1 The structure of the telecommunications regulatory system. (Telecommunications statistics 1996, 8).

As the state entered telecommunications in 1917, the PTT was subordinated the Ministry of Transport and Communications. The Council of State draws the main guidelines for telecommunications policies through regulations and decrees, while matter of more direct relevance to the day-to-day activities of the PTT, such as the drafting of legislations and policies on more detailed issues, preparation and handling of license matters and supervision the development and maintenance of the networks have been delegated to the Ministry of Transport and Communications.

The tendency in recent years has been to decentralise and liberate telecommunications further by means of regulations and decrees emanating from the Council of State. Through the new *Telecommunications Act* in 1987 the Ministry of Transport and Communications received regulatory powers over technical supervision and inspection of telecommunications services, allocation of radio-frequency and number planning, type approval and national standardisation. In 1988 the Telecommunication Administration Centre was established for these tasks. Up until 1987, the PTT has had a the double role of a telecommunications regulator and operator and has handled the above mentioned tasks. In 1990 the PTT was transferred from a state-owned monopoly into a state-controlled commercial enterprise, bound by the same rules as the telcos, and in 1994 into a limited company called Telecom Finland Ltd. Meanwhile competition on the networks has been encouraged as licenses have been granted for long-distance and international calls, in effect ending the monopoly of the PTT in these markets. Within the field of mobile telecommunications the monopoly position of the PTT prevailed up until 1990 as the telcos received a license to operate the GSM network through the founding the joint-venture Radiolinja Ltd. The PTT's monopoly over mobile networks until 1990 has been a logical extension of the fact that the PTT has controlled the radio-frequencies, along with the state-owned broadcasting association YLE. (Telecommunications statistics 1989/96).

4. THE KEY ORGANISATIONS INVOLVED, THEIR COMPETENCIES AND OTHER RESOURCES

4.1. The evolution, structure and competencies of the Finnish telecommunications equipment producers - the evolution of Nokia

The history of the Finnish telecommunications industry can be traced back to the early 1960s, despite the fact that some roots extend even further. Prior to the 1960s a foreign companies oligopoly, consisting of ITT-Alcatel, Ericsson and Siemens, shared the market, even though state-owned R&D units had established small-scale production in closely related technology fields. (Mäenpää & Luukkainen 1994, Koivusalo 1995). One major reason for the widespread establishment of production in Finland was that foreign firms sought to evade public procurement regulations concerning the domestic content of procurement orders (Interviews 1996). Since the regulations were avoidable, it seems that the Finnish market has been more open to competition than has been the case in other European countries.

While the foreign companies, and especially Ericsson and Siemens, have had a strong position on the Finnish market throughout, it is interesting to note the gradual emergence and market take-overs of the domestic telecommunication equipment firms. These trends are very much interrelated with the growth of the Nokia group (or Nokia for short) and an associated network of sub-contractors and component producers, especially within the fields of switching systems and mobile telephone technologies. Other smaller Finnish telecommunications equipment firms, such as Tecnomen, have typically entered the market much later, in the 1980s or 1990s.

The initial incentive for domestic telecommunications equipment production stemmed from the defence sector. During the early development phases of the telecommunications sector, the defence sector had established a R&D unit, Valtion Sähköpaja, to cater for defence sector demand of electronics and telecommunications equipment as well as maintenance and repair. In 1948 Valtion Sähköpaja became part of the PTT's activities, and in 1962 the name Televa was adopted. In the private sector, telecommunications equipment was produced at Suomen Kaapelitehdas (established in 1912) and Salora (established in 1928). Suomen Kaapelitehdas produced various cables transmission systems for fixed telephone networks, but had also established a small electronics department. Later on, in the 1960s and early 1970s, the electronics department diversified into computer and data processing services. Salora (established in 1928), on the other hand, was preoccupied with early consumer electronics (television sets and transistor radios) and radiotelephones. (Koivusalo 1995).

Valtion Sähköpaja, Suomen Kaapelitehdas and Salora were the main domestic suppliers of telecommunications equipment at the time. From the early 1960s onwards the telecommunications industry evolved as a combination of successful strategic choices by firms, though competition, extensive visionary R&D, public support and technology push from part of the main telecommunications equipment producers, as well as demand pull, often including close interaction with various private and public sector institutions, including the PTT. In the following the evolution of the telecommunications equipment industry is presented from the point of view of firms, while the role of public sector activities, and the PTT, is discussed in the following chapters.

In 1966 Suomen Kaaplitehdas, Suomen Kumitehdas (rubberworks) and Nokia (forestry and energy) merged to form the Nokia Group, or Nokia for short. Meanwhile, in 1976 Televa was transformed into an independent state-owned company, and in 1977 the new company

Telefenno was established as a 50-50 joint-venture between Televa and Nokia, in order to consolidate competencies in digital switching technology. The establishment of Telefenno coincided with a broader nationalisation initiative taken by the Social Democratic Party during the mid 1970s, when is was envisioned that the Finnish electronics industry should be reorganised into a large state-owned firm. As the socialisation initiative eventually failed, Nokia seized the opportunity and purchased a majority of the shares of Televa and in 1981 the Nokia division Telenokia was established. Telefenno had hence became completely decoupled from the state/the PTT. Meanwhile the remainings of Televa were sold to other domestic electronics firms. (Lovio 1993, Koivusalo 1995).

If the Finnish telecommunications equipment industry of the 1960s and the 1970s was characterised by small-scale pioneer production and the heavy involvement of state-owned R&D units and enterprises, the early 1980s marked the start of the growth of the Nokia both in terms of market shares volumes and in terms of the accumulation of competencies. During the same time the Nokia group diversified more forcefully into electronics, and especially into telecommunications. This diversification process is illustrated in figure 2 below.

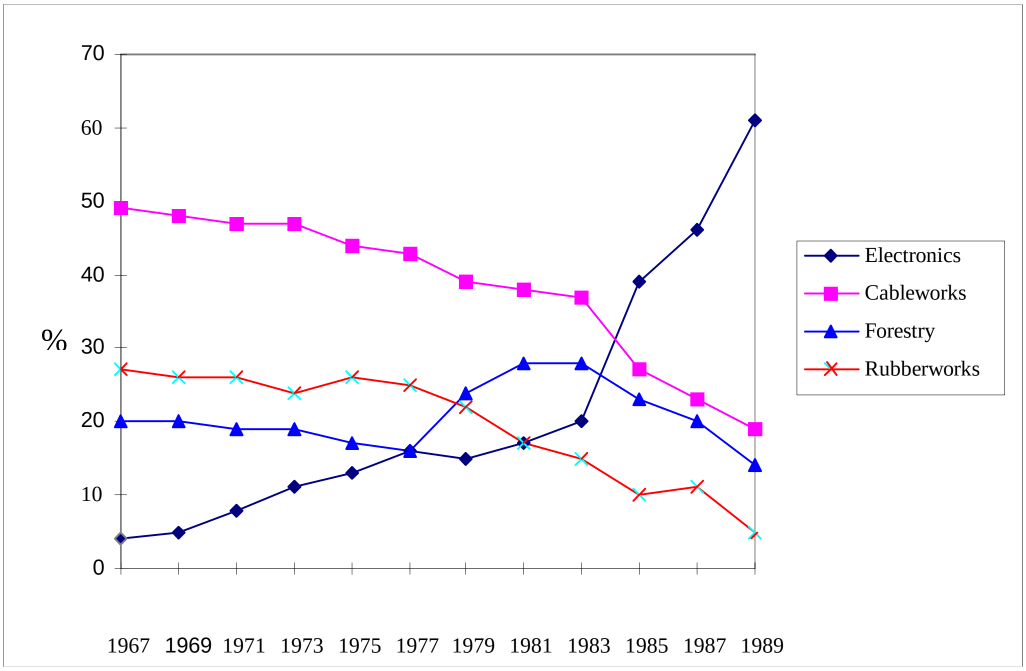

Figure 2. Distribution of Nokia's net sales 1967-1989. (Lemola & Lovio 1996, 207).

By 1980 Nokia had become the largest domestic electronics and telecommunications firm, while the foreign firms clearly had lost market shares. Within the field of switching systems resources and R&D at Telenokia were shifted towards developing early versions of the DX 200 digital system. Meanwhile, in 1979, a decision had been made to formalise collaboration between Nokia and Salora by the founding of the development company Mobira, to better meet anticipated future demand for mobile telephony. Salora was the main domestic carrier of mobile telephone and base station know-how at the time. During the1980s the Nokia group also acquired key mobile telephone component technologies, through firm acquisition and outsourcing. At the same time the Nordic PTT's were engaged in Nordic Mobile Telephone (NMT) standardisation. (Lovio 1996, Koivusalo 1995).

The NMT standard was crucially important for Nokia's diversification from fixed networks equipment into mobile telecommunications. It also paved the way for Nokia's aggressive internationalisation strategy, from the mid 1980s onwards. The final push for Nokia's global success was provided by GSM standardisation during the early 1990s. In 1988 the Nokia Cellular Systems unit was formed and Telenokia was absorbed into a larger business unit - the Nokia Telecommunications division, as base station technology, switching and transmission systems, was integrated as part of the cellular business concept. Mobira was likewise absorbed through the founding of the Nokia Mobile Telephone division. By the early 1990s Nokia had become a global player in telecommunications equipment, and R&D funds have subsequently increased significantly. Nokia Telecommunications accounts for a lion share (40%) of the funds. (Lemola 1996, Koivusalo 1995).

In comparison with other major telecommunications equipment suppliers, the scale and scope of Nokia's R&D activities seem modest. In the context of the Finnish telecommunications industry, Nokia has a very dominant position, while the remaining firms are medium-sized, small, or sub-contracting firms. Many of these sub-contracting firms have been established on the basis of close collaboration with Nokia. Examples include the Nokia spin-off Benefon (mobile telephones), Martis (transmission and cross-connecting equipment, network management systems), Tecnomen (paging and voice messaging systems), Sondi (public telephones and health care systems), Teleste (private branch exchanges, integrated systems), Bitfiled and VistaCom (videoconferencing systems). Examples of sub-contracting firms which are closely related to Nokia include LK-Productions (duplex filters) and Micronas (integrated circuits). The dominant position of Nokia is reflected in the structure of telecommunications exports, as illustrated in table 1.

Table 1. Top 10 Finnish telecommunications commodities in terms of OECD market shares. (adapted from Rouvinen 1996, 86).

	OECD export mkt share 1993, %	Export value 1994, MFIM	Share of national exports 1994, %	Annual growth 1990-94, %
1. Cellular and fixed network systems.	6,7	1767	1,15	34
2. Mobile telephones.	5,7	4481	2,91	61
3. Optic fibre cables.	2,3	52	0,03	102
4. Telephone switching apparatus.	1,6	291	0,19	-24
5. Parts for mobile telecom equipment.	1,5	1413	0,92	24
6. Parts of line telecom equipment.	1,2	1087	0,71	50
7. Electrical traffic control equipment.	1,1	12	0,01	7
8. Parts of electric traffic control equipment.	1,1	19	0,01	7
9. Cables for telecom systems.	0,8	206	0,13	10
10. Modulators for carrier-current lines.	0,5	98	0,06	-24

The main export commodities both in terms of export value and the share of total national exports in 1994; mobile and fixed network systems and mobile phones, are an integrated part of Nokia's core business area. (Rouvinen 1996). In terms of the export share of Finland's total exports of telecommunications and electronics, the share of Nokia is 90%. It could even be argued that Nokia is one of the most central actors in the Finnish system of innovation. Nokia accounts for some 30-40% of total Finnish high-technology exports, and some 25% of total

R&D performed in Finnish industry (excluding Nokia's R&D activities abroad). (Ylä-Anttila 1996). Tracing developments, the telecommunications sector has evolved from something resembling a foreign firms oligopoly towards a national oligopoly in the field of cellular and fixed network equipment, and finally into a near national monopoly with Nokia as the dominant producer.

4.2. The PTT as a public sector procurer - developing competencies and procurement strategies in a dynamic market

Turning to the history or evolution of the Finnish PTT it seems that very similar kind of technological and market opportunities that characterises Nokia's history have also been important at the public end of the market.

Above the early important role of the state-owned R&D laboratory Televa and the semi-public firm Telefenno was highlighted. While state ownership and R&D funding was important for the very early development stages, the role of the PTT's activities became more important during later stages. The PTT has foremost influenced the telecommunications equipment producers through technology procurement and R&D collaborative schemes, as the telecommunications networks have been modernised during the second half of the 20th century. Apart from the 'nationalistic' regulatory and normative framework discussed in chapter 3.2, the procurement decisions of the PTT have essentially been shaped by the fragmented market structure amongst the buyer's, or operators, which has forced the PTT to act more on the basis of profit-seeking entrepreneurship and customer satisfaction, as opposed to interventionism. While the telcos have co-ordinated their activities in drafting specifications and procurement plans through the Finnet association, as local networks have been modernised, the various telcos have foremost responded to local demand for new services and equipment. The telcos have closely monitored user needs, quality levels and technological development both in Finland and abroad, and this in turn has forced the PTT to react swiftly to new emerging telecommunications trends. Furthermore, a large number of different local networks have forced equipment suppliers, as well as the PTT, to provide special technological solutions in order to combine technically incompatible local networks into a national network. These conditions have fostered continuos development and renewal of telecommunications technologies and strengthened the competence of the PTT. (Rouvinen 1996, Interviews 1996).

The development of the PTT's competencies and procurement strategies can be traced back to the the late 1950s and 1960s, as the first steps were taken to modernise the telephone networks. The modernisation of the networks might be discussed along three partly overlapping dimensions; namely the *automatisation of the networks* , the *digitalisation of the networks* and the *emergence of mobile telecommunications* through the creation of standards. In addition digitalisation of the networks has enabled data transmission over the networks, which has vastly increased the supply of various networks services and led to the growth of the Finnish information industry.

The *automatisation of the networks* commenced already before the second world war, as new coaxial cable technology was entering the markets and increased the capacity of the networks. While cable transmission technology had to be renewed, this new technology also made manual switching systems obsolete and paved the way for electromechanical, and later computer controlled, switching systems. Owing to the above decentralised system of operators, consisting of the PTT and technologically progressive telcos, the first steps towards automatisation were taken by the telcos already in the 1920s and 1930s, while the automatisation of PTT's networks was initiated much later. Table 2 illustrates the rate of automatisation of the fixed network (the local and trunk networks).

Table 2. The automatisation of the networks in Finland (Puhelintilastot 1975, 29)

	1950	1960	1975
Manual	46%	19%	6%
Automated	54%	81%	94%

During the 1950s and early 1960s the PTT came under increasing pressure to keep a breast with developments on the networks operated by the telcos. The PTT had established a small telecommunications laboratory in 1932, and during the early stages of automatisation of the networks the main task of the laboratory was to check the reliability and quality of the procured cableworks and switching systems before deployment. For this task the laboratory had developed advanced measuring and quality monitoring devices. Later on, starting from the mid 1960s, more personnel was recruited and the laboratory also started to assemble systems in order to understand the inner logic of the equipment procured. This work was done with very modest in-house R&D financial resources. (Halme 1989, Interviews 1996). It was also during the mid 1960s that the PTT drafted their first nation-wide investment and procurement plans for modernising the networks, and a procurement department was established in order to handle legal as well as commercial matters of procurement (Posti ja telehallitus 1982).

While these organisational changes and strategic plans were initiated in anticipation of future trends in telecommunications, the fact that the PTT was subordinated the Ministry of Transport and Communications and a post-war scarce federal budget placed severe restrictions for a more long-term planing. The Ministry of Trade and Communications perhaps shared the view of the PTT on the importance of a modern telecommunications infrastructure, but the Ministry of Finance had their priorities elsewhere. This lack of consensus, long-term commitment and vision from part of higher instance governmental authorities forced the PTT to adopt a policy whereby competition between the suppliers (the obligatory four main bidders were usually Televa, Ericsson, Siemens and ITT-Alcatel) was encouraged in order to avoid a monopoly situation on the suppliers market where one producer could dictate prices. It also tended to slow down the rate of automatisation of the networks. Hence, despite the fact that higher instance government authorities sought to favour domestic producers on the basis of infant-industry and job creation arguments through a set of interventionistic regulations and norms, there was competition on the national market right from the start.

