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

Switching Relations: The Government Development Procurement of a Swedish Computerized Electronic Telephone Switching Technology

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Abstract:
The study describes and analyzes the development and commercialization of the Swedish AXE telephone switching technology that was a result of a Government Technology Procurement (GTP) project 1954-1980. This electronic computerized switching system was developed by the semi-public company ELLEMTEL for the public telephone utility Swedish Telecommunications Administration (STA) and the private industrial company LM Ericsson. The most important formal and informal institutions in the Swedish Telephony System together with the key organizations and their key resources are described. In describing the procurement process, the most important global and local changes influencing the user and producer before and after the formal procurement project are analyzed. The GTP process is divided into the phases of Proto-Procurement 1952–69, Procurement 1970–77, and Post-Procurement 1973–81. In the Proto-Procurement Phase the various learning and search activities among the user- and producer-to-be are analyzed, as are the creation of technological diversity, absorptive capacity and social trust. In the Procurement Phase the joint project that developed the AXE project is described together with its most important technological and institutional critical problems. The Post-Procurement Phase describes how the AXE technology reached commercial maturity locally and globally and how it passed through its first Adaptive Government Procurement. This included the first export orders as well as the adaptation to the new technology trajectories of digitalization and mobile telephony. Finally the social and industrial results of the AXE procurement projects as well as possible implications for innovation policy are discussed.

Key-words: Technology Procurement, Telephony, Electronic Switching, AXE, User-Producer Interaction, Social Trust, Interactive Learning, Reverse Salients, Collective Innovation, Development Pair

1. INTRODUCTION: Procurement of a Swedish Switching Technology

The case study treats the Swedish Government Technology Procurement (GTP) of the AXE telephone switch, 1954-1980. This electronic computerized switching system was developed by the semi-public company ELLEMTEL for the public telephone utility Swedish Telecommunications Administration and the private industrial company LM Ericsson. The first AXE telephone station was inaugurated by the buyer, STA, in 1977.

1.1 A Short Introduction to the Swedish Telephone System

The Swedish telecommunications system was rather stable during 1920-1980. Except for some very small private and co-operative telephone networks, Swedish Telecommunications Administration (STA) held a practical monopoly on providing telephone services to Swedish consumers. STA had been founded in 1853 and was a public enterprise under the Ministry of Communications and had the responsibility of operation and maintenance of the state’s national telephone network. STA was a Public Telephone Administration (PTA) but not a PTT (Post, Telegraph and Telephone) since there existed a separate Swedish Post Office, although it was many times suggested to merge the two. STA also had their own manufacturing branch TELI that produced switches and other telephone equipment for STA. Furthermore, STA also pursued independent development of new advanced technologies in telephony, especially automatic switching technologies.

LM Ericsson Telephone Company (LME), founded in 1876, was the largest Swedish manufacturer of telephone equipment but had no captive market in Sweden because STA manufactured most of its equipment in its own factories. Therefore LME exported the majority of its equipment. LME had manufacturing and selling subsidiaries in 15 countries.

Also, the American and Dutch electrotechnical companies, ITT and Philips, had Swedish subsidiaries. ITT's Swedish subsidiary was Standard Radio & Telephone (SRT), which specialized in telephone equipment for the Swedish military. After WWII, STA did not have enough production capacity of its own and therefore SRT got orders on electromechanical crossbar switches of STA's construction in 1946-61. In the early 1970s Standard Radio was taken over from ITT in a Swedish government joint venture and later merged with the SAAB company's computer division into the STANSAAB company. The other foreign subsidiary, Swedish Philips Inc., had a telecommunications division that also specialized in defence related telephone technology.[1]

LME also owned shares in two companies that were going to be very important for the introduction of AXE and mobile telephony. The most important of these was the ELLEMTEL company, formed in 1970 and owned by LME and STA. STA's shares in ELLEMTEL was bought by LME in 1994. The second was the company, Swedish Radio Inc. (SRA), formed in 1919, which specialised in radio technology and mobile telephony. LME in 1965 increased its ownership in SRA from 57 to 71 % by buying shares from the other owner, the Marconi Wireless Telegraph Company. From 1983 onwards SRA was wholly owned by LME and changed its name to Ericsson Radio Systems.[2]

When it comes to advanced engineering education in telecommunications technology, Sweden until 1961 had two technical universities, the Royal Institute of Technology (KTH) in Stockholm and Chalmers Institute of Technology in Gothenburg. Additional technical universities was founded 1961 in Lund in the south of Sweden, and in 1969 in Linköping in central Sweden and 1971 in Luleå in the very north of the country. In addition to this there was a handful of technical institutes that trained middle-level engineers. In the 1960s the lack of enough educated Swedish engineers with knowledge in the new areas of electronics and computer technology was a major problem for STA and LME in their efforts to develop computerized electronic switches.

1.2 The AXE Procurement Process

The development of the AXE technology did neither start nor end with the first procurement project. Therefore this study analyzes the most important global and local changes in connection with AXE that influenced the user, STA, as well as the producer, LME, before and after the formal procurement project. The description of the innovation process is halted when the technology has reached commercial maturity locally and globally, as well as having gone through its first Adaptive Government Procurement (AGP). Therefore the GTP process is divided into the three phases of Proto-Procurement, Procurement, and Post-Procurement.

In the *Proto-Procurement Phase* the socio-economic need that the AXE technology was supposed to provide was identified as improving Swedish telephony by providing less expensive and totally new kinds of telephone services for Swedish subscribers. The STA in the 1950s realized that telephone switches using the new electronics and computer technologies would make possible new services for the subscribers and improve the efficiency and capacity of the old services. LME also saw the possibilities of the new technologies, although they were not as enthusiastic as STA. LME considered its existing electromechanical switches to provide sufficient capacity, but invested in development of electronics as an insurance against unwanted and sudden technological breakthroughs. Both LME and STA, in the 1950s, started different development projects in electronic switching along two different technology trajectories. In the mid-50s, it was an attempt to coordinate these projects through the formation of the joint Electronics Council, where their different projects were discussed. In 1963, the two parties decided to share the development by developing two different but complimentary versions of electronic switches, one small switch for rural towns buy LME, and a larger one for major cities by STA. These prototypes came into operation in 1968 and 1969 respectively. Nevertheless, they were far from commercially viable technologies. Each would take several years of additional development. To reach a functional solution as early as possible, and to minimize the duplication of development work, the two parties decided to pool their resources with an agreement to form a joint development company.

The formation in 1970 of this new company ELLEMTEL was the start of the *Procurement Phase*. The new company was owned on a 50-50 basis by LME and STA and its mission was to develop and construct equipment for electronic switching, computer networks, digital transmission systems and advanced electronic telephones. But it was intended that the company should not have any manufacture of its own, this should be performed by its owners LME and STA. The company recruited engineers from both partners, and through this it got competence from both the user- and the producer-side. Its first and main task was to develop a computerized electronic switch that became known as the AXE switch. ELLEMTEL formally started its AXE project in 1972. AXE included several new technologies such as electronic switching, computer control, functional and service modularization, and allowed for change-over to digital switching and transmission. The functional requirements were specified by LME with the collaboration of STA. In 1977 the first telephone station using the new technology was successfully inaugurated in a small Swedish community.

Parallel with the development work on finishing the first Swedish AXE station, LME worked on getting export orders on the new technology. Although the first procurement project was not finished, the beginning of this *Post-Procurement Phase* was overlapping with the end of the procurement phase. The first export order came already in 1973, from Finland. This first order was followed in 1976 and 1977 with new orders from France and Saudi-Arabia. In these later orders, the AXE technology was further improved by the adaptation of digital switching. Furthermore, the AXE switch also became the foundation for LME's later success in mobile telephony in the 1980s.

2. INSTITUTIONAL FRAMEWORK: Switching Regulations and Relations

The institutional framework of the Swedish telecom system had its formative period in the late 1910s and early 1920s. The institutions that were established in that period remained – more or less unchanged – until the 1980s. This was true for the formal institutions as well as for the informal institutions.

2.1 Formal Institutions: Regulations in Swedish Telephony

There has never been a formal state monopoly in telephony in Sweden. It was open to anyone to build telephone networks and establish telephone utilities. However, before the introduction of mobile telephony in the 1980s the state has had a practical monopoly since 1918. In that year, STA bought the last large private telephone network in Sweden.

Furthermore, issues concerning telephony were rather un-regulated in Sweden and, except for several instructions to STA, Sweden did not have any special telecommunications law until 1993. The reason for this was that STA's dominant position made it possible for the government to regulate the sector indirectly without having to legislate about it since STA was a Government agency directly subordinate to the Ministry of Communications, and indirectly to the Ministry of Finance.[3]

Concerning telephone equipment, STA had for a long time a regulated monopoly on selling – but not producing – equipment that was to be connected to the telephone networks. Furthermore STA had to approve of all the equipment that was connected to the telephone network. It was forbidden to connect equipment to the public Swedish telecommunications network without a permission from STA. The selling monopoly was gradually abolished starting in 1971 with equipment that was not connected to the ordinary telecommunications net, such as mobile phones. From 1980 it also began to be dismantled for equipment used in the ordinary public network and in 1989 STA's selling monopoly was completely taken away.[4]

Furthermore, there existed a procurement edict (*upphandlingskungörelse*) from 1973 that regulated the different obligations concerning procurement that were incumbent on state authorities. In this, there was a special section concerning

STA which stated that STA, was not obliged to submit a procurement order to the government unless it concerned agreements with foreign authorities or agreements with foreign companies that were needed for Sweden's telephone traffic with foreign countries.[5]

2.2 Informal Institutions: National and International Relations

When it comes to informal institutions, the two most important for the procurement of AXE were two long-term social relations: one was a national relation and the other, an international one. The national relation was the long-term user-producer relation that, since the 1920s, had developed between STA and LME. This was one example of the prominent phenomenon of the forming of Development Pairs in Swedish industry. The international relation was that which STA had cultivated with the dominant company in the telecommunications industry: the American giant AT&T

2.2.1 National Relations: The Development Pair STA–LME

Probably the most important informal institution in Swedish telecom has been the long-term and close development collaboration existing between STA and LME. With a start in the 19th century LME and STA had conducted a plethora of various joint construction and manufacturing projects of more or less formalised characters and on all different levels in the two organizations and in most product areas.[6] This is one of several examples of the very long and successful Swedish tradition of using technology procurement as a policy tool, especially for large infrastructural projects and in the defence sector.[7]

There are several Swedish examples of how government technology procurements have been informally institutionalized (and, sometimes, formally, like in the case of the Electronics Board and ELLEMTEL) through the formation of so called *Development Pairs* (DPs). These are long-term user-producer relations around the development of new technologies between large Swedish engineering companies and government technical agencies. A DP is a tightly linked, long-term cooperative user-producer relation built up around several consecutive joint development projects between a manufacturing firm and a government customer.[8] A DP also includes joint development of different magnitudes and time spans, from informal day-to-day technical exchange and incremental improvement projects on delivered process and product technologies, to more large-scale experimental and long-term R&D activities, as well as formalised GTP projects. Aside from the DP between STA and LME on telecommunications technology other well known examples are ASEA's (today ABB) and the State Power Board's collaboration on electric power technologies, SAAB and the Defence Material Administration collaborating on aircraft technology, and ASEA and the State Railway Agency working on train technology.[9]

The DP between STA-LME went through two major institutionalization in the 1950s and 1970s that 'hardened' the relation. In the beginning of this joint collaboration it was mostly conducted through single engineers employed at STA who that came to LME to get support, resources, and money to develop their inventions into commercial technologies. There was also a lot of informal information exchange, between the two organizations because it was very common for engineers to change jobs back and forth between the two organizations. This was very widespread and existed all the way up to the highest executive levels. Gradually, this relation changed into a more formalised development relation. In 1956, the joint Electronics Council was formed to co-ordinate the development work of the two organizations, and in 1970 the next step in the institutionalization was taken through the foundation of the jointly owned development company ELLEMTEL.

Following is a description of some of the largest and most important of the different joint development projects.

Automatic Switching Technology 1910-24

In 1910, two STA engineers went to the USA to study automatic switching technology in order to prepare for a future automatization of the telephone network in Stockholm. One of these engineers invented an automatic switching technology and, in 1913, went into co-operation with LME to develop it into a commercial product. Similarly, another STA engineer also invented an automatic switching technology and went into a development co-operation with LME. In 1915, LME approached STA and asked them to procure an experimental switch. STA agreed, and also invited two other Swedish switching technologies to comparative field tests 1917-20. In 1919, STA invited tenders for automatic telephone stations for its Stockholm network. STA received tenders from North Electric, Western Electric, Siemens-Schukert and the two Swedish switching systems. STA, in 1921, chose one of the technologies manufactured by LME and after two years of trial operation the first automatic station was successfully inaugurated in 1924.

Crossbar Switches 1935-47

STA, during the 1920s, also continued to develop the other Swedish switching system into a functional technology. This was the so called crossbar switch, and in 1926 it inaugurated its first telephone station. In the 1930s, STA had exhausted its own manufacturing capacity and started negotiations with LME in order to make the company to also begin manufacture crossbar switches, something which LME also did. In 1943, LME also wanted to manufacture crossbar switches for export, and in 1943-45, LME and STA jointly developed a new model of the crossbar switch that would fit both STA's domestic needs and LME's export ambitions. The new crossbar switch started to be manufactured in 1947, and in the 1950s it got its international breakthrough. This technology made LME into one of the major international telecommunications companies.[10]

The Swedish Telephone Traffic Machine

In the beginning of the 1950s, STA together with LME constructed a telephone traffic machine. This was an analogue mathematics machine specially constructed for simulating traffic flows in telephone systems and when it was finished in 1952 it was the first in the world to produce reliable enough results in a reasonable short time. The Swedish Traffic Machine was in service until 1964, and after that the co-operation continued through the formation of a joint committee that was to conduct research and development in the area of traffic research.

Telephone Sets

The DP has also had collaboration around developing new telephone sets. In 1931, LME made one of the first Bakelite phones in the world. The year after, LME and STA went into a joint cooperation agreement concerning new and modified constructions. The Ericophone – or the Cobra as it was called in Sweden – was introduced on the Swedish market in 1957. Before this, the two partners had conducted a joint market investigation into the preferences of the customers. In 1962 came the new telephone set "Dialog", which had been a joint development project between the two parties. The last jointly developed model was the "Diavox", which was developed by ELLEMTEL in 1982.

2.2.2 Foreign Relations: AT&T

The other important informal relation was the relation that existed between STA and LME and the large American Telephone & Telegraph Company (AT&T). To this American giant belonged especially two organizations that were of central importance to the development of the AXE switch. This was AT&T's R&D organization Bell Telephone Laboratories (Bell Labs) and its manufacturing company Western Electric. In the same way as the DP between STA and LME, this came to be an important channel for information exchange concerning new technological developments, and also this relation was a mixture of informal and formal relations.

The first really important exchange, and one that is supposed to have laid a basis for the positive relation between Bell Labs and STA, came in the early 1930s, when engineers from Bell Labs visited Sweden.[11] At STA, they were shown STA's new crossbar switch and were given crossbar switching technology to bring back to the USA. Based on the Swedish switch, AT&T developed its own crossbar switching technology, which became a large success, and the dominant switching technology internationally from the 1940s on.

In 1947 STA's Director General used his personal friendship with Bell Labs chief engineer to send one of STA's leading engineers to spend half a year at AT&T in the USA. The engineer, Bertil Bjurel, developed a very good relation with engineers at AT&T and these relation were strengthened with further visits which was also to become important when he became STA's next Director General in 1966.

In 1950, AT&T approached LME about a mutual patent exchange which included AT&T's patent on the transistor. In 1951 LME and Western Electric closed such an exchange contract which also allowed LME's engineers to visit Bell Labs and Western Electric for studies and discussions. After LME and STA had started their joint collaboration in the Electronics Council, a similar contract was signed between STA and Western Electric in 1957. Included in this patent exchange contract was also an exchange of visits and knowledge between the parties.

Thanks to this several of the key engineers in the AXE project had the opportunity to visit Bell Labs and to openly discuss possible electronic switching solutions with AT&T's leading R&D engineers. Furthermore, they also had access to early operational results from AT&T's first transistorized and computerized switching station No 1 ESS. LME and STA got their first contact in 1957 when they were invited by AT&T to the so called Morris-symposium. This was an international switching symposium in New Jersey where AT&T to present the first computerized telephone switching station to their licensees.

This switching station was going to be installed in Morris, a small town outside Chicago. The Morris-station became operational in 1960 and Swedish engineers gained a lot of knowledge about the operation of computerized switching stations from the results of this station. STA kept on renewing their exchange contact until 1993.[12]

3. KEY ORGANIZATIONS: Developing Switching Relations

The two main partners involved in the procurement of the AXE switching technology were the Swedish switching user, the government agency Swedish Telecommunications Administration and the seller of switching equipment, LM Ericsson. However, since this was a joint development project also two joint ’bridging organizations’ was very important in the Proto-Procurement and Procurement Phases: the coordinator of R&D in switching the Electronics Council and the developer of switching ELLEMTEL. In addition to those, two foreign subsidiaries of LME, played important roles in the Proto-Procurement and Procurement Phases as well as in the Post-Procurement Phase. Since both STA and LME were using AXE in their activities they were both procurers of AXE, although the specific project that will be most in focus here had STA as the buyer. The company they procured the development of the AXE technology from was their jointly owned development company, ELLEMTEL, and the new AXE technology was manufactured within both procurer organizations. Since STA was a government agency it was also formally regulated by the Ministry of Communications, and, informally, by the Ministry of Finance. However the ministries were not so visible in the AXE procurement project.

3.1 The User: Swedish Telecommunications Administration

The Swedish Telecommunications Administration (today the state-owned stock company Telia Inc.) was the Government organization that was responsible for the Swedish telecommunications network. It was founded in 1853 to be responsible for the state’s telegraph network and, from 1902, it was in addition officially entrusted with the responsibility for handling all activities in connection with expanding and operating the state’s telephone network.

From 1911 STA became formally institutionalized as a so called State-owned public enterprise (*affärsverk*) with two different tasks. First, it should act as a state authority and control and regulate all matters that concerned telecommunications, and second, it should be engaged in profitable commercial activities by selling telephony services and telephone equipment to Swedish subscribers and companies. STA was subordinated to the Ministry of Communications and had to follow laws and regulations that applied to government administrations and had a legal status as something between a company and a government authority. STA's economic objective was to be self-supporting and they could decide without approval from the Government about how they wanted to use their operating income. To be in charge of STA the Government appointed a Board and a Director General.[13] The Director General was not responsible to the Board but only to the Government.

Since STA was responsible for the operations of the Swedish telephone network, it was the end-user of the telephone switching technology that was intended for telephone stations. At the same time, it also sold smaller switches of its own, of private manufacture to firms and other large establishments that had separate switches. In that sense, STA did not represent final demand.

STA was as an organization dominated by engineers and in the 1970s technological values was ”totally dominant” within STA that had as ”an implicit technical objective to aim for high efficiency through continual technical development and rationalization”. Around 1970, STA yearly invested around 600 million Swedish Crowns (MSEK) in material assets for improving the telephone network. 300 MSEK concerned equipment for switching stations and subscribers and, of that amount, 200 millions worth was ordered from STA's own factories and the remaining 100 MSEK mainly from LME.[14] In 1972/73 STA procured technically advanced products for 770 MSEK.[15]

STA was a highly competent user that could both formulate demanding functional requirements as well as independently evaluate the resulting technologies. This was because it had under its own control three different branches with expertise in three of the telecommunication system’s most important sectors:

• An *operational department,* with experience of the problems of providing telephone services and of operations and maintenance of telephone technologies

• A *technical department,* engaged in research and development of new telephone technologies

• A *manufacturing branch,* with knowledge and equipment to adapt new constructions for industrial mass production

The long experience of the exchange among expertise from operating telephone systems, independent development, and manufacturing, had shown STA that this arrangement had ”proved itself to be a particularly valuable […] for making the telephone service cheaper and more effective.”[16] STA was a very competent buyer of telephone equipment since it had this double competence of both being a user and producer thanks to its manufacturing branch, and was unique compared to other public telephone administrations (PTAs) around the world in that it also developed and manufactured telephone equipment on its own.

3.1.1 The User’s Manufacturer: TELI

STA stated in 1965 that, except for the American giant AT&T, it was unique in the Western world as a telephone utility who were themselves engaged ”in development and design work for specific objectives and have their own manufacture on a fully industrial scale.”[17] Since 1891, STA had its own manufacturing branch which in 1970 it had factories in five Swedish cities.

Aside from repairing faulty equipment their manufacture branch, in collaboration with the technical department, developed and manufactured new telephony technology. It also manufactured externally developed equipment for STA on license. STA had also introduced an internal competition by letting TELI compete for STA orders on equal terms with outside companies. This is supposed to have kept STA's manufacturing ”on a par with suppliers in the open market in respect of general rationalization and manufacturing techniques as well as in the designs offered.”[18] Thanks to this STA had an independent capacity and competence in manufacturing matters. This in-house competence was supposed to have put STA in the ”position to make an objective consideration of the best technical solutions, irrespective of whether the products are developed and manufactured within the Administration or ordered from outside suppliers.”[19]

In 1970, STA's manufacturing branch consisted of around 3.500 employees and 95 % of its production of equipment, worth 200 MSEK, was delivered to STA. But engineers at STA also desired that its products – especially its switching technology – should be exported. One representative of STA's engineers put it in the following way: ”Why not let the [manufacturing branch], which has such a quantitatively and qualitatively impressive manufacturing programme, produce also for export? And at least let our Nordic neighbouring countries join in and reap the benefits of this, of its kind, unique and rationally run manufacturing enterprise.”[20] This demand for export was something that was also included in the ELLEMTEL contract in 1970 although it was abandoned when the contract was revised in 1977.

STA redefined their activities in the 1990s and concentrated more on its operational activities and stopped being a manufacturer of telecommunications equipment when TELI was sold to LME in 1994.

Economic data (MSEK)	**STA**	**LME**
Sales 1975	4.576 (75/76)	7.240
Sales 1980	9.300 (80/81)	12.174
Growth 1975-80	2,0	1,7
Pre-tax profit 1980	2.502 (80/81)	935
Profit as % of sales	27 %	8 %
Cumulated profit 1976-1980 as % of cumulated sales	18 % (76/77-80/81)	7,5 %
Sale in main product area 1980	7.891 (80/81)	4.442
Swedish sales of main product area 1980	100 %	22 %
R&D costs 1975	55	510
Growth in R&D costs 1975-80	2,4	2,0
Average annual growth of R&D costs 1975-80	19 % (76/77-80/81)	15 %

Table 1. Data from Granstrand & Sigurdson, ”The Role of Public Procurement”, p 155, 158.

3.2 The Seller: LM Ericsson Telephone Company

LM Ericsson Telephone Company (today only Ericsson) was founded in 1876 and a hundred years later it was (and still is) one of the largest Swedish industrial companies and one of the largest international telecommunications companies. In 1970, LME had around 50.000 employees in 26 different companies in 15 countries, with around half of the employees in Sweden. From 1960, LME had increased its sales threefold, and, in 1969 it had a turnover of around 3 billion SEK.[21]

LME's main manufacturing was in switching and telephone subscriber equipment with a turnover in 1969 of 800 MSEK from its Swedish factories. Its main product was the electromechanical crossbar switches, which had been the dominant product within the telephone industry since the early 1950s. In the 1960s, LME ”was living on crossbar,” although it also pursued production and development in such sectors such as telephone sets and telex equipment, transmission, cables, radio and military electronics.[22]

LME was very much dependent on foreign markets and on its core business in telecommunications technology. It sold telephone equipment to around 130 PTAs and private utilities in all parts of the world. It 1970 the Swedish market stood for 37 % of its turnover and the largest export countries were, in descending order, Brazil, France, Mexico, Italy, Norway, Denmark and Australia.[23] In 1980, the Swedish market had decreased to 22 %, and of public telecommunications sales STA stood for 3 %.

In 1980, LME was Sweden’s largest spender on R&D with an expenditure of 1.013 MSEK, which was about 15 % of the total amount spent on industrial R&D in Sweden. The center of LME's R&D was concentrated in its Swedish companies. Between 1965 and 1970, LME's costs for its R&D almost doubled, from 122 to 226 million SEK.[24] A large part of this was due to the projects concerning new electronic switching technologies. The majority of LME's activities in electronic switching development were concentrated in Stockholm. After 1970, this was mainly done by ELLEMTEL but also included some important development work at LME in Sweden and at LME's American and Australian subsidiaries.

3.2.1 Foreign Resources: North Electric and EPA

In 1951-1967 LME owned the American telecommunications company, North Electric Co. The reason for buying North Electric was to get a foothold in the US market, and the subsidiary developed a special version of LME's electromechanical crossbar exchange that was sold on the US market.