The early 1970s marked the start of digital transmission and switching technology and mobile telephony. Furthermore the PTT received more budgetary freedom, which paved the way for longer-term R&D, network equipment investments and procurement. Automatisation was now almost completed (the telcos networks were automated in the early 1970s, and the PTT's networks were automated in the early 1980s) and the PTT initiated new R&D and procurement projects. This time the focus had moved from electromechanical and computer controlled transmission switching systems towards digital transmission and switching systems. At around the same time the first nation-wide mobile and paging networks were constructed, as mobile telecommunications technologies became available. (Tele 1993, Interviews 1996).

The history of *digital networks* in Finland can be traced back to the late 1960s and early 1970s. Again there was no long-term commitment and vision from part of higher instance government authorities, and the diffusion of digital technology from abroad was primarily catalysed through activities at the grassroot level. The first experimental moves into the field of digital technology were taken jointly in the form of a kind of pre-competitive research consortia involving the main telecommunications producers at the time, i.e. Nokia Electronics and Televa, the technical universities, the VTT, the PTT and some of the bigger telcos - most notably the Tampere and the Helsinki telco. The role of the PTT was primarily to transfer know-how from abroad, and to consolidate the digital technology R&D projects performed in industry through procurement decisions as the fixed networks were digitalized. (Toivola 1992, Tele 1993, Interviews 1996).

While the local private operators have had more budgetary freedom and flexibility, and were not bound by the interventionistic procurement regulations, the PTT was in a position to quickly acquire the centralised resources needed to specify and procure new technologies. The technical competence of the PTT foremost accumulated through own in-house R&D and field-trial activities, as more R&D funds were made available. It was also accumulated through collaboration with the VTT, the technical universities, and industry, and through contacts with other PTT's as well as various standardisation organisations abroad. At the PTT's telecommunications laboratory a digital technology research team was summoned in order to keep abreast with technological advances, and R&D was increased significantly. In addition R&D projects where often outsourced to industry, in connection with specific preferential procurement cases. (Posti- ja telehallitus 1982, Ekberg 1985). Table 3 illustrates the rough distribution of R&D within the evolving telecommunications block as of 1975. Noteworthy is the big share that was performed by the telecommunications industry already at this stage, and the clear difference in the volume of R&D between the PTT and the telcos.

Table 3. Distribution of R&D performed in telecommunications sector in 1975. (Ekberg 1985, 98).

Research institutions (VTT etc.)	6,1%
Technical Universities	7,8%
Industry	59,8%
PTT	20%
Telcos	6,3%

Even though the PTT now had outcompeted the telcos in terms of centralised R&D resources and research, it should be noted that the telcos also were eager to apply digital transmission and switching technologies in their networks. But while the telcos for the most part procured technology 'from the shelf', the PTT often participated in the development of the systems to suit their own needs. Only the Helsinki and Tampere telcos had noteworthy in-house R&D capabilities. In addition the PTT's orders tended to be bigger, as the trunk networks increased the demand for system capacity. (Interviews 1996). The rate of digitalisation of the networks upheld by the numerous telcos was faster than that of the networks operated by the PTT during the early stages, while there was convergence during the early 1990s. By 1996, digitalisation of all networks was completed.

The initial demand for *mobile telecommunications* was anticipated by the defence sector, the State Railways and other public sector authorities during the early 1960s, as the first local radiotelephone networks were constructed alongside important railroad, road and lakeland transportation routes. (Toivola 1992, Interviews 1996). There appears to exist two main reasons for why the PTT decided to enter mobile telecommunications. Alongside the more general mobilisation of resources underway for the automatisation of the fixed networks, a separate small, but energetic, business oriented radio department and an associated radiolaboratory had been established during the late 1950s. As the PTT possessed concessionary rights over the radio frequencies, and hence had a monopoly position in the field of mobile telecommunications, the main task of the radio department was to co-ordinate the frequencies of national radio-traffic as well as to grant radio-frequencies for amateur operators. Soon it was realised that even though radio frequencies were a scarce resource compared to telecommunications cables, they could be harnessed for new services and business opportunities if used correctly and efficiently through the creation of standards. This kind of business-minded attitude concerning radio-frequencies evidently was very important. Secondly the radio department had the responsibility for operating radiotelephone networks covering the coastal areas of Finland, and had thus accumulated extensive know-how in the field of early radiotransmission technology. These converging possibilities had inspired several detailed market analysis of the future potential of mobile telecommunications. During the 1960s and early 1970s the first nation-wide so called ARP network was constructed. (Tele 1993, Interviews 1996).

The second generation nation-wide mobile network is the NMT network, which is based on a common standard developed jointly with the other Nordic PTT's (Norway, Denmark, and Sweden). While the initiative for the creation of a common Nordic mobile network standard originated from the Swedish PTT, the experience gained through constructing and operating the ARP network were necessary prerequisites for the Finnish PTT's involvement in NMT collaboration. The ARP network demonstrated the development potential of mobile telecommunications and thus paved way for resource allocation towards this end, but it also provided the necessary technological skills both for the PTT and the domestic telecommunications equipment suppliers.

The PTT's next significant step in mobile telecommunications was to participate in the creation of the pan-European GSM standard. The GSM standard was the first standard, where concessionary rights were granted to the local private operators as well. The GSM standard was largely based on experienced gained from analogue NMT technologies, but also constituted the first steps towards fully integrating digital technology into mobile telecommunications. Meanwhile, alongside the construction of the NMT 900 mobile network and standardisation work for the GSM system during the first half of the 1980s, digital technology was also applied for the construction of the first nation-wide paging network. (Toivola 1992, Interviews 1996).

Table 4. Turnover of the PTT 1990-95 according to main field of operation, FIM million. (Telecommunications statistics 1996, 60).

Field of operation	1990	1991	1992	1993	1994	1995
National trunk calls and international calls	2 283	1 839	1 760	1 723	1 153	1 102
Local network services	989	1 001	926	928	892	947
Mobile telephone services	805	1 107	1 252	1 434	1 637	1 930
Miscellaneous income	906	1 011	1 068	1 103	1 245	1 472
Total	4 983	4 958	5 006	5 188	4 927	5 451

Table 4 illustrates the PTT's distribution of net sales 1990-95, according the main business areas. The table clearly illustrates the PTT's diversification from supplying basic telephone services over the trunk networks and local networks towards supplying mobile telecommunications (e.g. NMT-GSM and KAUHA paging services, satellite services), and other services such as VANS (e.g. value added voice services, data transfer services, Internet access and services) and special business communication services (e.g. voice/data/security services, logistical and mobile solutions). Especially striking is the strong reorientation towards supplying mobile telecommunications, as part of the rapid growth on mobile telephony. The PTT continues to actively participate in various international operations and standardisation efforts through a network of partners in Europe, even though the bigger telecommunications equipment producers now constitute the main players in creating standards.

5. ORGANISATION AND MANAGEMENT OF THE PROCUREMENT PROCESS

5.1. Developing the DX 200 system

From manual to digital switching systems

Digital switching systems are technologically very complex, and development work typically has involves large amounts of R&D investments and significantly more man-years than any previous automatic switching system. Before discussing the DX 200 case, it makes sense to recall certain major stages, or technological transitions, in telephone switching as each generation of switching systems builds on the previous generation. In contrast to many other industries, technological change, such as the diffusion of digital technology, has been absorbed by the industry without disrupting it too much. Figure 4 illustrates the main technological transitions in digital telephone switching.

Figure 4. Main technological transitions in digital telephone switching. (Adapted from Granstrand & Sjölander 1994, 370).[5]

Essentially, modern switching systems consist of a control unit, which provides the 'brainpower' for the various processes in the system, and a switching network. The switching network, in turn, consists of a group switch, connecting the various subscribers and a subscriber switch, which translates voice signals into electrical signals for processing within the switching network. These different components have gradually been upgraded, as switching exchanges have been modernised through the introduction of new technology. The first major technological transition was from manually controlled exchanges to automatically controlled exchanges, as switching operators duties were automated during the later part of the 19th century. Automatic exchanges are essentially either electro-mechanically controlled or electronically controlled. The transition from electro-mechanically controlled exchanges to electronically controlled exchanges was made possible through rapid technological advances in electronics during the 1960s, while computer software technology entered switching through so called stored program control (SPC) exchanges some time later on. These computer-controlled SPC exchanges displaced traditional electromechanical step-by-step (for example the so called Stoweger exchange) and indirectly controlled register control, and so called crossbar systems.

The introduction of SPC exchanges paved the way for the gradual transition from analogue switching to digital switching. The first generation SPC exchanges used analogue technology to connect subscriber transmission with each other over the switching network, while new advances in semiconductor technologies (microprocessors) was necessary for digitising the group switch, and later on also the subscriber switch during the late 1960s, 1970s and the early 1980s. Meanwhile, digital transmission technology (PCM transmission systems) had been introduced, which eventually lead the integration of digital transmission and switching technology - or the Integrated Data Network (IDN). At this point the switching exchange became as part of a larger digitised network system whereby it is more convenient to talk about switching *systems*. The latest generation of mutely-service digitised switching systems emerged during the late 1980s and 1990s, and are based on the CCITT Integrated Service Digital Network (ISDN) standard. (Volotinen 1991).

The rapid development and diffusion of digital technology starting from the late 1960s took many experts by surprise. French CIT-Alcatel was the undisputed forerunner in digital switching technology and experimented with their first prototype digital E 10 systems already during the late 1960s. Field-trial systems had also been constructed in the USA, Canada, Japan and Germany at around the same time. Above the diffusion of digital technology into the Finnish telecommunications sector was discussed from point of view of the PTT's attempts to keep abreast with developments as transmission and switching systems for the fixed networks were modernised. While basic research in the field of digital technology was conducted in the form of a pre-competitive research consortia amongst the central actors during the late 1960s, more focused research and a certain division of labour emerged during the beginning of the 1970s at the time when the history of digital switching commenced in Finland. (Olkkola 1986, Interviews 1996)

Entering digital technology - converging interests and needs

All the primary telecommunications firms at the time; Salora, Nokia and Televa, followed different paths of entry to the digital paradigm in telecommunications.

The sole domestic supplier and carrier of switching exchange know-how was state-owned Televa, and Televa was the only domestic competitor alongside Ericsson, ITT-Alcatel and Siemens as the fixed networks were automated. Televa had expertise in switching technology dating back to the 1950s. The first electromechanical so called KAU switching exchanges, based on relay technology, were small (25-50 subscriber lines) and especially suited for less-densely populated rural areas. By the mid 1960s, Televa had delivered some 200 exchanges to networks upheld by the PTT as the fixed networks were automated. Next Televa developed the so called KMK crossbar exchange, which had the capacity to handle a significantly larger number of subscriber lines. At the time the KMK exchange was considered a very competitive product, and with this exchange Televa managed to compete with other foreign suppliers for procurement orders from various telcos and the PTT. The KMK exchange played an important role as the rural telephone networks in Finland were modernised during the 1960s and 1970s (Olkkola 1986, Mäkinen 1995).

During the late 1960s Televa started to develop the first generation of electronic exchanges; the KAP exchange 'family'. The first procurement orders came from telcos, and in 1972 the first KAP exchange came into operation. Meanwhile the technological frontier had moved further, through the introduction of SPC exchanges, and through the coming of digital technology. At Televa the first official initiatives towards developing a computer controlled digital switching system, or the so called ADS switching system, were taken in 1971 as a visionary R&D collaboration scheme was initiated together with a telephone laboratory at the Technical University of Helsinki and partly subsidised by the Ministry of Trade and Commerce. Alongside this R&D project Televa had also initiated a second R&D project for the development of the next generation computer controlled KKY switching exchange, based on analogue technology, which was designed to cater for the PTT's demand for small switching exchanges as the final stage of the automatisation of the networks was under way. However, even though the ADS system applied digital technology whereas the KKY system was based on analogue technology, the ADS and the KKY projects very much competed for funds. Initially the KKY project was favoured, while the ADS project merely was anticipated as an exotic experiment. (Olkkola 1986, Interviews 1996).

At the time the general understanding was that computer controlled switching systems would provide significant cost-efficiency advantages over the previous generation electromechanical and electronic switches. The more disputable questions were related to timing and the specific technological design of a digital system. In most quarters it was believed that digital switching systems, although promising, would not penetrate markets for decades to come. (Olkkola 1986, Mäkinen 1995, Interviews1996).

As the PTT was drafting the last set of specifications and procurement orders for the remaining local rural networks there was increasing awareness that computer controlled switches indeed would be more cost efficient. In part the conclusion was derived on the basis of in-house R&D and more general trends in the field, but it was also realised that the KKY and ADS projects at Televa indicated that domestic production could be viable. So far foreign companies, especially Ericsson and Siemens, had been the main suppliers and the PTT often had to pay excessive prices for larger switches which were not optimally designed for the typical sparsely populated rural areas in Finland. If Televa could present a small SPC system which would be especially suited for the typical rural network conditions the PTT had all reasons to support development work. Against this background the PTT placed a first prototype order for the ADS system in 1972. This first order also marked the start of more focused user producer collaboration in digital switching technology. Overall then, the procurement order seemingly was not part of any broader government or ministerial policy initiative or scheme. Rather there were converging interests and needs emanating from both the PTT and Televa. Televa needed technical support, reference orders and field-trial possibilities, while the PTT felt the need to support and test domestic solutions in order to avoid overdependence on foreign producers. (Tele 1993, Interviews 1996).

The ADS-project as a collaborative procurement and R&D venture

The PTT's prototype order was for a small switching system with a limited number of subscribers in the south-western part of the archipelago, covering a couple of islands. The procurement order was based on the procurement regulations covering preferential procurement at the time, and the formal contract was formulated as a collaborative R&D scheme between Televa and the PTT. The specifications were drafted jointly and only contained general performance requirements of the system, to be deployed at the latest in 1977. Noteworthy is the fact that the system was to be based on a combination of the electromechanical KMK switch and the KKY system, but included an option whereby Televa had the right to construct parts of the network using digital ADS technology. Even though the procurement order was small in monetary terms, the stipulated contract and option reduced the risk in case of failure of the KKY or ADS projects. Hence, the PTT also came to favour the KKY project while the ADS system still was regarded with suspicion. (Mäkinen 1995, Interviews 1996).

This first prototype order was crucial for the continued support for the ADS project within Televa, since the ADS and KKY projects still competed for funds; the management could not decide on the priority of the projects. At the same time the PTT advanced very cautiously on the digital front, monitoring Televa's and other foreign producers technological advances. Essentially the first prototype order was a field-trial order, and the site was soon transformed into a pilot laboratory where various competing technical solutions and technologies of the different projects were tested and developed. Apparently, development work was organised on the basis of a division of labour between the PTT and Televa, where Televa focused on the pure technical side of the hybrid system while the main role of the PTT was to conduct extensive quality and reliability tests. The PTT's telephone laboratory had developed special equipment life cycle and quality programmes for this purpose, on the basis of the competencies gained in the field during the 1950s and 1960s as the network were automated. The PTT also played an important role in adapting specific technical solutions to emerging international CCITT standards - a necessity for future exports of the systems under development - as well as choosing reliable components for the system. (Olkkola 1986, Interviews 1996).

In the mid 1970s it was already becoming evident that the next generation switching systems indeed would be digital systems and that transmission and switching systems would converge along the lines prescribed by the IDN and ISDN standards. In the south-western Finnish archipelago the PTT also started to shift their interest from the KMK and KKY projects in favour of the digital ADS system, and Televa came under increasing pressure to finalise the ADS prototype. Meanwhile R&D costs were rising rapidly alongside the more general integration of computer software and switching technology, and Televa needed more resources. At the same time CIT-Alcatel, Siemens and Ericsson, where introducing digital prototype switching systems to the market. The next significant milestone for the ADS project was the founding of Telefenno in 1977; the 50-50 joint venture between Televa and Nokia. (Mäkinen 1995, Interviews 1996).

Reorganisation and market deployment - Telefenno and the DX 200 project

By the mid 1970s the Nokia division Nokia Electronics had accumulated competencies in the field of digital so called PCM transmission and signalling technology, and had delivered the first ever PCM systems for networks operated by the Helsinki telco, finalised with 30 channels according the prevailing CCITT standard. Next there were important breakthroughs on the Soviet market. In addition Nokia had decided to gain quick access to additional digital switching technology through a licensing agreement with CIT-Alcatel. The licensing agreement covered the E 10 switching system. The E 10 was a large switching system especially suited for densely populated areas, and Nokia envisioned that the E 10 could complement both their own projects in digital transmission technologies, as well as the KKY and ADS projects under development at the archipelago pilot laboratory.

Televa and Nokia Electronics had already collaborated in connection with activities within the joint-research consortia on digital technology, and the ADS project in the early 1970s. Following these early stages Nokia Electronics then independently pursued matters further through the E10 licence agreement and their own projects in digital technology.

However, as the ADS project gained followers while at the same time development costs were rising, there was also increasing pressure within Nokia to consolidate resources and competencies further. Interestingly enough there now existed two major and complementary digital switching R&D projects in Finland; the ADS and the E10 project. There was also the KKY project. These developments coincided with a broader socialisation initiative, taken by the Social Democratic Party, which came to play an important role for the subsequent history of digital switching in Finland. (Mäkinen 1995, Interviews 1996).

State-owned firms have traditionally played a visible role in the process of industrial renewal in Finland, especially in the metal- and forestry-industries. During the mid 1970s there was also initiatives to reorganised the Finnish electronics industry into a large state-owned conglomerate as part of industry-policy motives, where the electronics industry was seen as the major growth industry in the future. An additional argument was the need to diminish the negative trade balance in key electronic components. As part of these broader plans, the socialist block in parliament as well as the Ministry of Transport and Communications and the Ministry of Trade and Commerce sought to influence the PTT to place additional procurement orders of telecommunications equipment at Televa. Alongside these demands initiatives were taken to strengthen the position of Televa, and in 1976 Televa was transformed into a state owned stock firm as the ties to the PTT and the federal budget were loosened. The same year state-owned firm Valco was founded for the production of vacuum tube components for application in the consumer electronics industry. (Lovio 1989, Turpeinen 1996).

The next sequence of events were crucial, and had direct repercussions for the ADS collaborative procurement and R&D venture between Televa and the PTT. Come the late 1970s, and both Televa and Valco run into financial difficulties. In part reasons were poor planning and commitment from part of the government, but the socialisation initiative as a whole also met opposition from other political parties as well as Nokia - the single biggest electronics and telecommunications firm in Finland at the time. During the 1976 preparations were made to disembark on an alternative course to what had originally been planned; a course which to a large extent was designed by Nokia. On the basis of extensive negotiations involving both Televa and Nokia, as well as the

Ministry of Transport and Communications and the Ministry of Trade and Commerce, the decision was taken alleviate the Televa 'problem' through the establishment of Telefenno as a 50-50 joint venture between state-owned Televa and Nokia in 1977. Some time later on Valco was dissolved. Hence, starting from 1977, Nokia had effectively gained access to all the most important technologies and know-how in Finland which were needed for the construction of digital switching systems. Nokia had also gained access to the ADS prototype project in the south-western part of the archipelago. The main task of Telefenno was now to rationalise production in the field and to develop and market a digital switching system, while the remaining departments at Televa (radiotelephones, base stations and miscellaneous electronic equipment) where sold to other firms. (Koivusalo 1995, Interviews 1996).

The joint-venture Telefenno now possessed three competing R&D projects; Nokia's license-based E 10, and Televa's analogue KKY and digital ADS system. Even though there were overlaps and cross-fertilisation between the different systems, they were essentially still competing projects. The E 10 systems was marketed as the DX 100, especially suited for urban densely populated areas, while the ADS prototype was named the DX 200, and marketed as a system especially designed for rural sparsely populated areas. While there was some pre-market selection related to personal preferences and specific technical solutions, market selection gradually started to influence decisions within Telefenno.

The first prototype procurement order by the PTT was crucial for the continuation of the ADS project (later named the DX 200 project), but it is difficult to conclude whether procurement by the PTT or the telcos was more important for future developments of digital switching in Finland. Collaboration between the PTT and Telefenno continued successfully, and in 1980 the first switching system based solely on Televa's original ADS, came into operation in the south-western archipelago area. The contract was reformulated whereby the DX 200 system was extended to also cover the parts of the network consisting of KMK technology and the analogue KKY system in anticipation of future trends in switching technology. On the basis of extensive field-trials the PTT was now ready to fully embrace the DX 200 system. Meanwhile, the PTT had realised that the DX 200 would outcompete the DX 100 system, and in the end Telefenno only delivered 5 DX 100 systems to trunk networks upheld by the PTT. These procurement decisions initiated a chain of events which gradually led to the selection of the DX 200 systems. (Mäkinen 1995, Interviews 1996).

Market selection and the founding of Telenokia / Nokia Telecommunications

Amongst the local private operators the Tampere and Helsinki telcos were the most important buyer's and user developers. Despite the fact that the telcos lacked the necessary centralised resources and user competence that characterised the PTT, close personal ties and a business orientated mind-set paved the way for collaboration, as the Tampere and Helsinki telcos also ended up favouring the DX 200 exchange as opposed to the DX 100 system. Apparently the telcos were also strongly influenced by the successfully cut-over of the ADS project and prototype procurement by the PTT, and now followed pursuit. Collaboration between Telefenno and the above mentioned telcos resulted in the next generation DX 200 system, which was a hybrid system combining Nokia's PCM technology and ADS technology. This next generation version of the DX 200 included the first fully digitised subscriber switch and Intel's 8086 processor. In 1982 the first of it's kind was taken into operation in networks upheld by the PTT. After extensive user producer collaboration, involving the PTT, the Tampere and Helsinki telcos as demanding users, Telefenno now possessed a system which not only had outcompeted the domestic KKY and DX 100 system, but which also outcompeted the main foreign systems.

In hindsight it appears that the main reason for the success of the DX 200 was the flexibility of the system, as it had been proven possible to upgraded it to support increasing number of subscribers due to rapid technological advances in microprocessor technology (the processing speed of Intel's microprocessors was continously upgraded during the 1970s and 1980s). Despite the fact that the DX 200 originally was designed to cater for demand for small switching systems in rural areas operated by the telcos, it could also be adopted to support densely populated areas or trunk switching functions. Hence, even though the telcos procured more systems, the volume of the procurement orders of the PTT was bigger and the orders tended to be technologically more demanding especially vis-a-vis system to be deployed in the trunk network. A second major reason was the fact that Nokia had developed a whole range of different signalling modes in order to adjust individual DX 200 systems to the various technologically different local networks in Finland - this a major advantage when Nokia started to market the system abroad. In 1981, as Telenokia was founded and Nokia had purchased Televa's remaining share of the switching business, the DX 200 project was the main R&D project while the DX 100 project was scrapped and had not lead to any significant technological spillovers. (Olkkola 1986, Koivusalo 1996, Interviews 1996).

Even though certain elements of infant-industry arguments might explain the first prototype order and subsequent user producer interaction during the 1970s, as Televa was state-owned and subordinated the PTT, a noteworthy observation is that the DX 200 was developed in a competitive environment. During the 1980s Televa was gradually decoupled from state ownership, through the establishment Telefenno, Telenokia and later Nokia Telecommunications. At the same time the PTT and the telcos, also procured digital switching systems from foreign producers. Table 5 illustrates the distribution of orders for telephone networks as of 1980.

Table 5 Suppliers for the telephone networks 1980 (subscriber connections). (Ekberg 1985, 87).

	Networks upheld by the PTT.	Networks upheld by the telcos.
Televa / Telefenno	34%	2%
Siemens	28%	30%
ITT	19%	4%
LM Ericsson	18%	60%
Others	1%	4%
Total	100%	100%

By 1980 Telefenno had the biggest slice of all telecommunications equipment's for networks upheld by the PTT followed by Siemens, while LM Ericsson was the dominating supplier for private local networks. These figures clearly illustrate the presence of foreign competition. They also illustrate the degree of technological variety characterising the telecommunications networks in Finland. (Ekberg 1985).

During the first half of the 1980s the position of Telenokia on the domestic market was consolidated further, as Telenokia received bigger orders from both the PTT and the telcos, and in 1984 there were around 50 DX 200 systems in operation in Finland. The same year the first systems were exported to the Soviet Union. Starting from 1985 export volumes increased significantly and at the end of the 1980s Scandinavia and the Far East had become the most significant markets. In the meantime the DX 200 was upgraded and finalised to support the ISDN function and Intel 386 processor. During 1986 40 additional fully digitised ISDN system were delivered. While the further upgrading of the system primarily has been due to in-house R&D at Nokia, the PTT has played a significant role in transmitting information about international standards in general, as well as in specific procurement cases, up until the late 1980s and early 1990s as the telecommunications equipment producers increasingly participate in standardisation activities. In hindsight it seems fair to say that the history of the DX 200 system has been a success in it's own right, but also an absolutely essential innovation for the further growth and internationalisation of Nokia during the 1990s. (Koivusalo 1996, Lemola 1996, Interviews 1996). And while the DX 200 system has been a platform technology for Nokia's move into mobile network technologies, it has probably also been the largest R&D project and most important innovation in Finnish contemporary history.

5.2. Standardisation and procurement - developing NMT cellular systems

Mobile telecommunications - technological advances and the cellular concept

If the DX 200 system consolidated Nokia's position as a major telecommunications producer within the field of telecommunications equipment for fixed networks, then the NMT initiative and the PTT's subsequent procurement decisions were pivotal for Nokia's move into mobile telecommunications. By the time that the first prototype version of the digital DX 200 switching system had been taken into traffic in Finland in 1980, significant advances had been made within the field of mobile telecommunications technologies. Already in the late 19th century the Italian innovator and businessman Guglielmo Marconi had realised the future potential use of radio-frequencies for the transmission for telecommunications, and had developed and patented a simple transmission system based on antenna technology. During the early 20th century amplitude modulation was invented which made possible the transmission of voice over radio-frequencies, and during the 1920s and 1930s the first bulky vacuum-tube and oscillating crystal radio receivers and transmitters reached the markets.

After the second world war, the emerging radiotelephone industry had to look for ways and means of adapting their know-how for civilian markets. In the USA such companies as General Electric, RCA, Motorola and AT&T were soon marketing various mobile and portable radio communications products. In 1946 AT&T obtained approval from the Federal Communications Commission (FCC) to operate the first commercial car-borne, mobile, telephone system in St. Louis, Missouri. This very small system consisted of a single base station, on high ground, and was equipped with six channels. But due to the bulky transmitters needed for sufficient transmitting power, as well as the limited number of subscribers which could be connected over the same radio-frequency, new technology and a more liberal attitude from point of view of the FCC would have been needed for the more widespread adoption of this first system. The need for new technology was satisfied much sooner than the need for more liberal policies governing radio-frequency allocation. (Meurling & Jeans 1994, Mäkinen 1995).

Like in the case of switching systems, the further developments of mobile telecommunications technologies was very much spurred by advances in the field of electronics and particularly semiconductors. During the late 1940s Bell Laboratories in the USA launched the crucial cellular concept. In brief, the main idea was to the divide the area to be covered by radio transmissions into smaller areas, or cells, each with its own base station using a number of radio-frequencies to the traffic expected within the cell. In adjacent cells, other frequencies would have to be used in order not to risk interference, while the same radio-frequencies in cells further away could be re-used. The cellular concept included the 'hand-off' function, the switch-over from one cell to another of a call in progress when a car crosses a cell boundary, which had been made possible through the introduction of the transistor and the microprocessor later on in the early 1970s. The microprocessor also replaced bulky vacuum-tube technology and thus opened the way for miniaturisation, which in turn has contributed to today's smart design and pocket phone's. Another important innovation was the frequency synthesiser, which replaced oscillating crystal radio receivers and transmitters and made 'trunking' possible. The trunking principle means that several radio channels were combined into a single radio terminal, and at the time of connection any of the free channels could be chosen. The final important technology in the cellular telephony jigsaw was computer controlled SPC and digital switching technologies, developed during the 1960s and 1970s. Digital switching is essential in cellular systems for the speed with which it will switch a call, for the hand-off function and trunking, for example. And SPC provided the high level of intelligence, or processing power, that makes all the functions and features of a cellular system possible. (Meurling & Jeans 1994).

Despite the fact that the main technologies for cellular mobile systems were available already in the late 1960s and early 1970s, more widespread diffusion was effectively hindered by the FCC in the USA. In 1964 AT&T introduced the Improved Mobile Telephone Service (IMTS), designed on the basis of the cellular concept, for a geographically limited area. Meanwhile Television was entering the markets forcefully, and managed to acquire a large chunk of the available radio frequencies, and the FCC was unwilling to fight for radio-frequency to be devoted to cellular systems. It was only during the mid 1970s that FCC managed to make the decision to authorise the building of cellular systems on a larger scale. During the late 1970s construction work for so called Advanced Mobile Phone Systems (the AMPS standard) commenced. These AMPS systems typically covered major towns, but as each system was operated by different operators the different systems were not connected and did not constitute a nation-wide system. Furthermore they only supported outbound transmission from the mobile phones, while inbound calls were not possible. They also lacked the roaming function (introduced through the NMT later), and hence the subscriber had to know from which cellular area the call was to be made. During about the same time Nippon Telegraph and Telephone Corporation (NTT) was initiating construction work, and in England the first specifications were made for constructing the nation-wide Total Access Communications Systems (the TACS standard), while the French and German authorities initiated rudimentary plans for the construction of their own nation-wide standards. In the Nordic countries these developments had not passed unnoticed. (Meurling & Jeans 1994, Mäkinen 1995).

Identifying the need and main principles of a common Nordic mobile standard

The official kick-off for the NMT venture was the NordTel conference of the Nordic PTT's in Kabelvåg, Norway, in 1969. At the meeting the Swedish PTT presented a report on the future developments of mobile telephony, based on experience gained with the local Swedish MTA and MTB mobile network systems. It also included a survey of all existing mobile systems in the world. On the basis of the report it was proposed that mobile telephony could be a additional fruitful area for Nordic collaboration.

Apart from the strong tradition of Nordic collaboration in various fields ranging from law, education, labour health and technology, there appears to have been three or four primary factors explaining the common goal that committed the Nordic PTT's.

During the late 1960s the Nordic PTT's were operating local or regional manual mobile networks, which were incompatible with each other. In Finland the PTT initiated plans to extend the ARP network to cover the whole of the country as part of the plans which had been drawn by the working group subordinated the Military General Staff. On the basis of several market analysis in the individual countries it was anticipated that there was future demand for mobile telecommunications and it was realised that the creation of a common Nordic mobile telecommunications standard could yield profit for the PTT's as the number of subscribers was expected to increase. Implicit in these considerations was the intention to provide the necessary economies of scale for the Nordic telecommunications equipment producers, which would drive equipment prices down while at the same time provide a bigger market. Closely related to this business-minded attitude from part of the PTT's was the decisive fact that the people who controlled and assigned radio-frequencies in the Nordic countries (in Finland this was the task of the PTT) had a more liberal attitude towards harnessing these limited resources, than was the case for example with the FCC in the US. The final factor was related to technical advances that had been made in the Nordic countries, but especially at the Bell laboratory in the US. (Mäkinen 1995, Mölleryd 1996, Interviews 1996).

The NMT group was summoned for the first time at the Swedish PTT in Stockholm in 1970, and subsequently gathered 4 times in order to produce a first report. The first report was drafted in the form of a request for a mandate to pursue plans for creating a common Nordic standard, and was directed to the governing boards of the Nordic PTT's. The report stated that the group would investigate the possibilities to assign common Nordic radio-frequencies, and stipulated that development work should be expected to take around 10 years to complete - not only because of the volume of work, but above all so that new developments in microprocessor technology would become available in order to design a sufficiently advanced system. In 1971, in Reykjavik, the governing board of the respective Nordic PTT's approved the mandate. In Reykjavik the very important decision was also taken to allow subscribers to the PTT's mobile networks to purchase mobile stations, or mobile phones, directly from the manufacturer which essentially meant that the demand for mobile phones would be regulated by consumer demand while demand for other mobile telecommunications equipment would be regulated by the PTT's procurement orders. The next NordTel meeting in Copenhagen in 1973 laid down some broad guidelines for the technical specifications, and in 1974 development work for drafting the specifications was kicked-off officially. (Toivola 1992, Meurling & Jeans 1994).