Thanks to North Electric, LME got its first commercial order for an electronic switch. This was an order in 1960 of a fully electronic switch, 412-L, from the US Air Force. North Electric got the order, with LME as an undertaker for construction of the switch, while the manufacture was going to be at North Electric in the USA. The project was finished in 1963 and the experience that LME acquired concerning electronics technology was especially important for the future development work. When LME later also installed this type of station for the Swedish defence, it was the first electronic telephone station outside of the USA.

North Electric was not profitable however and was sold to an American company in 1967. In the sales agreement was included that parts about future cooperation between North Electric and LME and about technology transfer between the two parties.[25] Also some of LME’s Swedish engineers stayed on as employees at North Electric when it was sold. This became of crucial importance to the AXE project. LME had good contacts with North Electric, even after it was sold in 1967, and during the AXE project engineers from ELLEMTEL visited North Electric to learn the new ”wire technology”. This process technology gave the possibility to do changes 10 times as fast as with LME's existing manufacturing technology. This technology was crucial in making it possible to manufacture the new switches in a new and much faster way which made it possible to deliver the first AXE switch more or less on time in 1977.[26]

Since 1950 LME also had a subsidiary in Australia, LM Ericsson Pty. Ltd. (EPA). In 1954 EPA had got its first order on switching equipment from the Australian Post Office (APO). This was followed in the 1950s by several orders of large crossbar switching stations and in 1959 APO choose LME's crossbar switches as national standard which LME saw as opening ”wide vistas for the crossbar system, inasmuch as APO is internationally well-known for being independent and sincere in all their dealings.”[27] After this LME in 1962 built a manufacturing plant and in 1963 held a third of the Australian market for switches.

Since around 1970 a major part of LME's advanced development in digital switching was conducted at EPA. The reason that LME gave away this strategic development work to one of its foreign subsidiaries was the good possibilities of recruiting engineers in Australia, and that it was important for its relation to its large customer APO to show that it was performing advanced and independent construction work also in Australia.[28] This development work in digital technology became very important for the first exported AXE switch that was delivered to Turku in Finland in 1978.

3.3 The Collective Coordinator: The Electronics Council

In the early 50s both LME and STA organized special units that would work on developing new applications based on the new electronics technology. Because of large difficulties in recruiting enough skilled electrical engineers, the two parties decided in the mid-50s to coordinate their efforts in the new electronics technology. Therefore, the two parties signed an agreement in January 1956 to form the joint Electronics Council.[29]

The Electronics Council was to supervise and coordinate the two parties' development work on electronics in order to avoid doubling of the efforts in the new technology. It would in particular study the possibility of developing electronic switching systems. It had six members, three from LME and three from STA with the chairman alternating between the two organizations.

Despite the intent to coordinate the two parties' development work the two switching systems became, except for the same type of memories, almost entirely different. Two supplementary agreements to the first Electronics Council agreement was signed in 1963 and 1965. The first concerned the development of two switching stations using SPC, A210 and AKE12. The two stations was going to be developed separately by the two independent parties and the contract was in a way a recognition of the fact that the collaborative development had not been that very successful. Furthermore, the first agreement was revised and the manufacturing rights to equipment developed within the collaboration were regulated. The second agreement concerned developing advanced electronic telephones for computerized switching stations.[30] The Electronics Council meetings continued until ELLEMTEL was formed in 1970.

3.4 The Collective Developer: ELLEMTEL

In April 1970, LME and STA signed an agreement to form a joint R&D company. The new company, ELLEMTEL Development Inc. (ELLEMTEL Utvecklings AB) was owned on a 50-50 basis by LME and STA.[31] The company had as its task to develop and construct equipment for electronic switches, and equipment for computer networks, digital transmission systems and advanced telephones. But the company should not have any manufacture of their own which should be performed by either LME or STA.

There was resistance from some top-level management in LME to 'give away' the very strategic development project to an outside partly state-owned company but after tough negotiations an agreement was reached between LME and STA.

ELLEMTEL become organized into four departments, corresponding to its four main product projects. The new company's most important and largest mission to develop a computerized electronic switching system, was housed in the department for local stations, Dept. X, but at its start it also had three other joint development projects. These were to develop a new subscriber exchange for offices, to do a study of the building of a Swedish data network, and to develop a new electronic telephone.

ELLEMTEL recruited engineers from both partners and through this it got competence from both the user- and the producer-side. Since STA had dismantled their electronic switching project most of the ELLEMTEL's first employees, around thirty engineers, came from STA. From LME came the director and around five more engineers. At the start of 1971, ELLEMTEL had 69 employees and it was estimated that the company would have reached its full capacity with around 600 employees in 1975. However, when ELLEMTEL in 1975 moved into their own offices there was around 450 employees and it was not until 1979 that the figure 600 was reached. When the majority of the AXE development was finished in 1980 the sales of ELLEMTEL amounted to 175 MSEK.[32] The development costs of ELLEMTEL for the AXE project had amounted to around 500 MSEK. LME's part in this was around 75 %, and was financed through profits coming from their sales of the older electromechanical switches.[33] Several of the personnel left for LME during the 1980s, when the further construction of the products developed by ELLEMTEL was transferred to that company. After this the size of the personnel grew to 790 in 1994.[34]

In October 1995, STA’s shares in ELLEMTEL was sold to LME that became the sole owner of the company.

3.5 The Regulators: The Ministry of Communications and the Ministry of Finance

Since STA was a State-owned public enterprise its activities was formally regulated by the Swedish Riksdag and Government and the direct responsibility of the Ministry of Communications. However the Ministry did not apply direct rule of STA and the Government regulation before the mid-1980s was rather through the yearly negotiations between the Ministry regarding STA’s annual estimates of expenditure. During this period STA financed most of their investments from their income from their subscribers and without additional capital from the public treasury. Another means of regulation from the Government was that STA had to have its permission to buy house property more expensive than 200.000 SEK.[35]

Since the Government’s main financial responsibility belonged to the Ministry of Finance its minister was also instrumental in regulating STA. The minister in charge almost all through (1955-76) the AXE procurement was the powerful

Social Democrat, Gunnar Sträng. According to STA's Director General 1966-77 its investments was in reality governed by Sträng whose wish was that STA ”efficiently should contribute to the public treasury but at the same time keep down our investments”. Sträng did not want STA to ”grow unnecessarily” which meant maintaining a ”suitable” stock of subscribers-to-be waiting for telephones.[36] During the first part of the 1970s the Riksdag and Government agreed with STA in trying to reduce this queue and large amounts of STA's total investments was spent on switching stations with that purpose.[37]

4. ORGANIZATION AND MANAGEMENT: Constructing Switching Trajectories

When looking at the history of electronic switching in Sweden it can roughly be divided in three stages where the fist stage was concentrated on several learning and search activities within the new areas of electronic and computerized switching. The second stage was much concentrated on one specific goal directed project directed at developing a new technology. In the third stage the technology was further developed and exported to other countries as well as starting to be used on a larger scale in its country of origin.

Even if this division in stages might give an orderly and planned appearance the period between 1958 and 1981 was very much filled with contingencies and unforeseen technological events, changes in market opportunities and shifts in market strategy.

4.1 Proto-Procurement: Learning Trajectories, 1952-69

Important to this study is the importance of learning and how that led to creation of *absorptive capacity*. This is the ”ability to recognise the value of new information, assimilate it, and apply it to commercial ends” and it is developed through previous experience of knowledge and practice related to the new information that is going to be used in the innovation process.[38] Absorptive capacity can ”be developed as a by-product of a firm's manufacturing operations,” and such ”direct involvement in manufacturing” makes a firm ”better able to recognise and exploit new information relevant to a particular product market.”[39]

Both LME and STA had by the 1950s developed such an absorptive capacity in telephone switching by being actively involved in the established trajectory of electromechanical technologies and automatic switching. So, in several important ways, the new AXE switching technology included several areas where the two parties already had extensive knowledge and experience. However, the two new technological trajectories of electronics and computerization were by the early 1950s unknown and untried by virtually all engineers within LME and STA.

4.1.1 The Established Telecommunications Trajectories of Electromechanics and Automatic Switching

The *electromechanics trajectory* was the result in the 19th century of the fusing of mechanical technologies, made out of wood and metal, with electricity to power and operate these different mechanical components. This trajectory was the basis for all the telecommunication technologies that both STA and LME had been involved in since their respective starts in the 19th century.

Another major trajectory within the telecommunications sector was that of *automatic switching* which had its international and Swedish breakthrough in the late 1910s. The idea to connect a telephone call from one subscriber to another, automatically by machines instead of by using a human female telephone operator at a switchboard was almost as old as the telephone itself. In 1879 the first patent application came for an automatic switching system and in 1892 the first automatic telephone station was opened in the USA. In Europe the first automatic station came in 1901 and in 1910 STA began their efforts to automate their telephone network. STA's first automatic station was inaugurated in Stockholm in 1924 and used automatic switches constructed by LME (see above 2.2.1). This was the start of STA's and LME's build-up of absorptive capacity through its involvement in operating, manufacturing and developing different automatic electromechanical switching technologies since the 1910s.

During the following decades STA's national network experienced a substantial growth, on average 5 % annually from 1920 until 1973, which meant that the number of telephones in Sweden in this period increased ten times over.[40] The rapid growth of the network also meant that the switch-over from manual to automatic switching took a very long time. STA was among the leafing utilities in automatization. In 1955 around 40 % of the Sweden’s telephone stations were automatic to which 70 % of the country’s telephones were connected.[41] The most intensive period of the automatization period was during the 1950s and early 1960s.[42] The last Swedish telephone station was automated in 1972 and through this an almost 50 year long process of switch-over were completed. It was estimated that the cost of this process was 8.000 MSEK (equalling 45.000 MSEK in 1997). Thanks to STA's automatization activities, Sweden was one of the first countries in automating the national telephone network. Simultaneously as the last stages of the automatization process STA began another similar large process of switch-over to a new telecommunications trajectory when they in 1968 also began computerizing their automatic stations.

The basic technology of electromechanics was so firmly entrenched that many telephone engineers were extremely sceptical to electronics and its possibilities when it emerged during the 1950s. LME had managed to establish themselves in the lead of the trajectories of electromechanics and automatic switching. In the 1920s LME had been a laggard compared to many of its international competitors in getting involved in the automatic switching trajectory, and it was not to become one of the major international switching manufacturers until the late 1950s. This was because they then started manufacturing crossbar switches for export which became a large success in the 1950s and 1960s.

4.1.2 Entering the Electronics Trajectory, 1952-56

Before the invention of the semiconducting transistor at AT&T's Bell Labs in 1948 the technology of electronics consisted of valve technologies such as electron tubes and radio valves. In 1951 an improved transistor version was developed which took the transistor ”from the laboratory to the factory”.[43] After a couple of years the new transistor technology had been that much further developed that it became possible to use for telecommunications.[44] To telephone switching, the great advantage of electronics components, instead of traditional electromechanical ones, were primarily their high speed in switching on and off. In electronic components, that used electrical currents, it took about one millionth of a second which was 10.000 times as fast as the mechanical action of an electromechanical relay.

The main advantage with this high speed was that it was possible to send more telephone calls in the same telephone line, through the principle of ”time-division” or ”time-division multiplex” (TDM) techniques. Previously, the telephone calls had followed the principle of ”space-division multiplex” (SDM) which meant that if 100 telephone calls was going to be transmitted at the same time in the same telephone line, each of the 100 calls alternated in using the common telephone line, each for a micro-second at a time. Because the gap between every micro-second long part of an individual telephone call was so small (milliseconds), the human ear heard it as a continuous call without any pauses.

In the beginning of the 1950s, LME and, later, also STA, had separately studied the possibilities of exchanging certain electromechanical components with electronic components in their electromechanical switches.[45] Already in 1952, STA had introduced the new transistor in its switching stations. This was in a small field test of a new telephone with a keyboard digit dial, instead of the traditional rotary digit dial.[46] Two years later, in 1954, LME finished its first prototype of an electronic switching system, EMAX (Electronic Multiplex Automatic Exchange). The switch had a capacity of 100 lines and was a ”pure laboratory product” and very far from a reliable construction.[47] It did not use transistors but the old valve technology, where the central components were different glass electron tubes, together with the new TDM technology. However, its components were too expensive and not reliable enough. After this LME planned to go ahead with EMAX 2, which would be a larger more practical switch. LME ”neither believed in electronics nor wanted it” but saw investments in the new technology as an insurance against unwanted technological surprises.[48]

At STA, the director of its development department had spent half a year at AT&T’s Bell Labs in 1947 and had become a strong believer in that the new electronics technology could surpass the previous electromechanical switching relays. In 1955, he convinced STA’s Director General that it had become time for STA to start introducing the transistor in the electromechanical switching technology, and that it should be done in collaboration with LME. The Director General agreed and invited the chief executives of LME to a discussion about a collaboration in developing electronic telecommunication equipment based on the transistor.[49] STA’s argument for the development work on electronics was that it was going to become very important and its development would demand large resources. LME was however not so eager to start a large development projects on transistor technologies. The transistor was a rather new and unknown technology at this time and their crossbar switching technology was successfully exported abroad.