Drafting the specifications the NMT 450 standard

Laboratory studies, tests and field trials were undertaken by the different partners in the NMT group. Typically the technical advances which had been made in the participating countries were shared amongst the other PTT's during the meetings of the NMT group and the NordTel, and collaboration was characterised by a great deal of mutual respect, openness and trust. Evidently the work of the NMT group was not hindered by bureaucratic obstacles, and it is noteworthy that neither the governing boards of the PTT's nor higher-instance government authorities in the countries concerned intervened to any significant degree. Moreover the Nordic PTT's made no secret of the fact that ongoing development work and testing was also channelled through the participating delegates and PTT's to the telecommunications equipment producers in the respective countries. Apparently contacts between Ericsson and the Swedish PTT were especially intense, even though the

Finnish PTT also feed the Finnish producers (Nokia and Salora) with information of the emerging standard. Sometimes the PTT's outsourced specific R&D projects to the equipment producers in the respective Nordic countries and sometimes they were invited to attend meetings as consults, giving the PTT's important knowledge about available technologies and techniques.[6] These contacts with the equipment producers also functioned as cost and quality checks, and provided the PTT's with information about whether specific technical specifications were too ambitious, as well some indication of the price level for the equipment to be procured.

Above it was concluded that the cellular concept originated from Bell laboratories in the USA. Apart from the more local contacts with the various Nordic equipment suppliers, the NMT group was acquainted with the AMPS system and also closely monitored the development work carried out at Bell laboratories. Relatively early on during the drafting of the specifications it was concluded that a cellular architecture would also function as a basis for the Nordic system, in order to add flexibility and capacity to the system, but the 'state of the art' at the time would be supplemented with certain innovative features. Hence, the NMT group not only attributed to the diffusion of cellular technologies to the Nordic markets, but also played a major role for further technical advances in cellular technologies. (Meurling & Jeans 1994, Interviews 1996).

The main components of the proposed Nordic cellular system are *base stations*, *mobile stations* and *mobile telephone switching exchanges (MTX)*. The first phase of drafting the specifications was finished in 1975, and the NMT group submitted a second major report to the NordTel meeting that same year. Apart from including specifications both for the cellular system as a whole, as well as for the MTX switching system, the base stations and the mobile phones, it also included suggestions for technical solutions and guidelines for further action. In order to maximise the efficiency of the system the NMT group had decided to locate the crucial data-processing power of the air interface signalling in the mobile phones and the MTX system. The MTX system was specified as a computer-controlled digital switching system capable of handling digital signalling of large amounts of information up to a

---

[6]While the participating firms mainly were from the Nordic countries, such firms as Tekade (Germany). ITT-Alcatel, Martin Marietta, Motorola, as well as the Japanese firms Mitsubishi and NEC, were also consulted. (Mölleryd 1996).

speed of 1200 bits/second. It was also envisioned that the system should be capable of handling such features as the 'hand-off' and trunking mechanism, as well as the innovative roaming feature enabling automatic tracking of subscribers anywhere in the Nordic coverage area. Apart from the fact that digital signalling and the inclusion of roaming implied that the original plans for a manually operated system in effect were scrapped, it also had lead to especially demanding specifications for the mobile phones and the MTX system. In hindsight this was a very risky decision, since microprocessors and digital switching systems only recently had entered the markets. Furthermore the report concluded that the system would support 180 channels and operate within the 453 - 467,5 MHz radio frequency band, and also recommended that a common test-field network should be constructed in order to confirm that the specifications were necessary and adequate. (Toivola 1982, Meurling & Jeans 1994).

Introducing the producers - the Finnish PTT's procurement of NMT 450 equipment

One very important prerequisite for the subsequent procurement processes and market deployment stages was the fact that the NMT group had decided to supply the NMT 450 specifications free of charge to anyone interested and capable of supplying the necessary equipment. The PTT's realised that competition would lower prices for the various equipment, and since the specifications and especially the signalling interfaces were drafted in great detail so that the PTT's could distribute their procurement orders amongst several producers without endangering the overall compatibility of the system. In practice, however, the Nordic producers had already gained valuable insight into the technical details of the emerging NMT 450 standard through the various formal and informal contacts which had been established during the drafting of the standards, and hence had a competitive advantage. (Toivola 1992, Interviews 1996).

While the drafting of the specifications had been a very collective effort - a kind of a large Nordic technology standradisation and procurement project - the actual procurement and market deployment stages of the NMT project was delegated to the respective PTT's and hence the various national institutional factors came to play their role. In Finland the manually operated ARP network had been in successful operation for several years, and had proven the business potential and emerging demand of mobile telephony, and the PTT was now in a position to fully embrace the specifications and recommendations of the NMT group. (Turpeinen 1996, Interviews 1996). Meanwhile higher-instance government authorities had also started to realise that mobile telecommunications services and subscriber tariffs could bring more income to the federal budget, and the Ministry of Finance was being persuaded by the PTT to set aside the necessary funds for procurement and construction. Gradually, it seems, the Ministry of Finance also became willing to endorse the plan and in 1978 the budget of the radio department was increased significantly as procurement and construction plans were being formulated. (Toivola 1992, Interviews 1996).

Compared to the small-scale prototype procurement of the first (ADS) version of the DX 200 system described previously, the NMT 450 procurement project was significantly bigger and more complex and hence also required more carefully preparations and risk calculations from part of the PTT. The peculiarities of the subsequent procurement process are better understood once certain background factors are accounted for.

First of all, it should be remembered that the PTT had a natural monopoly in the field of mobile telecommunications since the PTT also controlled the radio-frequencies. The radiodepartment, and the associated radio-laboratory, was the main carrier of cellular technology competencies, which in turn implied that the PTT had all reasons to assume that the procurement decisions would become the driving force in consolidating networks of relevant actors and competencies amongst the domestic producers. Taking into account the broader institutional framework guiding procurement policies, and the nationalistic regulatory and normative framework governing bigger procurement orders such as those necessary for constructing the NMT 450 network, it seems evident that the PTT indeed was strongly biased to procure from domestic producers. Relatedly there were the more long-term infant-industry considerations as to what degree the PTT felt that domestic production should be stimulated in order to avoid overly dependence on foreign suppliers, such as Ericsson. Finally, there was the question of how the complex specifications should be transformed into functional user requirements accessible to the producers as well as how the quality of compatibility of the procured equipment should be tested. (Toivola 1992, Interviews 1996).

In 1975 the PTT had organised a seminar with the purpose of informing domestic producers of telecommunications equipment about the various technical specifications, and in 1977 the official procurement bid for tenders for the NMT system was announced for the public on the basis of the unaltered specifications drafted by the NMT group. Since the NMT 450 project was considered especially important and large, and required understanding of several related technologies, the PTT had established a special procurement group called ARPA 1 consisting of representatives from several departments at the PTT. Subsequently all responsibilities over the NMT 450 project was delegated to the ARPA 1 group. (Toivola 1992).

Turning to the main producers in Finland at the time, the industry was still very much characterised by small-scale production and the presence of the foreign firms Ericsson and Siemens. Picking up the history Salora and Nokia, the main domestic telecommunications equipment producers at the time, the first round of bid for tenders very much illustrates the important role that the NMT initiative played for the emergence of Nokia as a global player in the field of mobile telecommunications.

During the late 1970s the Nokia division Telefenno was entering the early prototype refinement and market deployment stages of the DX 200 switching system for fixed networks, and neither had the vision nor the resources to initiate a MTX project. Telefenno surprised the PTT by not submitting a bid, even though the engineers at Telefenno had made some efforts to initiate a MTX project alongside the DX 200 project in 1975 as a budgetary bid had been submitted to the NMT group. At Salora the radiotelephone division had been developing and supplying base stations and radiotelephones for the various local mobile networks, the ARP and other mobile networks abroad, but was primarily concerned with export activities of existing generations of mobile phones. Hence, despite the fact that both Salora and Nokia closely had monitored, and even participated in the drafting of the NMT 450 standard there were no domestic bids and the ARPA 1 group was forced to rely on foreign producers, especially Ericsson. (Toivola 1992, Interviews, 1996).

The subsequent period 1977-1979 was probably very important for the future of the Finnish mobile telecommunications industry. In 1978 the NMT group had been discussing different ways to formulate the complex specifications into more easily approachable functional requirements, as well as how to test various equipment prior to construction of the actual network. the mobile phones). Meanwhile, in 1979, the ARPA 1 group had procured the first MTX exchange from Ericsson (the AXE 10 system) and started to exert pressure on the domestic producers, trying to catalyse some joint R&D effort from their part. (Toivola 1992, Interviews 1996). Around the same time the Nokia - Salora joint venture Mobira, as well as the sub-contractors LK-Products (duplex filter components for mobile phones) and Micronas (semiconductors, AISC chips) were founded in order to consolidate competencies and resources in the field of mobile phones and base stations. (Koivusalo 1995).

In 1979 Mobira purchased an NMT simulator from the PTT - an important piece of equipment developed by a small Finnish engineering firm. Some time later on, in August 1979, Mobira did indeed present their bid for tenders for base stations. The ARPA 1 group did not hesitate to award Mobira with the contract even though there also were competitive bidders from abroad. In connection to the base station delivery Mobira also delivered some 50 mobile phones in accordance with the NMT 450 specifications, with special permission from the PTT, and Mobira and the ARPA 1 group extended the original procurement contract to also include collaboration and testing using the NMT simulators. During the period 1979 - 1981 the NMT 450 network was constructed, and in 1982 the network was opened to the public. (Toivola 1992).

The first NMT 450 network only covered the Helsinki metropolitan area, and the ARPA 1 group immediately initiated new plans to procure more equipment and extend the coverage of the network to include other population centres as well as rural areas. In hindsight it seems that the PTT, and the ARPA 1 group, had succeeded in promoting and consolidating domestic industrial activity in the field of mobile telecommunications. Both Mobira, LK-Products and Micronas gradually came to focus on developing NMT equipment and components, and the ongoing NMT 450 project, as well as the aggressive procurement strategy that the ARPA 1 group pursued, certainty played an important role for the strategies of the firms involved. However, even though the above mentioned Mobira 'cluster' successfully had moved into NMT technologies and were penetrating some newly opened NMT markets in continental Europe, development and delivery of MTX switching systems was still solely in the hands of Ericsson. Ericsson was about to become the main beneficiary of the NMT initiative, and was free to pursue a monopolistic pricing policy contrary to what had been the original intention of the NMT group. While this fact irritated the Finnish PTT, the management of Mobira also started to realise the strategic importance of being capable of delivering complete turn-key NMT cellular systems. (Toivola 1992, Interviews 1996).

The emerging mobile telephony boom and the drafting of the specifications for the NMT 900 standard

A salient feature of the NMT initiative was the fact that the PTT's consequently severely underestimated the popularity of mobile telephone services. Around the year 1983, only some years after the first version of the NMT 450 network had been erected in the Nordic countries, there were already signs that the radio frequencies reserved within the 453 - 467,5 MHz bandwidth would not suffice. At the time the penetration rate of mobile telephone subscribers in the Nordic countries was the highest in the world, and the NMT 450 cellular system was by far the largest single cellular system in operation. In Finland the situation was very much the same as in the other Nordic countries.

Table 6. Number of mobile telephone subscribers in Finland 1982-1986. (Telecommunications statistics 1996, 33).

Year	ARP	NMT 450
1980	23 482	
1981	28 278	
1982	31 232	2 648
1983	33 571	8 655
1984	34 145	17 865
1985	35 330	32 309
1986	35 560	49 672

Table 6 clearly shows what could be called 'the Finnish mobile telephone boom' from 1984 onwards, as the capacity of both the manual ARP system and the new automatically operated NMT 450 reached their highs. The practical consequences of this boom was that networks, and especially the NMT 450 network in the Helsinki metropolitan area, became congested despite the fact that the cellular architecture of the network as well as advancements in semiconductor technologies allowed for flexible capacity expansion and efficient harnessing of the radio frequencies. (Toivola 1992, Turpeinen 1996).

During the period 1977-1983 the NMT group still gathered for meetings in order to finalise technical details and monitor construction work, even though there had been some changes in personnel. On the national level the various PTT's were confronted with different choices to cope with the unanticipated popularity of the service. In 1983 the NMT group reached the conclusion that work would commence for the drafting of the second Nordic standard - the NMT 900 standard. (Toivola 1992, Mölleryd 1996).

Essentially the NMT 900 system was specified to function in very much the same way as the NMT 450 system, but the NMT 900 was in certain ways an improved more complex version. As the NMT 900 system had been assigned a broader band width covering more kHz of channel width the number of channels could be increased from 180 to 1000, which in turn automatically increased capacity. Furthermore, the system was specified as a small-cell cellular system whereby cells in each transmission area was further subdivided into so called micro cells, supported by a larger number of base stations, which would enable the construction of smaller mobile phones as airborne transmission had to travel a shorter distance. Finally, the signalling interfaces of NMT 900 system were specified as more complex in order to provide some additional services and features related to code security and interference hindrance.

From point of view of the equipment producers, the NMT 900 specifications did include innovative features, but these were mostly related the software requirements of the equipment that had already been developed for the NMT 450 system. In addition technological advances, mainly related to the upgrading and miniaturisation (microprocessors, batteries, new manufacturing techniques) , made possible the inclusion of additional finesse mainly for the phones. Again, the specifications were the most challenging and demanding vis-a-vis the MTX switching system, which was the most important and sophisticated component of the system. (Toivola 1992, Interviews 1996).

Initiating the procurement process - prototype trials and preparations

The NMT group presented the finalised NMT 900 specifications at the NordTel meeting in Copenhagen in 1985, and anew the procurement stage was delegated to the national level. In Finland it is possible to identify a change in strategy, both from part of the PTT as well as industry. Prior to what was above called 'the Finnish mobile telephone boom', as the PTT started to sense the coming of mobile telephony and the associated expected capacity problems, actions had already been taken at the operational level at the radio department in order to initiate the NMT 900 project. It seems that the Finnish PTT representatives, in collaboration with the domestic producer Mobira, played a quite active role in pursuing the NMT 900 agenda at the NMT group meetings.

At Mobira the first generation NMT 450 mobile phones and base station R&D projects had successfully been cut-over, and the product line was now upgraded and further developed in anticipation of further initiatives from part of the NMT group. Furthermore, in large part due to a so called Experimental Mobile Cellular Radio (EMCR) network developed in collaboration with the PTT, Mobira had also initiated R&D projects for the development of additional mobile phones and base stations for the NMT 900 network. In 1985, as the NMT group presented the specifications and the procurement process was initiated, Mobira was already capable of producing and marketing 'state-of-the-art' mobile telecommunications equipment.

During the mid 1980s the NMT competition on the producers side could be characterised as oligopolistic. Ericsson was the main MTX switching system supplier but had also managed to move into NMT mobile phone and base station technologies and thus had a significant competitive advantage as the main complete turn-key cellular systems supplier. Apart from Mobira the other main mobile phone and base station equipment suppliers were Danish Storno and KO-MA, but gradually such foreign firms as Motorola, Siemens and the Japanese multinationals NEC, Mitsubishi and Panasonic were catching up and entering the markets. (Mäkinen 1995, Koivusalo 1995).

Despite the fact that both the NMT 450 and NMT 900 standards were open standards, and thus allowed for the purchase of different network equipment from different suppliers, the management at Mobira was very quick to realise that the only viable means to compete with such bigger suppliers as Ericsson and Siemens, or Japanese multinationals, in the longer run would be to gain access to the production and exports of the kind of turn-key deliveries that Ericsson could provide, which not only would include base stations and mobile phones but also the MTX exchange and other transmission component equipment. There was increasing pressure for this kind of expansion of activities as the NMT 450 systems already had been constructed in several other European and Asian countries, while the competing TACS and AMPS as well as other cellular standards such as the German Netz C, and the French R 2000 standard were also being developed. It was also realised that turn-key deliveries would pave the way for special customer-tailored solutions, which could provide de facto monopoly positions over certain markets.

Starting from 1982, discussions were held between the Nokia subsidiary Telenokia and Mobira about the possibilities to co-ordinate R&D and production in the field of turn-key cellular systems. While the founding of Mobira had brought the Salora and Nokia teams closer together, Mobira continued to exert considerably pressure in order to initiate more extensive collaboration, which would also cover the development of a MTX system; the key to Mobiras´ further expansion. Lateral support was given by the Finnish PTT, and in 1984 Telenokia reluctantly agreed. In December the same year, Telenokia was awarded with a very crudely drafted contract for a single MTX system which essentially only contained information about delivery in 1987, as well as the price of the delivery. Among other things Telenokia was left with the decision whether to develop an MTX system in accordance with NMT 450 or NMT 900 specifications - the crude contract apparently was some kind of a manifestation of disputes between the radio department and the procurement department at the PTT. Evidently the contract was awarded in the same kind of infant-industry spirit that had prevailed previously, but Telenokia did manage to promise delivery at a lower price and on shorter notice than Ericsson's prior deliveries even though there were no other bidders for that specific order. Another important reason for supporting Telenokia was related to the anticipated superiority of the hardware solutions, or the expected technological adaptability of the system. (Mäkinen 1995, Interviews 1996).

The DX 200 MTX project and the founding of Nokia Cellular Systems

In chapter 4.1 the history of the DX 200 switching system was accounted for, from point of view of procurement by the PTT, up until

1986 when the ISDN function was fitted to the system and the DX 200 project in a sense was cut-over (incremental upgrading of the system has continued ever since). From point of view of the decentralised design of the control processor, the architecture of the NMT cellular and small-cell networks also implied that the hardware construction of the DX 200 system was especially suited as a platform for the software extensions which were required for the various signalling features which had been specified in the NMT 450 and NMT 900 specifications. This in turn would provide a more flexible and cost efficient way to construct small-cell cellular systems. When the ARPA 1 group placed the first order for the MTX system, these technical considerations paved the way for close collaboration between Telenokia and the PTT during the period 1984-1987, leading up to the first delivery of the so called DX 200 MTX switching system. (Interviews 1996).

The DX 200 MTX project might actually be traced back to the mid 1970s as the Telenokia forerunner and joint-venture Telefenno had submitted a budgetary bid to the NMT group during the drafting of the NMT 450 specifications. While only a budgetary bid, it had acquainted engineers at Telenokia with the technical details of NMT 450 MTX system. Later on, as all resources were concentrated on market deployment of the DX 200 system, any further investigations into MTX software requirements were put on ice. On the basis of collaboration between Mobira and Nokia, and outright persuasion by managers at Mobira, Telenokia gradually started to set aside whatever spare resources were available for developing a MTX system and in 1983 some additional R&D personnel was employed specifically for this purpose. At this point the 1984 procurement order by the PTT was the crucial factor which committed Telenokia to initiate development work. Development work was still organised alongside the DX 200 project, although the DX 200 project now had passed the critical market deployment stages. More R&D personnel was hired and Mobira had agreed to share the R&D costs of the project. Meanwhile the ARPA 1 group provided important information concerning the functional requirements of the system insofar as they had been altered compared to the original specifications, as the first MTX systems had been deployed in the NMT 450 network. In this way the ARPA 1 group also feed Telenokia with information about specific technical solutions and alternations which Ericsson had been forced to rely on in order to get deliver their first generation MTX system (the AXE 10 system). (Toivola 1992, Interviews 1996).

Taking into account the rather poor technical prerequisites as well as the very crudely specified procurement contract, it is interesting to note how quickly Telenokia and Mobira managed to adapt the DX 200 system to a NMT software environment and enter the turn-key cellular business. In a sense collaboration between the PTT and Telenokia paved the way for the required technical competencies, while mangers at Mobira very aggressively pursued exports. Following a predetermined strategy, it was decided to construct the system for the more advanced NMT 900 specifications as it was anticipated that demand for NMT 900 equipment would grow faster than demand for NMT 450 equipment. Meanwhile Telenokia and Mobira had already agreed to deliver the first turn-key cellular system to Turkey, and in the end Telenokia's first DX 200 MTX system was delivered to Turkey in 1986. A year later, in accordance with the procurement contract, Telenokia delivered their second system to the NMT 900 network upheld by the PTT.

Following these very important reference orders, NMT 900 systems were also delivered to France (through collaboration with Alcatel) and China. The final step towards consolidating competencies in the field of turn-key deliveries of cellular systems were taken in 1987, as collaboration between Mobira and Telenokia was internalised even further through the founding of Nokia Cellular Systems (NCS) - a business division subordinated the Nokia group. The next step phase was dedicated to the emerging GSM and DCS 1800 standards. Parallel to these developments the second significant Nokia business division - Nokia Mobile Phones - had been founded. By the early 1990s Nokia had emerged as a major supplier of both mobile phones and complete turn-key cellular systems, alongside the main competitor Ericsson. (Koivusalo 1995, Interviews 1996). Meanwhile the popularity of the NMT and GSM service had grown tremendously. Table 8 illustrates the continued growth of mobile telephony in Finland.

Table 8. Number of subscriptions to the mobile telephone networks 1987- 1999. (Telecommunications statistics 1996, 33).

Year	ARP	NMT 450	NMT 900	GSM The PTT	GSM Telcos	Subs. / 100 inh.
1987	34 262	69 560	2 038			2,14
1988	33 589	89 442	15 129			2,79
1989	32 062	112 046	45 923			3,82
1990	29 372	133 686	92 297			5,16
1991	27 896	149 573	133 478			6,35
1992	26 260	159 490	191 423	1 060	2 248	7,64
1993	23 240	172 656	267 307	10 168	8 943	9,63
1994	19 171	186 780	352 228	61 543	48 612	13,24
1995	15 223	197 849	439 044	253 203	127 500	20,37
1.7.1996	13 967	194 842	443 388	410 324	198 544	24,76

5.3. Tecnomen and radiosynchronized transmission systems for the KAUHA paging network

Paging networks as a complement to mobile telephony

The final case focuses on the PTT's procurement of radiosynchronised transmission systems for a nation-wide paging network. The case involves the SME Tecnomen; a second important firm in the Finnish telecommunications industry.

In terms of the hardware solution a paging network is somewhat similar to a mobile telephone network in that it requires base stations, a switching and transmission system and mobile stations - in this case paging devices or pagers. However, the software solutions are quite different. Signals are transmitted over radio-frequencies, but in paging networks transmissions are transmitted in digital binary digit text-coded form rather than as voice signals. Furthermore paging networks only support incoming signals. Subscribers receive text-coded messages to their pager, for example indicating incoming calls and messages. The subscriber can then chose when to contact the caller over the fixed or mobile telephone networks. Paging networks are significantly less complex and sophisticated than mobile networks, such as the NMT or

GSM system. The main clue is that paging networks are cheaper to construct and operate. Pagers are smaller and less expensive than mobile phones, and hence they function as complements to more expensive mobile telephone services.

Preceding pagers and wireless paging networks was the ancient system of light panels and different combinations of lights indicating different messages to different people. Typically this system was employed during 1940s and 1950s in firms and bigger public sector bureau's to increased reachability. The system was operated manually by the telephone operator lady. Since the system was a wired one, it was time consuming and difficult to construct. Furthermore, obviously the coverage of the network was very limited. (Toivola 1992). Technology-wise the development of wireless paging systems followed alongside the more fundamental advances made in the field of mobile telecommunications and digital technology. In a sense, paging networks combined digital technology and certain air interface and signalling features which were being developed for the first mobile telecommunications standards. (Interviews 1996).

The first wireless paging systems where wireless in the sense that the systems consisted of portable pagers while the network infrastructure still mainly consisted of cables. Primarily wireless pagers either function on the basis of electromechanical induction over radio frequencies. Following technological advances in mobile telecommunications it later became evident that radio frequencies would be a more effective way to transmit digital signals, and coverage could also be increased significantly. (Volotinen 1991). Owing to the fact that these paging systems were significantly less complex than mobile networks, they operated on one single MHz radio-frequency and hence very efficiently harnessed this scarce resource. While the radio-frequency constraints of mobile networks eventually were alleviated through the introduction of the cellular concept and cellular technologies, the main problem with paging network technologies was to avoid the problem of so called overlapping areas. When the same signal is received by a pager from two or more base stations simultaneously there are problems with signal reception, because of electromechanical interference. Places where this can happen are called overlapping areas.

During the 1960s and 1970s different methods were developed to overcome this problem. Two early methods aimed at avoiding such overlapping areas altogether. One method was to use different frequencies for different signals, but these kind of solutions obviously shared similar kind of problems associated with the limited amount of radio-frequencies which also had hampered more widespread diffusion of early mobile telephone systems. In addition, pagers also had to include channelling functions to switch over different frequencies, which made them bulkier and more expensive. The other so called time-zone approach used time division techniques. Later on synchronisation was introduced, whereby transmissions from different base stations were strictly synchronised and simulcast over the one and same radio frequency. During the late 1970s, among other things, the degree of synchronisation required (a difference of 188 microseconds at the base stations) was specified by the Post Office Code Standardisation Group (POCSAG) at the CCIR standardisation organisation. The POCSAG (even called the Radiopaging Code No.1) standard was primarily developed by the British PTT, and eventually became the dominant paging standard. (Tecnomen Radiosychronization, Interviews 1996).

During the 1960s the PTT's in several countries initiated R&D work and procurement plans to construct nation-wide paging networks for the general public. In 1964 the so called Autoruf system was taken into operation in the Benelux countries, including some parts of Switzerland. A similar system was constructed in France, in the UK and in Austria during the 1970s. By and large, these paging network systems became popular, and increased the reachability in teletransmissions significantly. Some unsuccessful attempts were also made to create a common paging network standard in Europe - the so called Eurocall standard. The Eurocall standard distributed the problem of overlapping areas over 4 channels, and reserved a capacity of up to 10 000 - 20 000 subscribers for each of the Nordic countries, but eventually only came to cover West-Germany and France. Hence, most European countries constructed their own paging network systems which were incompatible with each other. (Toivola 1992). It should also be noted that while these were all essentially competing national standards, the POCSAG standard only provided technical guidelines and did not specify European-wide roaming functions in the same way that the NMT standard for mobile telecommunications did in the Nordic countries. Pan-European roaming in paging networks has been introduced through the so called European Radio Message System (ERMES) standard later on. (Interviews 1996).

Again the Nordic dimension - identifying the need and discussing preliminary solutions

While the Nordic countries rejected the Eurocall system in favour of their own systems, the early stages of constructing paging networks in the Nordic countries was characterised by a very similar formula that had been applied during the drafting of the specifications for the NMT 450 and NMT 900 standards. Again, it seems, the initiative originated from the Swedish PTT. The Swedish PTT had experimented with paging solutions over the broadcasting networks at 57 MHz radio frequency, and ventilated the matter at the Nordic level sometime during the early 1970s. In 1973 the NordTel assigned a joint-Nordic working group called the NTR-73-3 the duty to "Consider the possibilities to construct a common Nordic paging system". While the very wording of the duties assigned to the group were similar to the NMT mandate, the fact that the same PTTs´ representatives tended to participate in both groups also illustrates the strong interconnections between the NMT and this paging initiative.

It is interesting to note that collaboration for the creation of a pan-Nordic paging network did not share the same kind of success that was the case with NMT collaboration - perhaps the much smaller paging project did not receive enough of attention and nourishment. Despite the fact that the Swedish PTT originally had brought the paging initiative to the Nordic level, there were signs early on that the Swedes would depart on their own trail and construct their own so called RDS-system.

The various market and cost-benefit studies conducted in the various Nordic countries all seemed to confirm that there was demand for paging network services. They also seemed to indicate that pan-Nordic roaming in the networks would increase the number of subscribers. (Toivola 1992). In hindsight these studies seem overly optimistic, and it should be noted that, at the time, the NMT group was still drafting specifications for the first NMT 450 network (Interviews 1996). On the basis of these positive signals and support for a pan-Nordic roaming it seems surprising that Nordic collaboration was not extended to also include the drafting of common specifications for a common paging network. The Swedish PTT was already procuring the network equipment for the RDS system, but the other Nordic countries were still pursuing the agenda towards a common system. Meanwhile the NTR-73-

3 group monitored international developments in the field, and especially work conducted at the CCIR for the development of the POCSAG code standard. Finally, in 1979, this whole Nordic paging was cut-over, and that same year the NTR-73-3 group submitted the final report to the NordTel. The report was drafted in the form of a comprehensive manual surveying all the major paging code standards available as well as how these standards dealt with the problem of overlapping areas. Credit was also given to the Swedish RDS standard. The same year the Finnish PTT took the official decision to initiate procurement plans for the construction of the so called KAUKOHAKU or 'KAUHA' nation-wide paging network. (Toivola 1992, Turpeinen 1996).

Towards specifying requirements for the KAUHA system - the problem with overlapping transmission areas...

In Finland the history of paging networks can be traced back to the late 1960s, when the PTT showed some interest in the German Autoruf system, but more far-reaching construction plans were eventually postponed. Alongside the more general mobilisation of resources for mobile telecommunications during the early 1970s, the radio department brought up the issue again and the more concrete plans were reactivated through participation in the NTR-73-3 group. Evidently the formal decision in 1979 also very much was influenced by the market and cost-benefit studies that had radio department had orchestrated back in 1974. The studies consisted of various surveys directed to a randomly selected set of potential end-users, or consumers. Apart from indicating the evident future demand and business potential these studies also indicated that the future popularity of the service very much would depend on the price that the consumers would have to pay for the pagers. Hence, cost considerations came to assume a central role in the subsequent drafting of the specifications and procurement stages. Another factor which also motivated the PTT was that the Helsinki telco already had constructed their own paging network, covering the local Helsinki metropolitan area, as the PTT had granted the required radio-frequencies and concessionary rights for this venture.

Above the emergence of the different Swedish RDS and CCIR POCSAG paging standards were discussed. The Finnish PTT was also engaged in development work for the drafting of a Finnish standard which would contain technical specifications for a paging network. This work was conducted following similar principles which were being used during the drafting of signalling specifications for the NMT 450 standard, even though the specific technical solutions differed as NMT was an analogue system while paging networks were digital and less sophisticated systems. Hence, at the outset the radio department essentially had to make a choice between employing the RDS standard or continue to develop the Finnish standard. There was also the emerging POCSAG standard, which already was attracting a lot of attention internationally.

Early on, the prevailing view at the radio department held that it would make sense to use the RDS specifications to construct a similar system to the one which was already in operation in Sweden, even though there also were other diverging opinions. It was envisioned that the RDS system could function as a interim system, which would bring income to the PTT and satisfy early demand until the POCSAG officially had been accepted as the prevailing CCIR standard. An important consideration was that the RDS system would be cheap and quick to construct since it was designed to operate through the broadcast network and the existing fixed telephone network, with the necessary basic infrastructure already in place. For this purpose the radio department and Yle, the public broadcasting company in Finland, concluded a R&D collaboration scheme to investigate the compatibility of the RDS system in Finnish conditions and a special so called VAKA working group was assigned in 1980 for this very purpose. The Swedish RDS specifications had solved the inherent paging network problem of overlapping areas through assigning a range of different radio-frequencies for overlapping areas in the network. While this solution unavoidable meant that pagers had to be fitted with multi-channeling functions, which made them bulkier and more expensive, it was approximated that the advantages of inexpensive infrastructure investments and quick interim market deployment would outweigh any additional costs to the consumer. But things did not turn out as had been planned.

The major bottleneck affecting continued development and drafting of the specifications was the public broadcasting company Yle. Yle did not seem to favour PTT's plans, once the technical implications of the plan became evident. Apparently Yle felt that paging services did not belong to their field of operation, as it represented targeted communication rather than public broadcasting. Yle also opposed the idea that additional radio band-width had to be assigned for overlapping areas, and claimed that the would be problems of signal interference affecting transmission of traditional media (this was also a problem in Sweden). Since there was now higher-instance government involvement or support involved, the VANKA working group had to conclude work and submitted the final report of this unsuccessful venture in 1980. This report in practice buried the PTT's attempts to go for specifications along the RDS standard. Shortly afterwards the decision was taken to construct an own national system, and in August that same year a special procurement group was founded to handle the drafting of the specifications. (Toivola 1992, Interviews 1996).