Nevertheless, after some deliberation LME agreed to a limited collaboration around developing electronic switching. In January 1956, LME and STA signed an agreement to ”collaborate and coordinate the activities that the parties conducts within certain for that purpose organized departments, and that concerns research and development work within the area of electronic switching technology.”[50] This led to the institutionalization of the so called Electronics Council. This was a forum that was supposed to coordinate of the various development projects on electronics at the two companies.

In December the same year the breakthrough of AT&T and the electronics trajectory came in focus when the Swedish Academy of Sciences awarded the Nobel Prize for Physics to the three engineers at Bell Labs for their research that led to development of the transistor. The following year was also going to be the general breakthrough for the electronic telephone station in the international telecommunications sector.

4.1.3 Entering the Computerization Trajectory, 1957

In 1957, LME and STA discovered that a new technology trajectory was to enter the telecommunications industry. This was once again thanks to AT&T, and their Bell Labs, that arranged a switching symposium in New Jersey, that presented the first *computerized* telephone switching station. AT&T had taken the technology of ”stored program control” (SPC) from the development of the first American mathematics machines, the first computers, in the late 1940s, and applied it to telephony. The new idea with the computerized telephone stations was that all switching operations of the electronic and electromechanical switching elements was controlled by a computer programme that were stored in a computer memory inside the station.

This was a completely new technology, in which LME and STA had almost no knowledge and experience at all, and many of LME’s high level engineers were very sceptical to SPC.[51] Among the handful engineers from STA and LME that attended the symposium, only one really understood the new technology. The reason was he had previous experience from the Mathematics Machine Board (MMN) that developed the two first Swedish computers in the early 1950s. The importance of MMN for the AXE project was that it trained a first generation of Swedish engineers in the new computer technology. Some of these engineers brought their expertise in computer technology when they later became involved in the different projects of developing computerized switching systems at LME, STA and ELLEMTEL.

MMN was a Government project that had started in 1948 with the aim to buy or construct a mathematics machine because of the needs of the Swedish military to do ballistic calculations etc. The first aim had been to buy a machine from the USA, but when that proved impossible due to its strategic importance it was decided to develop one in Sweden. Although the project was formally independent of STA and LME, it had several connections to the two organizations. The leader of the project was the engineer in charge of LME's and STA's joint project to build a Telephone Traffics Machine. On his proposal, the first mathematics machine, BARK, was constructed by using standard electromechanical components (relays) manufactured by STA and that were used in their electromechanical telephone switches. This made it possible to construct a mathematics machine in less time and with less money than by using electronic radio valves. BARK was finished in 1950. In parallel with the construction of BARK also an electronics mathematics machine using SPC was being constructed. When this machine, BESK, was inaugurated in 1954 it was the fastest mathematics machine in the world. BARK and BESK was in operation until 1955 and 1966 respectively.[52] However, the project leader from the DP's traffics research, had suddenly deceased during the project which ended his contribution to the further computerization of mathematics machines and telephone switches.

After the Morris-symposium, LME and STA entered a period of learning in and about the two new technologies. What they had been showed in the USA and soon discovered for themselves was what the advantages the SPC technology gave to telephony. These were its large flexibility that made it possible to very easily change the functions of the switching station just by changing the computer programmes stored in its memory, it made it possible to automatically localize errors in the stations functions, and to the subscribers introduce new kinds of automatic telephone services such as ”call-waiting signal”, ”automatic wake-up call”, ”automatic re-dialling when busy”, etceteras.

But except for these advantages they also discovered the problems of developing the different critical problems, technical as well as social, with developing the new technologies. As LME's and STA's ignorance of the new computer technology at the Morris-symposium had shown, it soon became clear that a critical problem in the project of developing computerized switches would be to acquire engineers with knowledge in computer technology. To be able to create this capacity, LME and STA after some time started a joint advanced education programme in computer science for new graduate engineers.[53] Advanced training in computer since was something that was to become central to their two projects to develop practically working computerized electronic switching stations.

4.1.4 Switching to Separate Paths: TEST 1 & 412-L, 1957-63

When the director of STA's development department had returned back from the USA he initiated STA's first project for developing an electronic switching station.[54] This project A205E, concerned replacing the electromechanical switching relays of a traditional electromechanical crossbar switch (A205), with electronics components of transistors and core memories. An engineer with extensive expertise in computer technology was recruited as a project leader of the about 15 persons large development group.

However, after a meeting with the Electronics Council in 1958 where LME and STA presented their switching projects, STA's new project leader decided that A205E was an unnecessary detour and terminated the project. The reason was that the switch was not computerized enough. Instead a new project, TEST 1, was started, where the prototype switching station should be operated with SPC and using ”systems logic in memories” (SLIM). The SLIM technology was closer to the way computer machines operated, with the operations of the switch controlled by programmes – the systems logic – stored in memories and distributed in the switch. This was a very flexible way of constructing the switch but was more expensive as it demanded many electronics component.

This was contrary to the development path that LME followed regarding computerization. LME’s path was called ”system logic in circuits” (SLIC) and was based on a more inflexible strategy of keeping the general lay-out of the old electromechanical switching stations, but speeding it up by substituting electromechanical components with electronics components and with a separate computer that regulated the different switching operations. This was ”a relatively conventional” technology. According to STA, the SLIC technology would give a rigid technology that ”did not give the cost advantages that a computerized solution would give and also not any flexibility for further development.”[55]

The two parties also went separate paths when it came to the choice between the more computer oriented TDM or the more traditional SDM technologies. But here the roles were switched and LME opted for TDM, while STA went ahead with using the more traditional SDM for its TEST 1 project. However, when TEST 1 had gathered speed the joint collaboration between STA and LME was derailed for a couple of years when LME put almost all its time and resources into a new switching project.

At the end of 1959, LME had planned to continue along the lines of their previous EMAX project with a new more commercially directed version, EMAX2. This was supposed to be a large electronic switching station.[56] However, at it suddenly got a commercial order to develop a small practical electronic switching station. In 1960, LME got involved in a procurement order that its US subsidiary North Electric had got to construct and deliver an small electronic telephone switching station, 412L, for the US Air Force. This was a very important order to LME in that in that it generated practical expertise in the area of electronic switching. Although this switch was relatively small, a few hundred telephone lines, although it did not use SPC it was a very advanced project, it used SLIC and TDM, and had high demands on reliability, speed and flexibility. Thanks to this project LME formed a large group of engineers that was going to be the core of the development groups that were to be formed around computerized switches.[57].When LME started with the 412L project it was around 20 persons working on electronic switches, and after two years they were 120.[58]

Meanwhile, STA's TEST 1 project had continued even if it had not become fully operational. There were only about 20 subscribers, employees of STA, that were connected to the experimental switching station. However, STA had learnt a lot from the project. Also LME would learn from the experience gained through this project when they restarted their collaboration in the Electronics Council for their next electronic switching project, A210.

4.1.5 Switching into Parallel Paths: A210 & AKE12, 1963-69

In 1963 LME and STA signed a supplementary agreement to the Electronics Council agreement regarding the collaboration on the development of two computerized switching stations for STA, to be put up in two communities outside Stockholm.

The strategy for the joint development work had changed for this second generation of electronic switches. LME had during the 412L project in 1961 begun a project on the AKE12 switch and STA in 1963 terminated their TEST 1 project and began with the new project A210.[59] Although the top management of LME and STA had tried to induce a cooperation through the Electronics Council it had not spread down to the engineers at the working level where ”the lack of cooperation, sharing and joint development had become embarrassing.”[60] It had therefore been decided that each party should concentrate on their respective development projects but that these projects should complement each other in the way that they would switch their traditional markets with each other. STA should concentrate on developing a switching station, A210, for cities, which was LME's traditional product market, while LME's focus was to be on a larger switch, AKE12, for smaller communities and rural areas which was the bilk of STA's switching manufacture. In this way the joint collaboration really took off as the two parties could benefit from exchange of each others traditional expertise.[61] One such exchange of information was around the SLIM technology that LME had decided to switch to from the SLIC technology. But even though it was collaboration of information exchange it was still aiming for two separate technologies. Their shared development work became concentrated to developing computer memories. Another thing was that the Electronics Council in 1964 presented proposals for the several new automatic telephone subscriber services such as ”call waiting”, ”automatic wake-up call” etc. that should be tried out on the subscribers in STA’s two new computerized telephone stations.[62] s

The idea behind the A210 project was to use more electronics and computerization to control the operations of electromechanical switches. STA conducted an investigation concerning what kind of electromechanical switching element that should be chosen for the new electronic switching system. STA's project leader found a solution for adapting the old crossbar switch to the new electronics. This made it possible to use most of STA's extensive knowledge from its development of the crossbar technology.

A major technical novelty in the two switching station was the very large computer programmes that operated the stations. And the difficulties of this had been seriously underestimated.[63] Critical to the development of the two new computerized switching systems was the necessary access to full-scale and realistic testing with subscribers connected to the switching stations. This was because of the specific characteristics of the computer software technology. In contrast to the construction of the electronics hardware, large programmes, as a technology, can not be tested out in dry-runs. The project leader of STA’s A210 project has described the problem in the following way:

> ”A hardware constructor can most of the time sit with his gadgets around him on a table with measurement equipment […] and can verify that the thing he has been assigned the task of doing is properly done. Those who shall create software are forced to perform full-scale tests; several subscribers have to get in and test it. And this we can’t work out on paper. It is out there in the field, not before, that it is decided.”[64]

Both the AKE 12 and A210 technologies suffered from serious problems concerning errors in the computer programming. The first of the two station’s that became ready for field testing was LME’s AKE12 project. Early in 1967, a few subscribers were connected to the station after it had been installed. These field tests showed that a single small error in the computer programming could give rise to major break-downs of the switching station. And in addition to this it furthermore was also very difficult to localize exactly where the error was in the very large programme. This first installations had showed how much more programming work that was needed to make computerized stations operational than the previous electromechanical stations. After long delays because of the programming problems the first AKE12 station was inaugurated in April, 1968.

The critical problems with the program errors raised serious doubts that AKE12 would ever become a functioning technology for local telephone stations. However, it looked more positive to use a modification, AKE13, for transit stations for international telephone calls. LME had got an order on a interurban transit station from a telephone operator in the Netherlands, and when working on this order in December 1967, an engineer came up with an idea to solve the critical problem of the large computer programmes. His idea was to construct the switch according to modular programs. That meat that contrary to the traditional system with one large computer with one large programme that controlled all the switches operations, small parts of the programme that controlled a specific function should be isolated with the data that belonged to the function. The switch should be divided into different isolated blocks depending on what functions it was performing. This would make it easy to localize any eventual errors in programming or function since the errors could not spread outside of its module. Furthermore, it would make it easy to modify the faulty programmes since it should only be the relatively small programme within the module that needed modification instead of the whole programme.[65]

4.1.6 Growing Concerns about Losing Time

During 1968 and 1969, the two chief executives of STA and LME had many discussions regarding more coordination and even a merger of their switching development. It had now become obvious to STA and LME that the development of the new switching technology would be of a completely different magnitude than with the previous electromechanical switching technologies: several hundreds compared to tens of man years. And the number of engineers was a critical problem to this development work.

According to STA's General Director it was clear for both LME and STA that they started ”to run out of time” because neither had a ”competitive technical solution in sight” when it came to *local* switching stations for cities or densely populated areas, that were the largest share of market for switching stations. LME sold two semi-electronic switching systems on the international market, the ARE 11 switch for local stations which belonged to the old family of electromechanical switches but had had ”some electronic make-up applied”, and the AKE13 which used SPC but was expensive and only used for the smaller volume of stations for trunk switching.[66] LME had began to be seized with panic.[67] To get a new generation of switching had become a matter of destiny to the company, without that its existence as an independent manufacturer was in peril.[68]

Many of LME's international competitors had publicized information on different projects on electronics and computerization switching, and as was stated in a contemporary article from a British conference in 1969 about current projects in electronic switching, ”for natural reasons many companies are not so eager to disclose what is going on in the development labs, why one can count on that there among some companies exists interesting projects that are not known”.[69] This secrecy was well developed among the telecommunications manufacturer and ”everybody suspected the competitors to have reached far in their development”.[70] Some of the projects in electronics and computerization was the following:

• Western Electric of AT&T had, since 1966, installed 75 switches of their ESS1 type in the USA, based on the first SPC station in Morris that had become operational in 1960.

• The American ITT had introduced its Metaconta switch which used SPC.

• In Britain, the British Post Office was developing electronic switches together with Plessey and Standard Telephones & Cables and three other manufacturers in the Joint Electronics Research Committee. The electronic TXE2 switch for 4.000 lines had been manufactured since 1968 and the development continued on the computerized TXE4 with 20.000 subscriber lines.

• In Germany, Siemens was developing two switching systems with electronic control, of which one in collaboration with the German Bundespost.

• In France the government agency CNET collaborated with French manufacturers in the SOCOTEL organization to develop the computerized switch PERICLES and the small digital switch PLATON for 2.000 lines. Furthermore, the computer company IBM in south of France experimented with a fully electronic and computerized switch, IBM 2750, for 750 lines.

• In Japan existed the experimental computerized DEX-1 for 16.000 lines and the DEX-T1 digital switch that had been developed in collaboration with NTT.[71]

LME did also experience the tough foreign competition first hand in 1969. In Australia LME had since the early 1960s been very successful in selling their crossbar switches and when the Australian Post Office (APO) invited tenders for large exchange LME was very optimistic. Australia had been an important market to LME and the project in question would mean a very good reference project for developing a new computerized switch. The tender concerned a transit switching stations that handled international telephone traffic which was exactly what the AKE 13 switch had been developed for. LME had ”high hopes” when it through its Australian subsidiary EPA delivered the tender in January, 1969. Therefore it came as a ”serious blow” when APO in September, 1969, declared that it had chosen ITT's Metaconta switch.[72]

As can be seen from the different international projects mentioned above, it was not unusual for the different government agencies to collaborate with national manufacturers in different kind of joint organizations like the Electronics Council. But the next step that LME and STA took together was going to be more unusual. In early September, 1969, STA's Director General and LME's President met with Chairman of the Board of LME, the banker and industrialist, Marcus Wallenberg (jr), to discuss a new phase in the switching development. It was then decided that a new jointly owned development company should be formed. The same day as the meeting, STA contacted the Ministry of Communications that was positive to the sharing of development costs and gave an informal approval and STA and LME went ahead with the formal process of creating the new company ELLEMTEL.[73]

This meant that the old development relation had switched to a new more procurement-directed relation. Thus, the procurement phase began in early 1970 with a formal institutionalization of the previous joint development.

4.2 Procurement: Developing Trajectories, 1970-77

In 1970 LME and STA formed their joint development company ELLEMTEL that was going to develop the AXE switching technology. In this company the two owner jointly procured the development of the AXE technology from its subsidiary ELLEMTEL. The process between the joint development contract was signed between STA and LME and until the first AXE switching station was successfully cut into operation was a development process that was going to take more than seven years. And all through the way of the development process, a collaboratively aimed organization of ELLEMTEL saw to that the two owners influenced the major decisions taken in the development projects. These seven years were filled with lot of sociotechnical development work concerning crucial decisions and critical problems, of which the most important are discussed.

4.2.1 The Development Contract

The formal agreement about the jointly owned ELLEMTEL company was worked out between STA and LME in the spring of 1970. The contract was signed in April, 1970, and approved by the Swedish Parliament and the Board of LME in May. This section discusses what was said in the ELLEMTEL contract and the government bill concerning the development cooperation.[74]

The contract ”concerning certain development and production collaboration in the area of telecommunications” that STA and LME signed on April 24 1970 included three separate agreements: one basic consortium agreement about the forming of the joint company ELLEMTEL Development Inc. and two appended agreements concerning intellectual property rights and manufacturing collaboration.

In the consortium agreement it was stated that contrary to conventional telecommunication equipment the new telecommunication technology put stronger demands on development resources and personnel. Therefore it was said that STA and LME ”thus stand in front of the demand to introduce a new technology, that successively will replace the present, at the same time as the development necessary to create this new technology demands larger developmental resources than what have been the case up till now”. The societal need that the new computerized switches was seen as solving was that the new computerized switches ”can be adapted to the varying conditions of the time and the customers can be given new kinds of [telephony] services”. Furthermore, another large advantage was that the computerized switches was seen as giving increased operational reliability and lower maintenance costs.[75]

The two largest problems about the joint development had concerned the ownership of the innovations and the division of the profits from the sold innovations. For LME's part, the largest obstacle to overcome concerned the intellectual property law agreement. Who should own the future innovations? STA had an ambition to start exporting their products and LME did not want to fund a potential competitor on its export market. The first idea was to allow STA to sell the jointly developed products only on the Scandinavian market. But LME could not agree on that. The result of the intellectual property rights agreement became the following:

• STA and LME was to share know-how about construction with ELLEMTEL and ELLEMTEL was not allowed to share this with outside parties.

• LME had the right to use (manufacture, sell and install) all over the world all patents and know-how about construction coming from ELLEMTEL. STA had the same rights in Sweden.

• ELLEMTEL owned all Swedish patents with the full rights of LME and STA to use them, while all foreign patents belonged to LME.

• LME and STA could use each others patents to manufacture products developed by ELLEMTEL.

• LME and STA had full rights to modify and further develop the products constructed by ELLEMTEL.[76]

This unbalanced situation about patent rights was balanced through an agreement concerning collaboration of manufacturing. This was to ensure ’equal growth’ of the two parties production of the products developed by ELLEMTEL. This meant that STA would sell and produce ELLEMTEL's equipment for the Swedish market, while LME produced for the export market, but only as large quantities as STA's domestic production. Since the export market was expected to grow more than the Swedish market the amount of export above that was to be shared between LME and STA and sold through LME's market organisation. It was seen as this agreement would mean large expansion of STA's manufacturing activities since it was estimated that this export of STA would within ten years time (1980) be 25% of its total manufacture. This meant that it looked as if STA's manufacturing divisions dreams about manufacturing for export would come true.[77]

Concerning the costs for ELLEMTEL they were divided according to an elaborate formula that meant that the major costs were shared proportionally between the two owners according to their respective turnover in the different product segments of ELLEMTEL. This meant that LME stood for about 65 % and STA for 35 % of the costs. ELLEMTEL's stock capital was initially 10 MSEK. In addition it got loans from STA and LME on 40 MSEK. In the Swedish Parliament the ELLEMTEL agreement concerning ”certain development and manufacturing cooperation in the field of telecommunications” was accepted without any discussion.[78]

The ELLEMTEL agreement was not changed until 1977 when the agreement concerning cooperation around joint production of products was taken away. The collaboration on production was according to the contract to come into effect in 1975 when the production of the technologies developed by ELLEMTEL was expected to start.[79] But in the mid-70s LME's growth in switching had became negative and LME had threatened to close a Swedish factory which changed the positive assumptions concerning the positive growth of LME which was the basis for the joint production agreement.

4.2.2 Organization of the Development

The development work that ELLEMTEL performed was organized in such as way that at almost all levels where decisions were taken, experience and opinions of both LME and STA influenced the development work. On the top level was the Board of ELLEMTEL with six ordinary members, three from each of the two owners. The Board among themselves appointed a Coordinative Committee consisting of five members, with two from STA, two from LME and the Director of ELLEMTEL. The Coordinative Committee had the following tasks:

• To decide accept or reject development projects that STA and/or LME wanted ELLEMTEL to work on.

• To follow and be informed about projects that ELLEMTEL worked on that did not come from the owners.

• Handle questions regarding the allocation of time and resources.

• Receive information from the owners regarding larger development projects within ELLEMTEL’s product areas.[80]

On the next level there were Functions Committees (FK) and Product Committees (PK) for each main product or technology area that prepared and discussed all issues that should be decided in the Coordinative Committee. In these STA, LME and ELLEMTEL was represented equally. In the Product Committee for Telephone Stations (PK-TS) all formal decisions regarding the technological choices in the AXE development was taken. The PK-TS did not meet very often, about every sixth week. Therefore, the members of the PK-TS, similar to the arrangement between the Board of ELLEMTEL and the Coordinative Committee, also appointed among themselves members to a Coordinative Group (TS-KG) that handled the running practical administrative and technical questions that had to be handled fast. Also this group consisted of representatives from the three parties. Connected to these Committees was a number of other coordination groups, expert groups, steering committees etc.

These different committees functioned as arenas for sociotechnical problem solving on different levels, from the TS-KG that handled practical questions on the micro level and participated in the actual development work, to the PK-TS that handled questions on a meso-level, while the Coordinative Committee and the Board handled the larger questions of funding and resource allocation to the projects. Another important purpose, except for the ”purely” technical problem solving activities of these various coordinating groups ”was to create consensus regarding different decisions about changes during the construction work.” In was in these different collaborative institutions, ”that the natural state of tension between the three cooperating companies would be expressed, the opinions broken against each other, and a common strategy and a handling finally be worked out to solve both problems on the level of requirement specifications as well as technical problems that arose during the construction work.”[81]

To start a project, like the AXE project, the purchaser filed an Order of Technical Work (BTA) that he sent to the Coordinative Committee. In the BTA was determined the time plan and cost ceiling for the project. The Coordinative Committee decided if the BTA should be approved or not depending on estimates that concerned if the resulting product would earn its cost, if there were a need for the product in Sweden or on the export market etc. When a project’s BTA had been approved it became the responsibility of its PK to handle the project. The PK could not increase the cost ceiling, which was the responsibility of the Coordinative Committee, but could change the level of ambition and the allocations of resources within the boundaries stipulated. After this it became the responsibility of ELLEMTEL to develop the product on its own.[82]

What follows in the next section are the critical decisions and problems before and during the development path of BTA-24 which was going to be the AXE switch. With the acceptance of this order of technical work to develop a computerized electronic switching station from STA and LME, the formal procurement of the AXE technology can be said to have started.

4.2.3 Reconstructing Supply and Demand, 1970-72

Just a few weeks before the ELLEMTEL contract was to be signed STA's A210 station was to be inaugurated in March 4, 1970. This was a big failure. The station did not work because of an error in the computer program and it took several days to get it functional. When ELLEMTEL began STA decided to terminate the A210 project and most of the personnel involved in the project transferred to ELLEMTEL and the A210 station was shut down after only seven months of operations.[83]

In May, ELLEMTEL was officially formed and started up its operations in July, 1970. Except for recruiting personnel one of the first tasks of ELLEMTEL was to evaluate the different proposals that STA and LME had produced for new computerized switching systems before ELLEMTEL had been founded. That was except for STA’s A210, two projects from LME (AK69 and AK70) that used that followed from the AKE13 project. By the end of 1970 ELLEMTEL had finished a study that proposed a switching AX technology in two versions: AX-N for local switches with up to 20.000 subscribers, and AXE-H that were for switches with more than 20.000 subscribers. The major difference concerned the different use of processors, the electronics that controlled the switching operations. The AXE-N used several decentralised processors to control the switching operations, while the AXE-H had one central processor and a number of processors that controlled different signals coming in and out of the switch.

The start of the AXE project was to come up with a proposal of a switching system that would fit the demand of both owners. These were in many ways conflicting since STA was mainly interested in a switch that would fit the certain characteristics of one specific telephone system – the Swedish. On the other hand, LME, that mainly wanted to export, was interested in a switch that fitted as many system as possible, preferably the whole world.

Therefore, ELLEMTEL, in early 1970, from a technical supply perspective began working on a configuration proposal for a new computerized switching system. Parallel to this, LME in September, 1970, began looking at the new switching technology from a demand perspective. This was the marketing department of LME's switching division, mainly consisting of engineers, that began writing a requirement specification regarding what the system should be able to do, how much it could cost etc. The purpose was to give a description of the ”ideal system” that was going to be adapted to the demands of LME's foreign markets.[84] Also, STA had a version of its requirements specification that reflected more the specific characteristics of the Swedish system, while LME looked at the whole world. Drawing on its extensive knowledge and experience from operational services STA, especially, put in a lot of work into the requirement specifications for various functions that was important in the operation and maintenance of the switching system.

A preliminary version of LME’s requirement specifications was finished in January 1971, STA’s requirement specifications was later developed into a range of different ”feature packages of great sophistication” that was to be important when the AXE-system was marketed to other telephone operators.[85] Now a dialogue started between the three parties and the configuration proposal and in mid-1971 some central joint conclusions regarding the requirements specifications from STA and LME had been reached:

• It should be a computerized SPC switching technology with large flexibility in what switching functions that was possible.

• It should be easily adaptable to fit all various kinds of telephone networks over the world.

• It should be constructed modularly to make it possible to take away or add new modules depending on the various demands on applications and functions from different markets.

• It should be flexible in time in the sense that it should allow for new undeveloped services, technologies and operational innovations to be included, such as digitalization and more efficient memory circuits.