The PTT had already accumulated some competencies in the field. These competencies were foremost based on Finnish scientific dissertations at the technical universities, but similar problems had already been encountered as the State Railways were constructing their own radio telephone networks during the 1960s and 1970s. Participation in the collaborative Nordic NTR-73-3 group was also valuable. At the outset the very important decision was taken to design specifications for a paging system which would operate over one single radio-frequency - at 146,325 MHz. This decision implied that the problem of overlapping areas had be resolved using a technique whereby transmissions from base stations in overlapping areas had to synchronised and simulcast at exactly the same time (radiosynchronisation). On the basis of extensive field-trial test in the fixed networks involving specific measuring devices developed for that purpose, among other things, the degree of synchronisation was specified to 500 microseconds. Different radiosynchronisation solutions were also discussed, and as early as 1980 the first round of bid for tenders for the procurement contract was announced. Meanwhile the technical specifications had been altered in accordance with the POCSAG standard (the degree of synchronisation was re-specified to 188 microseconds), which was accepted at the CCIR meeting in Geneva the same year. Evidently the nationally developed code standard did not differ significantly from the POCSAG standard, and this last minute change in the specifications primarily aimed at providing incentives in the form of economies of scale and export possibilities for the equipment suppliers. Meanwhile the rather modest financial resources which were needed had already been earmarked out of the federal budget. (Toivola 1992, Interviews 1996).

The procurement process and Tecnomen

The procurement orders was for one so called trunk exchange terminal, which was specified to handle the transmission interface between the fixed trunk or local network and the pagers, over a digital switching system and the base stations. In addition to the terminal and a large amount of base stations, the order also contained some rather inexactly specified hints concerning how radiosynchronisation in overlapping areas in the network could be achieved over the same radio frequency. (Toivola 1992, Turpeinen 1996). The component capable of synchronising transmissions was named the paging network controller (PNC), but the specifications left the basic problem unresolved. Essentially the order provided an outline of the principles and requirements which the paging system was specified to adhere to, in accordance with the POCSG standard (Interviews, 1996). The order also contained specifications of the pagers, but the pager business was not assigned a public goods label and demand was primarily regulated by end-user. (Turpeinen, 1996).

The PTT received 3 bids for the first round for tenders in 1980. Following this first round, a second round of bids for tenders was announced and sent to 19 firms active in relevant fields. By 1981 the PTT had received tenders from eight firms, and the PTT decided to procure 200 base stations from the Finnish firm Mobira while the procurement of the trunk exchange terminal as well as the PNC component, supposed to control radiosynchronisation in overlapping areas, was postponed. Again owing to some internal arguments between the assigned procurement group and the procurement department, subsequent rounds of bids for tenders was delayed for a couple of years and only in 1983 were several additional invitations for tenders announced. These order only covered the trunk exchange terminal and the PNC controllers. Eventually the PTT decided to procure some additional equipment and base stations from Mobira, and the trunk exchange terminal from the Swiss company Swissphone. The PNC supplier, was the small engineering firm Tecnomen. Following this round in 1984 the PTT concluded an R&D collaboration contract with Tecnomen, covering the PNC controllers, which eventually solved the problem of overlapping areas through application of the world's first ever radiosynchronised solution for single radio-frequency paging networks. (Toivola 1992, Interviews 1996).

Turning to the telecommunications equipment producers at the time, the main base station supplier Salora (later Mobira), had already adjusted the production line to incorporate digital paging technologies and codes. This work was done in-house, but Salora also purchased concessionary rights over scientific dissertations and other codified material which had been produced by the PTT during the 1970s. The first paging base stations, and pagers, were exported to the RDS network operated by the Swedish PTT during the mid 1970s and Mobira had subsequently gained a very strong position on that market. Mobira hence already had sufficient prerequisites to successfully enter the competition for tenders for base station and pagers. (Koivulsalo 1995). The other important Finnish supplier, Tecnomen, was founded in 1978/79 by a group of engineers recently graduated from the Helsniki Technical University. Initially this small firm experimented with microprocessors and various digital technology software and hardware applications in the field of teleinformatics, seemingly without any clearly defined focus. Starting from the 1980 Tecnomen started to specialise in the field of factory automation, with special application in the metal, glassware and forestry industry, and gradually started to employ more personnel. Alongside these developments, Tecnomen also developed various measuring apparatus for modernising analogue switching systems in collaboration with the PTT. (Interviews 1996)

While Tecnomen thus had developed competencies in the more broadly defined fields of teleinformatics, especially telecommunications, and factory automation, the early 1980s marked the start of more focused activities in the field of voice messaging and paging systems. In 1980s, as the PTT provided the technical specifications and started to construct the KAUHA system, Tecnomen invested R&D funds in order to provide new methods to eliminate the problem of overlapping areas in the specified paging network. It seems that Tecnomen explicitly very closely sought to monitor the PTT's needs for miscellaneous software applications for various infrastructural investments such as the KAUHA; a flexible user-led strategy had already proven successful previously and the partners had experience in collaborating with eachother. Regarding the specific technical competencies needed, and the innovative features of the PNC controller prototype that Tecnomen subsequently presented to the PTT, these were to a large part based on previous experience in the field of factory automation in the glassware industry. (Interviews 1996).

From point of view of the PTT, the compatibility of the main components to the KAUHA network was an important issue and therefore Tecnomen had strong incentives to collaborate with Mobira and Swissphone. Prior to the third round of bids for tenders, Tecnomen and Swissphone had negotiated an agreement whereby Swissphone would be the main contractor and supplier of the trunk exchange terminal while Tecnomen, as a sub-contractor, would supply the PNC solution. Motivating such an agreement was also the fact that similar kind of procurement plans were initiated by the Swiss PTT, and it was envisioned that Swissphone and Tecnomen also would be the main equipment suppliers in Switzerland. Hence prior to the signing of the procurement contract in 1984, Tecnomen had managed to convince the PTT that they possessed enough resources to provide a compatible and viable solution for the KAUHA network. (Interviews 1996).

Market deployment of the KAUHA system and Tecnomen as a new innovator

Despite the fact that the procurement order in 1984 had been concluded between the PTT and the Swiss firm Swissphone as the main contractor on the supplier side, the PNC controller for the KAUHA network was primarily developed in-house by the Finnish subcontractor Tecnomen. Following the signing of the formal agreement, in a sense, R&D efforts for the development of the PNC controller was delegated from the PTT to Tecnomen but the PTT still came to play an important part in fine tuning and modifying the controller as well as fitting the controller components to the other elements of the KAUHA network (the trunk exchange terminal, the switching system, the base station and the pagers). The PTT and Tecnomen were involved in a constant dialogue over technical details and problems and the final version of the prototype was delivered to the network in 1985. (Interviews 1996). On May 15th, 1985, the first transmissions were sent over the network, and some months later the complete radiosynchronised KAUHA network was opened for the public. (Toivola 1992).

Above it was suggested that the PTT's severely tended to underestimate the popularity of different generations of the NMT standard. In the case of paging services, it seems that estimations were slightly overoptimistic and the general impression is that paging network services in Finland have been developed in the shadow of the hugely successful mobile telecommunications services. These differences are quite naturally explained by the fact that mobile telecommunications services offer more flexibility and mobility even though they are more expensive. Responding to these challenges, the various complementary paging services have been upgraded and broadened to also include VANS at the intersection of different NMT-GSM cellular systems and paging, such as answering systems, voice messaging systems (audiotex and voice response systems) and other information and data collection systems. Table 9 illustrates the growth of subscribers to the paging networks upheld by the PTT, or Telecom Finland, and the Helsinki telco.

Table 9. Number of subscribers to the paging networks 1985-1995. (Telecommunications statistics 1996, 36).

Year	The PTT / Telecom Fin.	Helsinki telco	Total
1985	3 102	5 067	8 169
1986	10 850	4 691	15 541
1987	18 418	4 744	23 162
1988	26 890	4 789	31 679
1989	34 219	4 843	39 062
1990	39 788	4 771	44 559
1991	40 429	4 612	45 041
1992	39 494	4 150	43 644
1993	42 073	3 781	45 854
1994	43 986	3 483	47 466
1995	45 229	2 982	48 211

For the PTT as a procurer and user, the KAUHA networks has been an important platform technology for diversification into various above mentioned VANS, even though investments and profits have been modest compared to those of the NMT-GSM services. (Interviews 1996, Telecom Finland Annual Report 1996). For Tecnomen the procurement order was crucial, and the first delivery was pivotal for Tecnomen's technological and market diversification from various more unspecified subfields of factory automation to mobile telecommunications. As anticipated, the next buyer was the PTT in Switzerland. Meanwhile property right arguments between Swissphone and Tecnomen led to the dissolvement of the ties between these two small firms. As late as in 1986, a patent was filed for the PNC controller technology and subsequently Tecnomen gained a unique global monopoly position in the field of radiosynchronised paging networks, harnessing this new innovative solution for problems with overlapping areas. Following these first important reference orders Tecnomen has supplied paging systems to many European countries and countries in the Middle and Far East. Since 1985 Tecnomen is part of a larger forestry conglomerate Kyro Ltd. The PTT has also played a role as stimulator for exports and market diversification as the unique radiosynchronised KAUHA network was presented to representatives of foreign PTT's visiting Finland. (Interviews 1996, Toivola 1989).

6. APPRAISAL OF SOCIETAL AND INDUSTRIAL RESULTS AND POLICY IMPLICATIONS

6.1. Structural tensions in the Finnish telecommunications industry - the history revisited?

On a very general level the three cases presented above provide examples of rather succesful coupling of public sector user, and private sector producer, needs. From a theoretical point of view the cases clearly illustrate the limitations of strict linear science and technology-push as well as demand pull interpretations of the innovation process. They are examples of technological development at the intersections of supply and demand factors, involving a whole range of different actors and institutions...compatible with a system of innovation approach to technological change.

Despite the fact that the chosen cases only represent snapshots of development in a broader field, the story that unfolds is one of industrial development where the Finnish telecommunications equipment industry, has evolved in a sequence of something closely resembling Dahmen's and Carlsson's interpretation of Schumpeterian transformation processes, or structural tensions. Even though managerial decisions and strategies should not be underestimated, the cases suggests that the PTT has played a more important role in this transformation process than has so far been documented for (see for example Mäkinen 1995, Koivusalo 1995, Rouvinen 1996, Lemola & Lovio 1996). This observation seems especially relevant given that both the DX 200 switching technology and competencies in NMT cellular technologies have been absolutely essential for Nokia's global success - the DX 200 has functioned as an important platform technology for subsequent switching and transmission systems, and MTX modifications for different mobile standards, while the move into NMT and cellular technologies was pivotal for further organic growth in the direction of subsequent standards and markets (e.g. TACS, AMPS, GSM/DCS/TDMA). Similar statements are applicable in the KAUHA/PNU case in relation to the growth of Tecnomen.

It is outside the scope of this paper to give a complete interpretation of the evolution of the Finnish telecommunications industry. However, in terms of the three constituent elements of development blocs, or technological systems - the institutional infrastructure, knowledge/competence networks and economic competencies - the following observations seem relevant:

1) Apart from the more basic institutional factors which have not been discussed in this paper (e.g. the educational system, labour, factor, capital and fiscal market), the most important institutional factor shaping the development of telecommunication technologies has been the decentralised system of operators, or users of telecommunications equipment as well as the set of regulations and laws which have prompted competition on the market, and the strong early presence of foreign competitors on the home market. A duopsonistic buyers market, and the early presence of foreign firms, has enhanced competition and technological diversity (different technical solutions for different users' functional requirements) on the market, which in turn has induced the various users and producers, and Nokia predecessors/business units (Televa, Salora and Telefenno-Telenokia, Mobira) to engage themselves in the process of continual product and system upgrading and renewal. This competitive situation has not only been restricted to the private end of the market (the telco's) but is equally evident from the point of view

of the PTT's activities. Despite the fact that the PTT and the telco's have not competed for market shares, the PTT has had to adjust to competitive pressure stemming from the rapid upgrading of other parts of the network. In this context the procurement regulations and norms affecting the PTT's procurement decisions have added additional elements of competition, even though a certain mismatch between the protectionistic, infant industry favouring stance of higher-instance government authorities and the more entrepeneurial, business-minded attitude of the PTT is evident. Nokia is not a national champion.

The role of basic research at the technical universities and the VTT has been important, especially in pre-paradimatic stages of development such as those prevailing before the wider diffusion of digital switching and mobile telecommunications. R&D labs, both in industry, at the PTT and the larger telco's (especially the Helsinki and Tampere telco's) have shared the responsibility for more applied research, and especially important research and testing has been undertaken in the R&D laboratory at the PTT's radio department. Prior to the wider diffusion of mobile telecommunications the PTT's radio department was an important consolidator of cellular-technology know-how in Finland. Later these competencies diffused more broadly, mainly through the NMT 450 and 900 specifications.

2) When the perspective is broadened to cover also the significance of interactions and links between the above mentioned various institutions, it seems obvious that competence networks, and information flows, have played an important role.

Owing to the dominant position of Nokia in the field of high-technology, the telecommunications equipment industry forms the core of the Finnish innovation system. The role of Tekes, as a bridging institution at the industry-industry, and industry-university-VTT interface, has been especially important in this field since electronics and information technology have been prioritised areas in Finnish technology policy. From the point of view of this paper, the most significant dimensions are the user-producer, or buyer-seller linkages, as well as collaboration and the vertically and horisontally integrated relationships between the various telecommunications equipment producers. The cases presented in this paper illustrate the blending of visions (technological expectations and opportunities) and vested interests of the various actors which is manifested in the form of joint experimental R&D collaboration, investments and joint marketing efforts. The cases illustrate processes of network creation around specific technological problems and opportunities - a set of complementarities - occurring at different points in time.

The diffusion of digital technology in Finland is a good example of joint effort directed towards understanding the fundamentals of the emerging IDN / ISDN paradigm in telephone switching. Following the pre-competitive research consortia, consisting of representatives from industry, the technical universities, the VTT, and the operators, a close mutually beneficial R&D venture evolved between Televa/Telefenno and the PTT. This venture eventually paved the way for the digital switching trajectory and Nokia's important DX 200 project. In the case of mobile telecommunications, an additional important set of collaborative relationships have been those between the defence sector, the state railways and the PTT, especially during the early days of mobile telecommunications in Finland (see also Palmberg 1997). Later on, the Nordic NMT initiative strongly influenced the consolidation of competencies of the prime carriers of mobile telecommunications know-how in Finland. Apart from the establishment of Mobira / Mobira-Nokia (a joint mobile phone venture between Nokia and Salora), LK-Products (duplex filter components for mobile phones) and Micronas (semiconductors and AISC chips), an extensive sub-contractor network was also established closely related to Nokia. The role of the PTT was primarily to disseminate information on the technical details of the emerging NMT 450 and 900 standards - the crucial issues was related to the signalling and software compatibility of the various system components (base stations, mobile phones and MTX systems) which in turn explains the need for a clustering of resources around cellular system technologies. In the KAUHA case, a similar network was established around the paging technology trajectory.

Common for all the cases is the crucial role that the PTT's procurement projects evidently have played for the clustering of resources around the specific technologies - from this perspective procurement projects undertaken by the PTT have had an apparent system, or network-creating, effect. At this point, however, it should be strongly emphasised that the procurement activities, and user producer linkages involving the PTT as a user and buyer, primarily have stemmed from the PTT's needs to develop a modern functional telecommunications infrastructure to meet socio-economic needs, while there have not been any clear links to any explicit government-level technology policy schemes etc. It is only the fact that the PTT is a public sector organisation which justifies labelling the PTT as a technology procurement policy maker. Hence, the most interesting issues of the procurement efforts of the PTT relate to the entrepeneurial spirit and mutuality which characterised user-producer interaction between the PTT and the telecommunications equipment rather than the public policy content of this relationship. Policy issues and links to government policy thus seems less relevant than the parameters which have shaped the organisation, management and effectiveness of the procurement processes in each of the specific cases (see chapter 6.2.).