• It should be easy and fast to manufacture, install and maintain. It should be possible to reduce the installation time to about half which was around six months, it should rapidly detect and localize any faults and stop them from spreading in the system.

• It should have a capacity corresponding to 40.000 subscribers with a certain average telephone traffic.[86]

ELLEMTEL’s systems specifications was finished in mid-1971. A central aspect of the AXE system that also had been presented in January to STA and LME was that it was going to have a functional modularization. This was an extension from the ideas developed at LME in connection with the development of the AKE 13 switch. Now was also introduced a special signalling system that isolated the different functional modules from each other. This was the solution to the critical problem of the error-sensitivity of large software program. The majority of other switching manufacturers saw this as a problem, but more or less accepted this as a ’fact of life’. This had led to the critical solution of ’modular software’ that now was extended to also include the hardware that belonged to the functions to also be included in the modules. In the proposal was also included the construction of a new processor that had to be specially developed to support the specific characteristics of the modular software, a completely different central processor from what was conventional. However, the proposal from ELLEMTEL was not concrete enough and in July, 1971, they got orders to produce a more specific proposal for the design of the new technology. By early 1972 a new more detailed proposal with a project plan for a development program was presented.

In the Spring 1972, an evaluation group from LME presented a new report that focused on three main issues: the high cost especially for smaller exchanges below 4.000 subscriber lines, the fact that ELLEMTEL still couldn’t reach the capacity of 40.000 subscribers for large switches, and the reliability that was seen as too low. Regarding the high cost, LME had analyzed the previous first order installations for electromechanical switches and had found that their customers for their first order had ordered a switch for 2.000 subscribers. LME saw it as a risk that a customer would not buy the AXE if the prices for small switches was too high and through this buy itself into another system that it continued expanding from the smaller switch instead of changing to AXE. However since the prices for electronics components was going down and another market looked more promising made the ELLEMTEL proposal acceptable from the point of view of costs. This other market was the replacement market for very large city switching stations and that made the capacity requirements very important. These were switches for capacities between 20.000 and 40.000 lines However, since they were among the oldest electromechanical switches they should be among the first to replaced. ELLEMTEL's specifications did only reach 32.000 subscribers, but managed to get the same traffic capacity as that of the 40.000 subscriber requirements by speeding up its processor which was accepted by LME.[87] The requirements about reliability was connected to the regional processors that was different from the central processor APZ 120. These processors handled simpler receptive switching functions while the central processor handled more complex and less frequent switching operations. In contrast to the central processor the regional processors had not been duplicated which meant that if a regional processor failed around 100 subscriber lines would be disconnected. The solution became that these processors also became doubled although not for the first Södertälje station.

One major technological feature of the ELLEMTEL proposal that was going to cause a major crisis among LME, was the need to develop a new processor. This forced LME to make a crucial decision since it had not, like STA, stopped their other electronic switching development but had continued with developing their AKE switch. LME's development department had made an inquiry concerning a local station switch that was based on the AKE 13 switch and that should use the APZ 150 processor that was already being developed by LME for the AKE switch. During the autumn the development department presented results that showed that it would be possible to construct an AKE switch that should be less expensive than the ELLEMTEL proposal. Among the major differences between the two proposals that came to be pitched against each other was that the AKE-proposal did not include the necessity to develop any new specially designed processor like in the ELLEMTEL proposal. The difference was a matter of 100 MSEK which was the price of developing ELLEMTEL's processor.[88]

But if LME took the decision to go ahead with the proposed AXE project it meant that they had to stop with further development of the AKE series of switches. Even though the AXE project with the new processor seemed to seemed to promise larger gains in capacity there were several reasons that spoke in favour of developing a switch based on the AKE concept. The major problem was that the AKE-concept was based on known and proven technology and would be finished faster than the AXE project that was not planned to be finished until 1976. Meanwhile, LME's foreign competitors had released, or were preparing to release, new models of computerized switches. If LME opted for the AXE project, it would mean 4 years without having a competitive product to offer its customers. This crisis within LME continued between February and May, 1972. Four persons, two from LME and two from ELLEMTEL, had been given the task to compare the two processors. Even though STA supported ELLEMTEL's proposal the decision had to be taken by LME since they were the one of ELLEMTEL's owners that had an alternative to give up in the APZ 150. The result of the evaluation was that the APZ 150 was going to be cheaper and faster but with less capacity potential. The choice LME had to do was between capacity or speed. At the decision in May, 1972, the management of LME decided to go ahead with ELLEMTEL's proposal since it was ELLEMTEL that had the task to develop the new switch, and it would be best if they did something ”that they really believed in” instead of a processor that they already had failed. This meant that LME stopped further development of the AKE switch and put all their money on the AXE card.[89]

This meant that the BTA-24 for the development of the AXE system that had been presented May 1st now could be approved by ELLEMTEL's Board. At about the same time also BTA-15 that concerned a new way of building the switching racks modularly was also approved. Through this the AXE technology had now got its major design determined and could go into practical development.[90]

4.2.4 Critical Development Problems, 1972-76

After the BTA had been approved followed an intense period of practical design of the different software and hardware included in the systems were some of the most important is the new construction practice of modular building and a new programming language adapted to telephony.

One of the major features of the AXE system that is developed during this period is the construction practice of modular building of the AXE switching stations. The requirement specifications demanded that all equipment should be connected without permanent connections, only with easily inserted and removed plugs and jacks. Therefore the switching is put up in racks in the forms of ”bookshelves” where the different modular hardware units are put up in the form of ”magazines” and plugged in to the rack, like books standing next to each other.[91]

During early 1974 all new improvements are stopped in the ELLEMTEL system since it now becomes crucial to finish the system on time. These improvements are collected and saved for further adaptations in future orders.

Thanks to the specially designed processor, APZ 210, it also became possible to introduce so called high-level language to programme the station. One of ELLEMTEL's engineers had while working at LME developed a special telephony language Eriplex. This was now further developed into the special high-level telephony programming language Plex that made it possible to program much more efficiently. It is estimated that a programmer becomes three times as efficient by using Plex than in the normal assembler machine language. Around 20-30 % of the total development cost of the AXE project, amounting to about 700 MSEK was saved through this.[92] However, not all of the development of Plex cuts time and in the Autumn 1974, a method of using Plex to faster check the programming codes is introduced that however has to be abolished in 1975 after a lot of misspent development work.[93]

One of the problems for the ELLEMTEL and LME during 1974 is to avoid to get involved in a project, AGAX, that STA wants to get developed. This is to develop a computer system to control STA's first generation of electromechanical switches. The inquiries about AGAX is drawn out in time and LME has problems finding personnel for the joint committees. The BTA never becomes finished and the project does not come into effect.[94] But that did the AXE project and during 1974 the date of the inauguration of STA's first AXE station is discussed and changed several times.

4.2.5 Enter Operation: Delivery of the first AXE-station, 1976-77

In September 1973 it had been decided by LME and STA that the first practical installation of the AXE technology would be in April 1st, 1976, in STA's switching station in Södertälje, a community in the south vicinity of Stockholm. When discussing what station to use for the first AXE switch STA had had "strong views on location and how it should fit into the Swedish telephone network" and LME had considered it important that the switch was in close reach of Stockholm so that it could easily bring foreign visitors there and give presentations about its new technology.[95] The Södertälje station was a rather small station, only 3.000 subscriber lines which was about the tenth of the size for a normal city station, and through this a suitable first project for the new technology.[96] The electronic and computerized AXE technology would replace the station's previous switches of the first electromechanical generation.

The date stipulated by LME was earlier than 1977 which was the estimate of the AXE project at ELLEMTEL. The reason for this early date was because it is supposed to be in time for the centenary birthday jubilee of the telephone and the LME company. But as the estimates of man-years increase, this date is pushed ahead several time during the project. In January 1974, it becomes October 1st, 1976 and in October 1974, it becomes December 1st, 1976. Finally, in October 1976 the date is changed to March 1st, 1977. But despite this date it was decided to demonstrate a working station in 1976 and the trial operations is to start in December that year.

Issues regarding the process of handing over the AXE technology to LME is accentuated during 1976. One way was that ELLEMTEL during 1975-76 borrowed several engineers from LME to work on the AXE technology and through ”hands-on” work learn the new technology first hand. At the same time, parts of the switching equipment for the Södertälje station was manufactured by LME in their new electronics work-shop. This was also a way of transferring the manufacturing knowledge from ELLEMTEL to LME.[97]

The first large public presentation off the AXE technology to the Swedish audience was in the spring of 1976 in connection to the centenary jubilee of LME. It was considered very important that LME was seen as the manufacturer of the AXE technology and at presentations to foreign customers ELLEMTEL was not mentioned and their engineers presented as coming from LME. Finally, the station went on trial operation during late 1976. All subscribers that was connected to the switch was the employees of STA that lived in Södertälje. Through this several smaller errors in the electronics set-up as well as in the programmes was found and could be corrected before the official inauguration in March with all the station’s 3.000 subscribers.

The actual installation of came during the night March 1st, 1977. Then all of the stations 3.000 subscribers were switched from the old crossbar switches to the new AXE technology. The switch-over went without any problems.[98] The first telephone call fro the new station went to a manager at LME that the following day was going to demonstrate the AXE station to engineers from the Australian Post Office that was interested in buying the new technology. The call came through and he got the message that LME now could demonstrate a operating computerized switching technology to their international buyers, and later the same day STA inaugurated its new station.

With this development of the AXE technology switched into path that it had entered a couple of years before, but that now become more accentuated, and that was to export the AXE .

4.3 Post-Procurement: Adapting Trajectories, 1973-81

The post-procurement phase describes when LME goes out and try to sell its new technology on the export market, and when STA files its second order on an AXE station. Since most of these new buyers were Government agencies these were also cases of GTP. Many of the new orders were for AXE switching stations that were not fully developed or included development or adaptation to major new technologies. Two of these new technologies were the technology trajectories of digitalization mobile telephony, that in this way assisted and was assisted in their breakthrough by the AXE technology.

4.3.1 Switching Expansion: Adaptation to Foreign Markets 1973-77

During the first period of the AXE development project, LME kept a strict secrecy outwards about the development AXE project. This was in some ways to stop their customers from buying their ARE and AKE stations but also because it was not finished enough to be presented as a commercial product. It was not until the end of 1973 that LME started to talk to foreign telephone operators of its new technology. The first marketing strategy for selling AXE abroad was to gradually introduce single small stations in the markets where LME already had established good relations to certain customers such as Denmark, Finland, Mexico, Brazil and Australia. When AXE successfully had been introduced in these regions it was time to try to expand to other regions. However, this strategy would only work for the first export order.

The first export order for an AXE exchange came in 1973 from the Turku Telephone Utility. This was a customer with which LME had a long relation and the utility had in 1969 ordered an AKE 12 with the understanding that it would take some time before it was installed. When LME in 1972 gave up the development of the AKE family it tried in early 1973 to make the utility to change its order for an AXE exchange instead. The utility accepted and placed an order for an AXE subscriber switch of 4.000 lines. This was going to be the first AXE which were adapted with the new digital switching technology. LME's subsidiary in Australia had been working on a digital switching technology since 1970 and since June 1974, ELLEMTEL was working on an accepted BTA concerning a digital switching technology to be included in the AXE switch. In 1975 it was also decided that the first digital switch was going to be installed in Turku in December 1977.[99]

So far the strategy of introducing small switches had worked but in late 1974 the effects of the oil crisis was felt in the telecommunications sector and most utilities did stop buying new switching stations.

One that did not do that however was APO in Australia. LME had had some success in Australia after the failed AKE 13 order in 1969 when it was beaten by ITT and their Metaconta switch. The first success was that the Metaconta switch failed to become operational in 1973 and the second came in early 1974, when APO ordered two ARE 11 local switching stations. It was also known that APO in 1975 would make long-term choice for what switching technology they were going to use for local exchanges. LME wanted to sell AXE but APO insisted that the switching technology had to had proven itself in service when offered. LME together with its Australian subsidiary EPA, in November 1974 managed to convince APO to let AXE be included in the invitation to tender that went out in 1975. In July 1975, LME submitted its AXE proposal.[100] In September 1976 APO announced that only ITT's Metaconta and LME's AXE was the only remaining in the tender process.