3) Turning to issues of entrepeneurship and economic competencies of the actors involved, these concepts seem especially relevant to illustrate the process of industrial transformation of the technological system underlying the telecommunications equipment industry.

Carlsson & Stankewicz (1991, p.18) points to the importance *of "..something or someone to get the process started...". "...the role of the entrepreneur is to provide the spark of the vision that turns a network into a development block...*[who]*...has to perceive the (future) need, identify the necessary ingredients, secure the resources that may be missing initially, and communicate his vision to the relevant agents..."*. In the case of the evolution of Finnish telecommunications, entrepreneurial activity and economic competencies is foremost identifiable at the level of the tightly-knit network of engineers at Televa, Telefenno/Telenokia, Mobira, other Nokia affiliates and Tecnomen - the producers of telecommunications equipment. The main point of this paper is that similar kind of entrepeneurship and economic competencies is also identifiable on the user side of the market, especially at the different departments and hierarchies of the PTT *despite* the fact that the PTT was a public sector organisation. These structural tensions, which have developed through intensive interactions between the various producers and the PTT (through technology procurement schemes), have been one major force driving the evolution of the Finnish telecommunications equipment industry. This observation seems valid during the period up until around the mid 1980s, when Nokia initiated an aggressive process of global growth.

In the DX 200 case the initiative for the development of digital switching stemmed from Televa (positive and negative transformation), notwithstanding the fact that Televa formally was subordinated the PTT. The prototype ADS project was endorsed by the PTT, through the first experimental preferential procurement order in 1972, as part of a more long term wish to establish domestic production of digital switching systems, counterbalancing Ericssons' strong presence in the field. Subsequently developments came to favour the digital switching paradigm, and the order was crucial to counterbalance the scrapping of electromechanical switching systems, which eventually might have driven Televa out of the business and hindered the further advancement of the digital technology trajectory. Meanwhile a combination of selective capabilities (correct component choices, crucial follow-up orders and market openings, cross-fertilisation of the different switching technologies etc.), organisational capabilities (the consolidation of switching technology competencies through the foundation of Telefenno/Telenokia), and other technical and learning abilities from the part of the public and private actors involved, paved the way for Nokia's move into the field of digital switching, MTX and other cellular technologies.

Moving on to the Nordic NMT initiative, prior accumulation of competencies in mobile telecommunications laid the foundations for a set of positive transformation processes - cellular systems did not replace fixed systems - which were set in motion at the national level by the aggressive procurement strategy of the PTT. Like in the DX 200 case, the prime background motive was related to infant-industry arguments, despite the fact that there was competition amongst the suppliers, where the PTT wanted to avoid becoming overly dependent on Ericsson's monopolistic pricing policy. The NMT initiative opened up avenues of new technologies (upgraded cellular technologies - for example the pan-Nordic roaming function) and markets (through the wider diffusion of the NMT standard), as well as new methods of production and marketing (miniaturisation, the cellular business/turn-key-deliveries and network value-added services). Again a combination of selective capabilities (semiconductor components and duplex filter production, NMT simulator, exports to Turkey etc.), organisational capabilities (the founding of Mobira, LK-Products and Micronas, the ARPA 1 group etc.), technical (the MTX project, joint engineering and marketing etc.)

and learning abilities set the stage for Nokia's breakthrough in the cellular business. The PTT has benefited as a monopoly provider of mobile telecommunications services. In the KAUHA case similar mechanisms were at work, but on a smaller scale. Technology procurement by the PTT catalysed technological change along a new trajectory for the mutual benefit of both Tecnomen and the PTT. In contrast with the previous cases, however, the procurement order was awarded to Tecnomen on the basis of the technical superiority of the radiosynchronised solution for the KAUHA network, while infant-industry arguments had no role to play.

6.2. Organisation, management and effectiveness of technology procurement in the Finnish context

Above it was suggested that the public sector content of the PTT's procurement activities (formulation of clear procurement policies and strategies, links to higher-instance authorities and technology policy aspirations) seem less relevant to analyse than the parameters which actually shaped the organisation, management and effectiveness of the procurement processes underlying structural tensions of user-producer interactions in each of the specific cases. Table 10 summarises the cases in terms of the parameters which seem especially relevant from a theoretical/empirical point of view.

Table 10. Some critical parameters shaping the organisation, management and effectiveness of the procurement processes.

Case	Market structures and competition	The PTT's user competence	Technological development and policy mix	Political factors and institutional rivalry

DX 200, *(1972-1986)*	Users Oligopsonistic/ fragmented, competitive structure. The PTT as one procurer alongside the telcos (mainly the Helsinki and Tampere telcos). Producers Oligopolistic competition (Televa, and mainly Ericsson and Siemens) couple with the gradual growth of Nokia.	Pre-paradigmatic research consortia on IDN/ISDN involving the PTT, the telcos, the technical universities, the VTT and industry. In-house R&D and external contacts to other PTT's.	Pre-paradigmatic research consortia, R&D subsidy and adaptive oriented procurement during early stages of developments in digital switching. Lack of policy co-ordination and links to government policy.	Televa as a state-owned producer... gradually de-coupled from the PTT. Conflicting interests/ institutional rivalry related to government socialisation initiative. Government infant-industry arguments conflicting with the interests of the PTT.

NMT *(1975-mid 1980s)*	User Monopsonist, with strong market power and technical competence. Producers Oligopolistic competition on the Nordic and global level due to open standard.	In-house R&D. Competencies accumulated during construction of the ARP network, Nordic collaboration through the NMT group, outsourcing of specific research and testing to industry.	Standards and combination of aggressive development and adaptive oriented procurement during early stages of developments in cellular technologies. The PTT as a regulator (monopoly over radio frequencies) and procurer.	Lack of government involvement; a necessary and crucial condition? Tradition of Nordic collaboration mitigated institutional rivalry.
KAUHA and PNC, *(1979-1985)*	User Monopsonist, with strong market power and technical competence. Producers Competitive market.	In-house R&D, collaboration with technical universities, Nordic collaboration.	Standards and development oriented procurement of novel enabling technology during the maturing of paging technologies. The PTT as a regulator (monopoly over radio frequencies) and procurer.	Lack of government involvement. Conflicting interests and institutional rivalry on the Nordic and national level, and within the PTT.

It is evident that market structure and competition have been of central importance. Essentially this paper has dealt with two types of buyer, or user, markets; oligopsonistic/fragmented and monopsonistic.

The DX 200 case provides an interesting example of development oriented technology procurement in an fragmented market situation closely resembling oligopsonistic competition (even though competition was not for market shares), where the procurement decisions of a few large buyers - the PTT and the Helsinki and Tampere telcos - have been the central elements of the selection environment which led to the successful selection of the ADS/DX 200 project at Televa/Telefenno/Telenokia. It is interesting to note the role that the PTT has played as a 'quality leader' - the telcos very closely monitored technological developments following the PTT's first prototype procurement contract and experimental development work at the field-trial location, and clearly were influenced by the actions of the PTT. Later on, as the digital technology trajectory became more stable, other bigger telcos ended up favouring the DX 200 project. The telcos provided important inputs for the further development of the original prototype, as the system was continuously upgraded alongside technological advances in complementary technologies such as Intel's microprocessors. Competitive pressure on the producer side of the market stemmed from the strong presence of such foreign firms as Ericsson and Siemens. The first prototype order was based on preferential procurement while follow-up orders were based on the technical adaptability of the domestically developed DX 200 exchange.

Turning to the NMT case, the monopsonistic market power of the PTT stemmed from the crucial fact that the PTT had a monopoly in allocating and harnessing radio-frequencies in Finland. This monopoly was efficiently harnessed through competencies that had been developed during the construction of the first nation-wide ARP. In contrast with the DX 200 case, it is evident that this monopsonistic market power was the fundamental factor which enabled the PTT to influence innovative activities, and consolidation of competencies, on the producer side of the domestic market. However, one important additional circumstance is the fact that the domestic producers faced duopolistic competition and a duopsonistic buyers market on the Nordic level for the *same* NMT cellular technologies (the NMT specifications were made public). This competitive situation evidently created a situation where there was limited room for 'national champion' policy, whereby only one Nordic producer would have been favoured despite the monopoly of the PTT's on the national level. In Finland, the PTT almost forced domestic producers (Mobira and Telenokia) to enter the field in order to avoid a situation where producers would dictate prices. Furthermore, the duopolistic producers market enabled the Nordic PTT's to cross-check quality and prices of the equipment to be procured. In the KAUHA case the importance of the PTT's monopsonistic market power is more clear-cut, and Tecnomen had strong incentives to innovate closely in line with the PTT's functional requirements.

Turning to issues of public sector user competencies, the major observation relates to the fact that the PTT itself has been the user of the technologies procured (the DX 200 switching system, NMT base stations and the DX 200 MTX switching system, the PNU component for the KAUHA paging network), which in turn has forced the PTT to closely monitor technological advances through own in-house R&D activities and contacts abroad. The PTT has used these technologies to sell telecommunication services to consumers or end-users, who thus only have had limited capacity to influence the procurement processes. A common characteristic of all the cases is the role that the PTT has played as an early user of new technologies which later have diffused more widely in Finland and abroad (especially as was the case with the NMT cellular standard and radiosynchronised paging networks). In a sense the PTT has acted as a 'lead user' in the sense that von Hippel has used the concept.

Above the basis of the PTT's competencies was discussed from point of view of interactive learning in a system of innovation context (interactions between the main actors - industry, the technical universities, the telcos, the defence sector, the state railways etc.), especially in the case of the pre-paradigmatic stages of digital switching and the ADS/DX 200 project. Earlier in this chapter it was also suggested that the market power of the PTT in the field of mobile telecommunications (the NMT and KAUHA cases) primarily derived from the fact that the PTT had a monopoly over radio-frequencies and also had developed original competencies in the field, especially through Nordic collaboration (the NMT group and the NTR-73-3 group in the case of KAUHA). A final noteworthy factor in this contest relates to way that the PTT, as a user, communicated or transferred these competencies to the suppliers or producers.

Noteworthy for all the cases is the significance of standards (IDN, ISDN, NMT 450 & 900, POCSAC) underlying the technical specifications of the systems procured. Furthermore, in the DX 200 case, and the case of NMT, the importance of prototype testing and instrumentation was crucial (the early ADS prototype, NMT simulators and the EMCR network). The PTT has played the important role as mediator, monitoring external technological developments through active participation in the various international standardisation initiatives and organisations. This information has then been transferred to industry through the various technical specifications, which have been drafted using prototype systems and simulators. While the drafting of specifications has been a very interactive process, involving both the PTT and the producers, it seems that the main problems have been related to internal rivalry between the various departments and hierarchies inside the PTT, especially between the procurement department (responsible for commercial and legal aspects of procurement) and the technical/planning departments.

The NMT case very clearly illustrates a strong interconnection between standardisation (at the Nordic level) and procurement. Through the specifications, and subsequent collaboration with the PTT, Nokia gained valuable information on the systematic elements of cellular technologies while the ARPA 1 group at the PTT also could inform Nokia on how Ericssons previously delivered equipment functioned in the NMT 450 environment. The NMT simulators, as well as the EMCR prototype network enabled the domestic producers to deploy and test the technologies before actual market deployment. In the KAUHA case the POCSAC standard provided the broader specification guidelines for a solution to the problem of overlapping areas in paging networks, while the novel radiosynchronised solution foremost was developed in-house by Tecnomen. The importance of technical specifications formulated in line with emerging and dominant standards is also obvious from the point of view of the export potential of the systems developed.

When the significance of the different stages of technological development (following the Kline & Rosenberg 1986, 'chain-linked model' and the Rothwell 1994, technology activity approach), as well as the potential role of complementary public is included in the discussion, the cases support the claim that public technology procurement has greatest impact at the early stages of the technology life cycle. Common to all the cases presented here is that the PTT has created an important early, experimental market, through important reference orders supported by advanced user competencies (development oriented procurement). Later these market openings have directly influenced the diffusion and marketing of the system procured. At this 'stage' of technological development, the PTT has acted as a risk sharing user, providing important user feedback on the basis of prototype deployment (adaptive oriented procurement...especially in the case of the DX 200). An essential future for the commercial success of the systems procured has been subsequent more widespread demand and export opportunities. This interpretation lies very close to Burenstam-Linder's hypothesis of demand-induced exports, and in chapter 6.1. it was already suggested that the PTT has adhered to infant-industry arguments...primarily for selfish reasons rather than for industrial policy reasons.

The potential of early public sector demand also seems to be greater during early stages of the technology life cycle, when technological change is rapid and technological and financial uncertainties are high. For example in the DX 200 case technology procurement decisions by the PTT were decisive for the future of the ADS project (instead of the KKY project, and later the license based E10/DX 100 project), and later affected the procurement decisions of the telcos. In the NMT case the PTT's were operating at the technological frontier, while uncertainty was reduced through the 450 and 900 standards and their rapid, wider diffusion.

Another observation in this context is how difficult it is to disentangle the relative role of technology procurement by the PTT from firm managerial decisions and strategies, other feed-back links, and public promotion, which all have played their part in the development of the systems procured. From the point of view of public sector activities, for example, the research consortia on digital switching technology was originally funded through R&D subsidy by the Ministry of Trade and Industry, as Televa was part of the PTT. In later stages, when connections to the PTT were loosened and the joint venture Telefenno (later Telenokia) was established, the PTT 'intervened' through preferential procurement and R&D collaboration, while the role of standards has been evident in the NMT and KAUHA cases. If the time span is extended to include also the market deployment, commercialisation and diffusion stages, the cases illustrate how technology procurement has lead to R&D collaboration and prototype refinement, while especially the NMT and KAUHA cases provide some evidence that the PTT also has put effort to market the systems (NMT and paging network construction and services) in order to create business opportunities of their own. These difficulties to disentangle, or even identify, the relative significance of technology procurement by the PTT obviously is problematic from an analytical point of view. Furthermore it is not possible to quantify costs and benefits of procurement in monetary terms.

Last, but not least, the cases illustrate the significance that political factors, and institutional rivalry in the public sector, undoubtedly play in public goods markets and public sector intervention....also on the demand side.

It has already been noted that it is difficult to identify any clear policy-links between higher-instance government authorities and the PTT. In fact the main tensions have been related to a clash of interests between the two, as the PTT has sought to nourish competition on the market while the regulations, norms and political lobbying has aimed for a larger domestic content of the PTT's procurement order for employment reasons. In the cases where there is reference to infant-industry arguments - most visibly in the DX 200 and NMT cases - these have originated from the long-term needs of the PTT rather than anything else, and the impression is that it would have been advantageous for the PTT to have more autonomy vis-a-vis the state as procurement plans were drafted and put into practice. Similarly, the fact that the PTT was subordinated a scarce federal budget complicated long-term planning and procurement, which in turn , ironically, undermined protectionistic tendencies and 'national champions' policies at the ministerial level as the PTT was forced to encourage price competition on the market. Later, in the late 1980s and early 1990s, the trend towards decentralisation has been very rapid while the last rudiments of protectionistic procurement regulations have been dismantled.

Running through the cases is also conflicting interests related to technical and organisational aspects of procurement, as well as rivalry within the PTT. In the DX 200 case the state-owned firm Televa was the host of the digital switching project (the ADS project) until Nokia acquired 100% ownership of Telefenno in 1981. Even though Televa officially was subordinated the PTT, the engineers involved in the project frequently had to fend of threats related to political lobbying and financial priority-setting within Televa. In the mid 1970s, when there were plans to socialise the Finnish electronics industry, decisive action by managers at Nokia was the main factor which 'saved' the ADS project as Telefenno was established in 1977, as a 50-50 joint-venture between the state (Televa) and Nokia. During these critical stages, any other path might have lead to the divestment of the digital switching trajectory in Finland since continued financial support for state-owned bigger R&D ventures came under scrutiny after the Valco failure (the government initiative to establish domestic production of vacuum tube components for the emerging consumer electronics industry).