Meanwhile, as the Australian tender process had progressed, another AXE order had very suddenly become very promising. This was France whose old telephone network was in need of serious modernization. In the summer of 1975 the French Ministry of Telecommunications invited tenders for computerized local switching stations. One demand however was that the companies that offered the switches had to be French. LME therefore offered AXE through CIT-Alcatel with which its French subsidiary had a joint company. The result became that AXE was chosen but that it had to be manufactured by the French firm Thomson-CSF. To get a large order from a major European country in tough international competition was seen as very important to LME and it therefore accepted this and order was placed in December 1976. This also meant that LME sold its French subsidiary to Thomson that acquired a license to manufacture AXE. This was the first large order for AXE and it was not given to LME.[101]

When it comes to the further use of AXE in Sweden no new switches had been installed after the first in Södertälje. This AXE-station was operating without problems and in addition to its normal operations it was very important to LME's international marketing as the company used it to show visiting potential customers that they had an electronic computerized switching system that was not only on the drawing board but that was also operational. After the first AXE-station in Södertälje it took three years before the AXE-switches began to be introduced on a more larger scale in the STA's national network. This had, however been decided in 1977 and was pushed through in connection to the Australian order.

In 1977, LME because of the recession threatened to shut-down one of their Swedish factories and with this threat had managed to persuade the Government had promised to come up with supporting purchases but had not filed any orders yet. However, in 1977 when the decision regarding the Australian tender was to be taken, APO told LME that if not even STA had bought any more AXE exchanges how could then APO buy any. the Managing Director got into contact with STA's General Director and gave him this message and asked if he could do anything before the decision was taken. The General Director got into contact with the Ministry of Communications that the following day answered that the Ministry of Finance had approved of the purchase. The Director General with short notice called in the Board of STA that took the decision and with a telephone call to Australia one day before the decision was going to be taken he could give the message to APO that STA also had ordered AXE exchanges. This Swedish purchase was for 10 new digital AXE stations for various cities and an substantial extension of the Södertälje station, totally 240.000 subscriber lines that should be ordered from LME in 1979-81.[102] In September 1977 the APO announced that it would chose AXE as the standard for local switching stations.[103] The Battle of Australia was won.

At the same time the major international breakthrough of AXE came in 1977 when LME managed to get ”the telecommunications affair of the century”. In the summer of 1977 the Ministry of Telecommunications invited tenders for the modernization of the country's telephone network which included SPC exchanges for nearly half a million telephone lines. This was the largest telecommunications order ever and LME joined forces with Philips and Bell Canada. The telephone stations were divided between Philips and LME with the large local stations and large trunk stations to LME and the AXE technology while the smaller stations was going to be supplied with Philips's PRX switches. Bell Canada was supposed to be in charge of operating the system for five years. The AXE delivered in this AGP also incorporated digital switching technology. The consortium submitted the tender in September 1977 and it had the American companies ITT and Western Electric as its most serious competitors. In December 1977 the Saudi Government decision was announced that the LME bid had been chosen and in January 1978 the contract was signed. The contract included that the network should become operational within a year after its signing which LME managed to accomplish thanks to the new construction practice of modular building.[104]

The breakthrough in Saudi Arabia gave AXE the lead in digital switching but the first digital AXE switch had been inaugurated in May 1978 in Turku. This was about the time when the digitalization trajectory had its breakthrough among the international telephone utilities. LME, thanks to its early development on digitalisation and the large flexibility of the AXE system that allowed it to add-on the new technology, was together with the Canadian Northern Telecom the first companies to offer full digital switching systems. The French E10 switch that had been the first digital switch had been developed for small rural switches and had previously not been marketed actively abroad. LME could through AXE in 1978 offer functioning digital switching systems while most of its competitors were busy developing theirs.

This happened in September 1980 when to AXE-stations was inaugurated outside Stockholm and Gothenburg. These new switches had been further developed compared with the switch that was installed in Södertälje and had a digital signal system. STA's further installation of digital AXE switches led to the fact that Sweden in the late 1980s became the first country in the world to offer national digital coverage.

4.3.2 Switching to a New Trajectory: Introducing Mobile Telephony, 1977-81

STA had, since the end of the 1940s, been pursuing research and development in mobile telephony when engineers, on the order of the Director General, started developing an experimental system for mobile telephony.[105] This system was finished in 1950 and was developed in collaboration with LME and its subsidiary, SRA. The new system, (MTL/MTA), began operation in Stockholm in 1956 and had a range of 30-40 km. Another STA-system followed, MTB, which began operation in 1965. And it was at this time that one started to realise the potential of the new technology.[106] LME and SRA were the central private companies involved in the MTA and MTB projects. LME developed switches and SRA developed base radio stations and telephone sets for the two systems.

The next major phase of he mobile telephony trajectory came in 1969, when STA informed the other Nordic PTAs that they were intending to work on the next generation of mobile telephony. This led to plans for a common mobile telephony network in the Nordic countries, called NMT. Several technical standards for the new system were decided in co-operation between LME and STA. In 1977, a test system was installed in the Stockholm region and, until

1978, LME and STA, in co-operation, conducted extensive tests on the prototypes of this switch.[107]

STA, around 1977, convinced LME that they should construct a modified version of their AXE-switch for mobile telephony. When STA was going to offer an order for a new mobile telephony system, they wanted a modern computerised switch for that, but LME considered that their computerized electromechanical AKE 13 switch would suffice. But STA insisted and also threatened to buy their technology from a Japanese company if they did not get the AXE switch. LME changed their mind and offered a modified AXE-switch.[108] LME got the NMT order which included switches to Sweden Norway, Finland and Denmark. In 1978, STA signed the contract for the new switches and, in 1981, the Nordic countries inaugurated their NMT-network.

5. SOCIETAL AND INDUSTRIAL RESULTS: Switching Advantages

The GTP of AXE has been very profitable for both LME and STA. AXE is today the most sold automatic switching system for telecommunications in the world. Furthermore, thanks to the adaptability to mobile telephony the AXE-switches has given LME a steady foothold in mobile telephony.

5.1 Societal Results: The Profits of STA

STA has benefited very much from the AXE-system when it comes to the quality of its network. In 1977 STA estimated that all switching stations was going to be digitalized by the year 2020, i.e. a period of 33 years to be compared with 48 years for the automatization of the telephone network. However, by the year 1997 it looks as if that goal with the help of modernized versions of the AXE system ”will be achieved more than 20 years earlier than what was considered possible at the start of this large project.”[109]

According to its own evaluation STA during the 1980s and early 1990s with the help of AXE had built ”one of the most modern telephone networks in Europe and could show that the telephony fees still was among the lowest in the world.”[110] If STA had not bought a Swedish switching system, it would probably would have not been able to handle a large part of the manufacture itself through TELI. Furthermore, it most likely would have been more difficult for STA to have one single system for the whole country if it was going to buy new switches gradually from abroad. With the help of a modified AXE technology, the so called AXE-M system, made it possible for STA to supply the new telephony services such as ”call-waiting”, ”automatic wake-up call” etc., also to subscribers belonging to electromechanical switching stations.

Thanks to the extensive build out of AXE stations Sweden became the first country in the world to offer national digital coverage. This was because it in 1987 existed at least one AXE exchange in every Swedish city and major community which made it possible to set up 64 kb/s connections to any location in Sweden.[111]

Last, but not least, comes the benefit to the Swedish end-consumer, who has got a very modern telephone system of high technical standard with a large array of new telephone services such as call-waiting, automatic wake-up call etc.

5.2 Industrial Results: The Profits of LME

According to LME: former President, Björn Svedberg, it would have been a ”catastrophe” for Ericsson to be without the AXE switch.[112] LME would most likely not have been able to remain an independent telecommunications company. The three major development, of AXE meant three major results:

The company successfully changed its production from the electromechanical trajectory to the higher value-added electronics trajectory. The development of the AXE switch was the major reason behind why LME managed to change from one old technological trajectory to another new trajectory. LME's main product segment was ’switching’ and, before the 1970s, the majority of LME's manufacture was based on the ”electromechanical trajectory”, i.e., products consisting of combinations of mechanical and electrical machinery. After the 1970s LME had entered the ”electronics trajectory” with its main manufacture consisting of products based on electronics and computerized components.

The development of the electronic and digital switch meant that LME had one of the most advanced switches in the market, which gave it several large export orders that doubled LME’s share of the world switching market. In 1992, LME had sold AXE stations for 56 million telephone lines to 87 countries and in 1990 had around 13 % of the world market measured in the number of installed telephone lines. With this it was the fourth largest after Canadian Northern Telecom (15 %), French Alcatel (15 %), and American AT&T (14 %).[113] More so, in the late 1980s LME also managed to enter the large US market for telecommunications thanks to the AXE system.

And the last and one of the most important results of the AXE technology was that it laid the ground for LME's successful entry into mobile telephony trajectory in the 1980s. LME was very early to enter the mobile phone market and in 1992, with orders for almost 400 AXE switching stations for mobile telephony networks, LME had 40 % of the world market.[114]

6. CONCLUSIONS: Switching Relations in History and Policy

6.1 Interdependence

When it comes to the interdependence between different elements in NSIs, the AXE case has mainly been focused on the effectiveness of user-producer interaction. In this the government user provided crucial resources for the innovation activities through technical and financial risk-sharing and technical collaboration activities. These innovational dynamics is interesting to compare to the results of *3.2.3 Financing of Innovation* which analyze the innovational dynamics of borrower-lender interactions and government support via funding and economic risk-sharing. It might be possible to say something about the relative importance to industrial companies of financial resources and economic know-how vs. technical resources and technological know-how.

Another interesting aspect is the interdependence of different innovational activities which is also discussed in the paper on GTP and innovation theory by Edquist & Hommen in *3.2.2 Government Technology Procurement as a Policy instrument*. The division of three stages or phases of innovation (here: proto-procurement, procurement and post-procurement) is something that is very ordinary in traditional innovation theory, visualized by discussions of the linear model of technological development and S-curves of product innovations etc. As has been shown in this case the proto- and post-procurement phases are very much integrated to the procurement phase and the research, development and market-introduction activities are not isolated to one specific phase. Post-procurement as a locus of marketing activities that are strictly after and independent of the locus of development, procurement, is an assumption that is very misleading as the two phases are overlapping in time and the activities are very much integrated with each other and effecting each other in both ways. The two phases are parallel and dependent on each other, especially when you have ordered something that is not finished yet, as is the essence of technology procurement. This analytical construction of phases is therefore of theoretical interest in that it focus on how integrated with forward and back-ward linkages that research and development is with market introduction and technology transfer, or as it is also called by a misnomer; technology diffusion.

6.2 European Integration: Constructing technologies with ’integrative flexibility’

When it comes to the matter of European integration the AXE case is interesting in that it highlights how an awareness of cultural and regional differences can be a strong marketing argument and also help in inducing new kinds of technological breakthroughs.

By this I mean how the demands of LME's marketing branch to cover in as many different markets as possible in the requirements specifications supported the extensive modularization of the AXE switch. This modularization was going to be one of the AXE systems strongest points. The AXE system is an example of an technology and a way of constructing technologies that in its conception tries to take into account the various characteristics of different cultures and to ’build in’ this into the technology and in that way give it an ”integrative flexibility”.

As an opposite example to technologies with high ”integrative flexibility” it could be possible to talk about technologies with ”isolative rigidity”. One example of such a very rigid technology that is less open to cultural integration can be the railway systems developed during the 19th century whose different gauges raised – and raise – obstacles to integration rather than the opposite.

6.3 Links to other ISE projects

There are naturally many interesting comparisons to be made with the other papers looking at government technology procurement in sub project *3.2.2 Government Technology Procurement as a Policy instrument*, and especially those papers looking at other European cases of GTP in telecommunications. But there also exists links to other sub projects in ISE.

The general theoretical perspective used in this case study is connected to those systems and evolutionary approaches treated in *3.1.1 Systems Theories of Innovation: Policy Implications*, Especially as in *3.1.3 European Integration and National Systems*, the role of diversity in supply and demand and learning is emphasized.

The Development Pair between LME and STA, as well as ELLEMTEL, was a ”corporate governance mechanism” that was very positive for innovation performance and organizational learning as discussed in *3.2.4 Corporate Governance and Innovation Performance*.

The AXE case also exemplifies of a simultaneous technological and sectoral entry as discussed in *3.2.5 Technological Diversification vs. new Innovators*, of a large company. Since it is a rather detailed case study it gives a good example of how a large firm has handled this diversification process. In the discussion of the mobile telephony it also shows an example of an in many ways unplanned diversification process. The case of mobile telephony is also discussed more in depth in a paper by McKelvey, Texier and Alm in sub project 3.2.5.

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Notes

[1]Hans Heimbürger & Karl Väinö Tahvanainen, *Telefon, telegraf och radio 1946-1965*, vol. 6 of *Svenska telegrafverket: Historisk framställning* (Stockholm, 1989), 13-16; Ove Granstrand & Jon Sigurdson, ”The Role of Public Procurement in Technological Innovation and Industrial Development in the Telecommunication Sector: The case of Sweden”, in: Ove Granstrand & Jon Sigurdson, eds., *Technological Innovation and Industrial Development in Telecommunications: The Role of Public Buying in the Telecommunication Sector in the Nordic Countries* (Gothenburg, 1985), 156.