Turning to the NMT case, it seems that the limited role of political involvement by the Nordic governments was an important explanation for the evident success of Nordic collaboration in the field in general. Again there was no clear link between higher-instance authorities and the PTT's initiatives (at least in the case of the Finnish PTT's involvement in the collaborative venture), and the NMT group was given a broad and independent mandate to pursue matters further on the basis of technical consideration alone. Supporting the venture was a strong tradition of Nordic collaboration through the Nordic Council, while the fact that the Finnish PTT (as well as the other PTT's) also had concessionary right over the radio-frequencies was apt to mitigate institutional rivalry at the national level. In the KAUHA case these elements were also in place, but collaboration on the Nordic level was more problematic. At the national level the main problems seem to have been related to rivalry between different departments at the PTT with representatives in the ARPA 1 group (mainly between the various R&D laboratories and planning departments, and the procurement department). The KAUHA case also illustrates problems of conflicting interests between the public broadcasting company (Yle) and the PTT's plans to implement procurement decisions cost-efficiently. It is the existence of political tensions and institutional rivalry, present throughout the procurement processes described in this paper, rather than the fact that they were overcome in these specific cases, which are interesting when discussing policy.

6.3. Policy implications

The lack of a Finnish model of technology procurement as well as the limited public policy content of the PTT's procurement decisions makes a discussion of policy implications difficult. Rather attention inevitably shifts to those above mentioned parameters, which have shaped the evident favourable outcome of technology procurement by the PTT. The policy contributions of this paper thus deal with such issues market structure and competition, and the relations between standards and procurement.

The most salient issue arsing from the cases is the tensions which might exist between, on the one hand competitive procurement, and on the other the importance of competent public procurer with strong market power.

The Finnish experience seems to suggest that a monopsonitic buyers market, where a competent public sector agency places procurement orders based on transparent competition and open standards/technological specifications, coupled with a competitive producers market are favourable conditions. The obivous example is the NMT and the KAUHA case, even though there were also infant-industry consideration behind the PTT's aggressive procurement stance vis-a-vis the producer. The policy conclusions from this could be to enhance competition on the producers market in sheltered sectors through complementary policies (e.g. antitrust regulations and industrial policy measures) combined with transparent procurement rules, such as those already strived for within the EU...in so far as they also contain clausuls incorporating non-price factors as product or systems selection criteria.

The importance of a competent public procurer with strong market power is less obvious and might primarily be relevant concerning big technology procurement projects, such as the historic example of defence sector procurement in the US, or here the exampel of the NMT project in the Nordic countries. Big orders, when misplaced, cause potential more adverse effects on technological development than smaller orders. Likewise the present trend towards liberalisation and privatisation of public utilities in traditional public procurement sectors (e.g. energy, water, telecommunications) are at odds with any resort to technology procurement on a larger scale. Rather the issue seems to be to pin-point such sectors in the economy with greatest potential for demand-induced innovation, and areas where a competent public agency might have potential to act as a lead user, or quality leader notwithstanding that the agency is not in a monopoly position on that market. Overall the implications for public technology procurement of the present trends towards liberalisation and privatisation in many sectors need much closer considerations than has been possible in this paper.

Another policy issues relates to timing and sharing of risk over the technology life cycle. Here public technology procurement does seem to have most potential during early stages of technological developmenmt when technical and finacial uncertainties are high. Public technology procurers can here reduce the risks for producers, and aid in broader adoptation of a new technology. On the other hand any such statements are subject to the problems of the unceratinty in a complex, evolutionary, world. How can the policy maker identify emerging, promising technologies? In the same way that firms might misinterpret the technological and institutional environment, so can the public procurer. Rather it would seem that public procurers should strive to coordinate small, fragmented, users markets where they might act as catalysers for technology diffusion and reduce incompatibility by providing a common user-base upon which varieties of products/systems may be introduced (see also Malerba 1996).

This brings the discussion to the potential of combining standards and technology procurement - indeed much of the institutional machinery (e.g. the regulatory powers of the Commission, organisations such as the ETSI) is already in place at the EU level. It would seem that standardisation, as some kind of intermediate form of technology procurement, is the way forward in an EU-context. Standardisation would hence replace active procurement policies with a more passive kind, where public and competent agencies strive to valorise incompatibility between technological solutions within the EU...but delegate the actual procurement decissions to end-consumers. On the other hand there is the problem of betting on the wrong standard, as well as political and institutional rivalry between different economic-social groupings. Furthermore, standardisation is now a global issues, and subject to political rivalry between different regional areas (e.g. between the US, EU, Japan and Asia).

Malerba (1996, p.17) suggests that "public policy may bring into the industrial realm a vision that is different - more general, more related to the public interest and sometimes with a longer horizon - from the ones of firms...". Edquist & Homén (1997) take the point of departure that "...goverenment technology procurement must be the satisfaction of *genuine* social needs -- in other words, specific societal needs inlikely to be met by the market". Subject to the difficulties of actually identifying *genuine* needs, as well a public sector incompetence, difficulties to identify emerging, promising technologies and betting on the 'right' standards , it would seem that these observations make the strongets case for public technology procurement. Nonetheless the most serious mistake that proponents of public technology procurement could make is to adhere to an overly linear demand-pull view on technological change...in the same way that supply-oriented public promotion tends to rely on an overly linear science and technology-push view on technological change.

REFERENCES

Literature

Arrow, K. 1962. The economic implications of learning by doing. *Review of Economic Studies*, vol. 29, 155-73.

Burenstam-Linder, S. 1962. *An essay on trade and transformation.* New York: Wiley.

Carlsson, B & Stankiewicz, R. 1991. On the nature, function and composition of technological system. *Journal of evolutionary Economics,* vol. 1.

Carlsson, B & Eliasson, G. 1994. The nature and importance of economic competence. *Industrial and corporate change*

Carlsson, B. 1994. Technological systems and economic performance. In Dodgson, M & Rothwell, R (eds.): *The handbook of industrial innovation.* Cheltenham, UK: Edwar Elgar.

Dahmén, E.1950. *Entrepreneurial activity in swedish industry 1909-1939.* Stockholm: IUI.

Dahmén, E. 1989. Development blocks in industrial economies. *Scandinavian economic history review,* vol. 1, pp.3-14.

Dalpe, R. 1994. Effects of government procurement on industrial innovation. *Technology in society,* Vol. 16, No. 1, pp. 65-83.

Davies, A. 1994. *Telecommunications and politics*. London: Pinter Publishers.

Edquist, C. 1996. Government Technology Procurement as an instrument of technology policy. In Teubal, M (ed.)*Technological infrastructure policy.* The Netherlands: Kluwer Academic Publishers.

Edquist, C & Homén, L. 1997. *Government technology procurement and innovation theory.* Paper submitted to the EU Commission, June 1997, for the research project Innovation Systems and European Integration.

Edquist, C. 1997. Introduction in *Systems of innovation - technologies, institutions and organisations*. London: Pinter Publishers.

Ekberg, J. 1985- The case of Finland. In Granstrand, O & Sigurdson, J *Technological innovation and industrial development in telecommunications: the role of public buying in the telecommunications sector in the nordic countries.* Lund: Tryckericentralen AVC.

Faucher, P & Fitzgibbons, K. 1993. Public demand and the management of technological risk in large-scale projects. *Science and public policy*, vol. 20, no. 3, pp. 173-185.

Freeman, C. 1994. The economies of technical change. *Cambridge journal of cconomics,* no. 18, pp. 463-514.

Freeman, C. 1987. *Technology policy and economic performance: lessons from Japan.* London: Frances Pinter.

Geroski, P.A. 1991. Procurement policy as a tool of industrial policy. *International Review of Applied Economics,* vol. 4(2).

Granstrand, O & Sigurdson, J (eds.). 1985. *Technological innovation and industrial development in telecommunications. The role of public buying in the telecommunications sector in the Nordic countries.* Lund: Research policy Institute.

Granstrand, O & Sjölander, S. 1994. Managing innovation in multi-technology corporations. In *The handbook of industrial innovation.* Cheltenham, UK: Edward Elgar.

Imai, K, Nonaka, I & takeuchi, H. 1985. Managing the new product development. In Clark, K & Hayes, R (eds.). *The uneasy alliance. Boston:* H.B.S Press.

Insinööriuutiset 1983

Johnson, B. 1992. Institutional learning. In Lundvall, B-Å (ed.): *National Systems of Innovation and Interactive Learning.* London: Pinter Publishers.

Kamien, M.I & Scwartz, N.L. 1975. Market structure and innovation: a survey. *Journal of Economic Litterature*, vol. 23, no.1, pp. 1-37.

Kline, S & Rosenberg, N. 1986. An overview of the process if innovation. In Landau, R & Rosenberg, N (eds.): *The Positive Sum Strategy: Harnessing Technology for Economic Growth.* Washington DC: National Academy Press.

Koivusalo, M. 1995. *Kipinästä tuli syttyy: Suomalaisen radiopuhelinteollisuuden kehitys ja tulevaisuuden haasteet.* Jyväskylä: Gummerus Kirjapaino.

KTM:n työryhmä- ja tomikuntaraportteja 13/1996. Oy Edita Ab, Helsinki.

Lemola, T. 1993. Characteristics of Technology Policy in Finland. In Vuori, S & Vuorinen, P (eds.): *Explaining Technical Change in a Small Country* - *The Finnish National Innovation System..* Heidelberg: Physica-Verlag.

Lemola, T. 1995. Evolutionary Economics: Implications for Technology Studies and Policy. *Science Studies*, vol. 8, no. 2.

Lemola, T & Lovio, R (ed.).1996. *Miksi Nokia, Finland.* WSOY, Juva.

Lemola, T. 1996. Riittääkö kolme miljardia markkaa? In Lemola, T & Lovio, R (eds.) *Miksi Nokia, Finland.* WSOY,Juva.

Lovio, R. 1989. *Suomalainen menestystarina - tietoteollisuuden verkostotalouden läpimurto.* Helsinki: Painokaari.

Lovio, R. 1993. *Evolution of firm communities in new industries - the* *case of the Finnish electronics industry.* The Helsinki School of Econonomics and Buisness Administration, Series A:92.

Lovio, R. 1996. Yhtymien muodonmuutokset ja liiketoimintojen kiertokulku. In Lemola, T & Lovio, R (eds.). *Miksi Nokia, Suomi.* WSOY, Juva.

Luukkonen, T. 1993. Suuntana osakeyhtiö - Telen muutoskausi 1984...1993. In Tele: *Poimintoja teletoimen historiasta,. Osa 5.* Helsinki: Painatuskeskus Oy.

Lundvall, B-Å. 1992. User-Producer Relationships, National Systems of Innovation and Internationalisation. In *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.* London: Pinter Publishers.

Lundvall, B-Å. 1992a. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.* London: Pinter Publishers.

Malerba, F. 1996. *Public policy in industrial dynamics: an evolutionary perspective.* Paper presented during the Innovation Systems and European Integration-workshop in Athens, March 13-15, 1997.

Meurling, J & Jeans, R. 1994. *The mobile phone book - The invention of the mobile phone industry.* Communications Week International, London.

Ministry of Transport and Communications 1996.

Mowery, D. 1995. The Practice of Technology Policy. In Stoneman (ed.): *Handbook of the Economics of Innovation and Technological change.* Blackwell Publishers.

Mowery, D & Rosenberg, N. 1979. The influence of market demand upon innovation: a critical review of some recent empirical studies. *Research Policy,* vol. 8, pp. 102-153.

Mäenpää, K & Luukkainen, S. 1994. *Teletekniikasta monimuotoiseen viestintään.* Tampere: Tammer-Paino Oy.

Mäkinen,R. 1984. *Julkiset hankinnat innovaatioiden edistäjänä - johtopäätökset.* SITRA, Sarja B, Nro. 73.

Mäkinen, M.1995. *Nokia Saga.* Jyväskylä: Gummerus Kirjapaino Oy.

Mölleryd, B.G. 1996. Så byggdes en världsindustri - entrepenörskapets betydelse för svensk mobiltelefoni. *Teldok,* no. 28.

Nelson, R. 1959. The simple economics of basic scientific reserach. *Journal of Political economy,* vol. 67no. 3, 297-306.

Nelson, R. 1993. *National Innovation Systems - A Comparative Analysis.* Oxford: Oxford University Press.

Nokia Annual Report 1995.

Olkkola, K. 1986. *DX 200 vaiheita I ja II.* Unpublished note.

Palmberg, C. 1997. *Public technology procurement as a policy instrument? - Selected cases from the Finnish telecommunications industry*. VTT Group for Technology Studies, Working Papers no. 28/97

Porter, R. 1990. *The Competitive Advantage of Nations.* London: McMillan.

Posti & Telehallitus 1982. *50v tutkimusta ja kehitystä 1932-1982.* Teletutkimuslaitoksne julkaisu A1.

Rothwell, R & Zegveld, W. 1982. *Industrial Innovation and public policy.* London: Pinter Publishers.

Rothwell, R. 1994. Issues in user-producer relations in the innovation process: the role of government. *International Journal of Technology Management,* vol. 9, Nos. 5/6/7.

Rouvinen, P (ed.).1996. A*dvantage Finland - The Future of Finnish Industries.* Etla Taloustieto Oy, Helsinki.

Tecnomen Radiosynchronization.

Tecnomen Annual Review 1995.

Tele 1993. *Poimintoja teletoimen historiasta. Osa 6- Elämäntyö telealalla.* Helsinki: Painatuskeskus Oy.

Telecom Finland Annual Report 1996.

Toivola, K. 1992. *Poimintoja teletoimen historiasta. Osa 4: Kertomus Suomen Matkaviestinnästä.* Karjaan Kirjapaino.

Toivola, K. 1989. *Virkamiehen Sattumukset.* Valtion painatuskeskus.

Turpeinen, O. 1996. *Yhdistämme 2. 200 vuotta historiaa - haasteena tulevaisuus.* Oy Edita Ab, Helsinki.

Volotinen, V. 1991. *Tietoliikenne - verkot ja päätelaitteet.* Werner Söderström Osakeyhtiö.

von Hippel, E. 1988. *The sources of Innovation.* New York: Oxford University Press.

Vuori, S & Vuorinen, P. 1993. Outlines of the Finnish Innovation System: The institutional Set-up and Performance. In Vuori, S & Vuorinen, P (eds.): *Explaining Technical Change in a Small Country - The Finnish National Innovation System.* Heidelberg: Physica-Verlag.

Ylä-Anttila, P. 1996. Teollisuuspolitiikan ikuisuusongelman ratkaisu? In Lemola, T & Lovio, R. (eds.) *Miksi Nokia, Finland.* WSOY, Juva.

Statistical material

Puhelintilastot 1975.
Televiestintätilastot 1995.

Telecommunications statistics 1989.
Telecommunications statistics 1996.

Legal material: laws and regulations

Valtioneuvoston päätös 136/1939
Asetus valtion tavarahankinnoista 714/1965
Kauppa ja teollisuusministeriön päätös valtion hankinnoista 1071/1979
Laki julkisista hankinnoista 1505/1992

Personal in-depth interviews.

Halme, Lauri (Telecom Finland)
Johansson, Veikko (PTT)
Koski, Aimo (Telecom Finland)
Makkonen, Matti (Telecom Finland)
Melamies, Lauri (Nokia Telecommunications)
Mustonen, Arvo (Tecnomen)
Nevanpää, Tapani (Telecom Finland)
Olkkola, Keijo (Televa, Nokia)
Palonen, Vesa (Ministry of Transport and Communications)
Pasanen, Matti (Telecom Finland)
Rajamäki, Timo (Telecom Finland)
Räsänen, Erik (PTT)
Salminen, Sakari (Nokia Electronics/Telefenno / Telenokia, Nokia Telecommunications)
Toivola, Keijo (State Railways, PTT)
Toivonen, Seppo (Televa, PTT, Finnet)
Valle, Jorma (PTT)
Vallström, Eero (Mobira, Nokia)

Interviews over the telephone

Kirves, Liisa (Telecom Finland)
Kangasluoma, Martti (PTT)
Koivusalo, Mikko (Nokia)
Pasanen, Juha-Heikki (Nokia Electronics, PTT, State Railways)