[2]Bengt G Mölleryd, *Så byggdes en världsindustri: Entreprenörskapets betydelse för svensk mobiltelefoni* (Stockholm: Stockholm School of Economics, 1996), 81-83.

[3]Dimitrios Ioannidis, ”I nationens tjänst?: Strategisk handling i politisk miljö : En nationell teleoperatörs internationalisering och strategiska allianser”, unpublished dissertation draft (Dept. of Marketing, Distribution and Industry Dynamics, Stockholm School of Economics, August 1997), Chpt.5, 14.

[4]Magnus Karlsson, ”The Liberalisation of Telecommunications in Sweden: A History of Regime Change from 1961 to 1993”, unpublished dissertation draft (Dept. of Technology and Social Change, Linköping University, May 1997), Chpt 1; Ioannidis 1997, Chpt. 5, 42.

[5]Ioannidis, Chpt. 7, 3.

[6]See: Sterky, ”Ett högfrekvent halvsekel”, in: *En del om el: Minneskrift utgiven till Sveriges Elektroindustriförenings 50–årsjubileum 1968* (Stockholm, 1968), 27-56; Malte Patricks & Christian Jacobæus, ”LME:s samarbete med televerket och medverkan under automatiseringen”, *Tele* 78 (1972), 41-46; Bertil Bjurel, ”100 år med Telefonaktiebolaget LM Ericsson som leverantör och samarbetspartner”, *Tele* 82 (1976), 1-9; Björn Lundvall, ”LME:s samarbete med televerket”, *Tele* 83 (1977), 129-131.

[7]Among several examples, see: Hans Westling, *Technology Procurement for Innovation in Swedish Construction*, BFR D17:1991, (Stockholm, 1991), passim, esp. 73-76, 100-101.

[8]Mats Fridlund, "Ett svenskt utvecklingspar i elkraft: Aseas och Vattenfalls FoU-samarbete, 1910–1980", BI Forskningssenteret forskningsrapport 1995/2 & Senter for elektrisitetsstudier 1995/312/7 (Sandvika: Handelshøyskolen BI, 1995), 1-2. – I have previously used a somewhat broader definition, see: Mats Fridlund, ”The ’Development Pair’ as a Link between Systems Growth and Industrial Innovation: Cooperation between the Swedish State Power Board and the ASEA Company”, Working papers from the Department of History of Science and Technology 93/9 (Stockholm, 1993), 4.

[9] See for instance: Jan Glete, *Storföretag i starkström: Ett svenskt industriföretags omvärldsrelationer - en sammanfattning baserad på "ASEA under hundra år"* (Västerås, 1984); idem, "High Technology and Industrial Networks: Some Notes on the Cooperation between Swedish High Technology Industries and their Customers", (Paper presented at ”International Research Seminar on Industrial Marketing” at Stockholm School of Economics, Stockholm, August 29-31 1984); *Framgångsrik utveckling av energiteknik*, IVA-M 278 (Stockholm, 1992), 6; Charles Edquist & Bengt-Åke Lundvall, ”Comparing the Danish and Swedish Systems of Innovation”, in:

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[10]Attman & Olsson, 191-92.

[11]Walter Broberg, ”En historisk anläggning tas ner: länkkopplat system i Sundsvall”, *Tele* 83 (1977), 53; Vedin 1992, 39.

[12]Cristian Jacobæus et al., *Teletekniskt skapande 1876-1976*, vol.3 of *LM Ericsson 100 år* (Örebro, 1976), 409, 411; Fredrik Neumeyer & Nils Rönnblom, ”Uppfinningar och patent hos televerket”, *Tele* 71 (1965), Special issue, 266; Göran Fredriksson, ”AXE – En lång historia”, *Tele* 96 (1990):4, 3; Lernevall & Åkesson, 701-702.

[13]Granstrand & Sigurdson, ”The Role of Public Procurement”, 153; Karlsson 1997, 3-4.

[14]First quote from former General Director Tony Hagström, see: Tony Hagström, ”En brytningstid”, in: Sven Lernevall & Bengt Åkesson, *Från myndighet till bolag 1966-1993*, vol. 7 of *Svenska telegrafverket: Historisk framställning* (Stockholm, 1997), 12; Sunesson, 46.

[15]Granstrand & Sigurdson, ”The Role of Public Procurement”, 152.

[16]Arne Angerby, ”Manufacturing Activities of the Swedish Telecommuications Administration During the Past 25 Years”, in: *Tele: Information from the Swedish Telecommunications Administration : Retrospective Survey of the Last Twenty-Five Years* (Stockholm, 1965), 48.

[17]Angerby, 48.

[18]Angerby, 48.

[19]Angerby, 48.

[20]Erik Nihlfors, quoted in: [Lasse Karlsson,] *Automatik för millioner: En presentation av televerkets verkstadsrörelse* (Stockholm, 1963), 117.

[21]Bertil Sunesson, ”Televerkets utvecklings- och produktionssamarbete med LME”, *Tele* 76 (1970), 146.

[22]John Meurling & Richard Jeans, *A Switch in Time: AXE – Creating a Foundation for the Information Age* (London, 1995), 2.

[23]Artur Attman & Ulf Olsson, *Räddning återuppbyggnad världsföretag 1932-1976*, vol.2 of *LM Ericsson 100 år* (Örebro, 1976), 262-64; Sunesson, 146.

[24]Attman & Olsson, 265.

[25]Meurling & Jeans, 174.

[26]Vedin, 149-50.

[27]Attman & Olsson, 247.

[28]Vedin, 187.

[29]Jacobæus et al., 138.

[30]Lernevall & Åkesson, 703.

[31]The name ELLEMTEL reflected the shared ownership. The firt part (ELLEM) sounded like LM in LM Ericsson and the second (TEL) was the first letters in STA:s name in Swedish (Televerket).

[32]Granstrand & Sigurdson, ”The Role of Public Procurement”, 154.

[33]Gunnar Eliasson & Ove Granstrand, ”The Financing of Technological Investments”, in: Ove Granstrand & Jon Sigurdson, eds., *Technological and Industrial Policy in China and Europe: Proceedings from the First Joint TIPCE Conference 1981* (Lund, 1981), 243.

[34]Lernevall & Åkesson, 706, 718.

[35]Lernevall & Åkesson, 72-73.

[36]Bertil Bjurel, ”Elektronikens barn AXE-systemet och mobiltelefonen föds: Televerket får ny organisation”, in: Lernevall & Åkesson, 6.

[37]Lernevall & Åkesson, 73.

[38] Wesley M. Cohen & Daniel A. Levinthal, "Absorptive Capacity: A New Perspective on Learning and Innovation", *Administrative Science Quarterly* 35 (1990), (128-52,)128.

[39]Cohen & Levinthal, 129.

[40]Helgesson Claes-Fredrik Helgesson, *Omvadling i tekniska system: Avvecklingen av den manuella*

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[41]Percentage values read from graph in: Helgesson, 33.

[42]Lernevall & Åkesson, 113.

[43]Stan Augarten, *Bit by Bit: An Illustrated History of Computers* (New York, 1984), 228.

[44]Lernevall & Åkesson, 113.

[45]Heimbürger & Tahvanainen, 19.

[46][Karlsson], 24.

[47]Jacobæus et al., 137.

[48]Bengt-Arne Vedin, *Teknisk revolt: Det svenska AXE-systemets brokiga framgångshistoria* (Stockholm: Atlantis, 1992), 31**.**

[49]Vedin, 85-86.

[50]Patricks & Jacobæus, 44.

[51]Vedin, 34; Lernevall & Åkesson, 114; Göran Fredriksson, ”Etikettsbrott bäddade för RACE-medverkan”, *Tele* 97 (1991):2, 17.

[52]Hans De Geer, *På väg till datasamhället: Dataekniken i politiken 1946-1963* (Stockholm, 1992), 24-28.

[53]Vedin, 62.

[54]Lernevall & Åkesson, 114.

[55]Bengt-Gunnar Magnusson, quoted in: Brita Norinder, ”Nu satsar AXE:s pappa på framtidens telesystem”, *Tele* 93 (1987):2, 33.

[56]Vedin, 69.

[57]Jacobæus et al., 140.

[58]Fredriksson, ”Etikettsbrott”, 18.

[59]Vedin, 65-66; Lernevall & Åkesson, 115.

[60]Meurling & Jeans, 28.

[61]Norinder, 34.

[62]Heimbürger & Tahvanainen, 21.

[63]Fredriksson, ”Etikettsbrott”, 18-19.

[64]Bengt-Gunnar Magnusson, quoted in: Norinder, 36.

[65]Vedin, 104;

[66]Meurling & Jeans, 91-92.

[67]Bjurel, ”Elektronikens barn”, 8.

[68]Vedin, 57.

[69]Bertil Forss, ”Elektronisk kopplingsteknik just nu”, *Tele* 76 (1970), 13.

[70]Bjurel, ”Elektronikens barn”, 8.

[71]Forss, 11-13; Meurling & Jeans, 24-26.

[72]Meurling & Jeans, 29.

[73]Göran Fredriksson, ”AXE – En lång historia”, *Tele* 96 (1990):4, 4-5; Meurling & Jeans 1995, 31-32; Vedin 1992, 95-97; Bo E Åkermark, ”Drivkraften bakom nallen”, *Dagens Nyheter*, 14/10-96, p B:5; Bjurel, ”Elektronikens barn”, 8.

[74]This subsection and all quotes from the agreement and the government bill is, if not otherwise stated, taken from: Sunesson, 145-51.

[75]Sunesson, 148-49.

[76]Sunesson, 148-149.

[77]Sunesson,147-149; Vedin 1992, 98-99.

[78]Quote from: Vedin 1992, 100.

[79]Vedin 1992, 98-99.

[80]Lernevall & Åkesson, 706.

[81]Lernevall & Åkesson, 707-8.

[82]Göran Fredriksson, ”Så fungerar ELLEMTEL”, *Tele* 84 (1978):4, 2-3.

[83]Göran Fredriksson, ”Pålitlig övervakning i 20 års tid”, *Tele* 96 (1990):4, 56-57.

[84]Meurling & Jeans 1995, 36.

[85]Meurling & Jeans, 37.

[86]Vedin, 138; Meurling & Jeans, 38.

[87]Vedin, 141: Meurling & Jeans, 141-2.

[88]Göte Andersson, ”Egna lösningar bäddade för AXE-framgång”, *Tele* 93 (1987):7-8.

[89]Vedin, 144-46; Andersson, 8.

[90]Vedin, 200.

[91]Meurling & Jeans, 78.

[92]Andersson, 5.

[93]Vedin, 204.

[94]Vedin, 203.

[95]meurling & Jeans, 82-83.

[96]This ’small is beautiful’ strategy was also followed for the first procurement order i the development of the HVDC technology as discussed in my other report in the ISE subproject, see: Mats Fridlund, *Shaping the Tools of Competitive Power: Government Technology Procurement in the Making of the HVDC Technology*, Report to ISE Sub-Project 3.2.2 Government Technology Procurement as a Policy Instrument [Stockholm, 1997].

[97]Vedin, 206, 176.

[98] Only one major problem was discovered, that the AXE could not communicate with certain small private switches, and that was easily solved (Vedin, 216-7).

[99]Vedin, 187, 203-5; Meurling & Jeans, 111-12.

[100]Meurlng & Jeans, 113-14.

[101]Vedin, 222-23; Meurling & Jeans, 120-21.

[102]Vedin, 223; Lernevall & Åkesson, 122; Kai Lervik, ”Satsning på Teli”, *Tele* 83 (1977), 57.

[103]Meurling & Jeans, 114.

[104]Vedin, 224-27; Meurling & Jeans, 117-20.

[105]This section on mobile telephony is if not stated otherwise based on: Mölleryd.

[106]*75 år av teknik:Ingenjörsvetenskap och industriell utveckling 1919-1994* (Stockholm: IVA), 91.

[107]”De baxade Ericsson mot toppen", *Ny Teknik* (1994):45, 27; *Framgångsrik utveckling av energiteknik*, IVA-M 278 (Stockholm: IVA, 1992), 84.

[108]Meurling & Jeans, 198.

[109]Lernevall & Åkesson, 75.

[110]Lernevall & Åkesson, 80.

[111]Meurling & Jeans, 140.

[112]Vedin, 16.

[113]Vedin, 249, 266.

[114]Vedin, 251.