2. PUBLIC TECHNOLOGY PROCUREMENT IN SWEDEN: THE X2000 HIGH SPEED TRAIN

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INTRODUCTION

This chapter describes and analyses the development of Sweden's high-speed train (HST), the X2000, as a case of public technology procurement. The case study is based mainly on primary data collected in recent (1997) interviews with some of the main actors involved in the procurement process, but it also draws upon relevant secondary sources. The analysis employs evaluative criteria defined from the standpoint of public policy (as elaborated below) and develops a critical perspective on the case that leads to more general policy implications.

To situate and characterise the case briefly, the procurement of the X2000 occurred during the mid-1980s, culminating the development of proposals, plans and technical preparations for a Swedish HST over a period of some 20 years (Flink & Hultén, 1993; Pålsson, 1987; SJ, 1969). Throughout this period, there was close collaboration between the Swedish state railway company, SJ, and the Swedish railway equipment manufacturer, ASEA, in joint research concerning a future HST (Andersson, 1983; Flink, 1992; Flink & Hultén, 1993). The eventual procurement was a case where the only existing user – SJ – also represented final demand for the trains. The market was also very concentrated on the supplier side and it can be questioned whether the chosen supplier, ASEA (now AD Tranz), had any real competitor, because of the way the procurement process was organised. The previous very close interdependence between SJ and ASEA is the main basis for this scepticism about competition.

Since the procurement of the X2000, there have been several changes in the corporate identity of the supplier. Originally, the supplier of the X2000 was the Swedish corporation ASEA and, more specifically, its division for the manufacture of railway equipment, ASEA Traction. However, shortly after the procurement of the X2000 was finalised in 1986, ASEA merged with the Swiss corporation, Brown Boveri, in 1988, to form ABB, a multinational corporation of which ASEA owned 50%. ASEA Traction then became ABB Traction. Several years later, in 1995, ABB together with Daimler-Benz founded the joint venture, AD Tranz, which was responsible for all business of ABB within the rail transportation sector. Thus, the supplier of the X2000 became AD Tranz, of which ABB owned 50%. In the beginning of 1999, ABB sold its part in AD Tranz to Daimler, which had (almost simultaneously) merged with Chrysler to form Daimler-Chrysler. Hence, AD Tranz is now wholly owned by Daimler-Chrysler.

One of the most notable aspects of the X2000 procurement was the length of time required for its completion. As early as 1964, the R&D department at SJ (Swedish State Railways) had considered the benefits of a high speed train (Flink & Hultén, 1993: 89). SJ's interest in developing a Swedish HST was due to the increasing competition from road and air transport during the 1960s. Furthermore, there was a general pessimism about the future of railways. This concern, together with a forecast indicating an increasing demand for fast reliable passenger transport, legitimised the vision of a high speed train within SJ. However, SJ took a very long time to realise this vision. The analysis presented here suggests that this delay was based in large part on SJ's initial lack of the competence required to carry out the train's procurement. The critical evaluation supported by this analysis points to certain negative competitive and innovative consequences for the producer of the X2000, AD Tranz (formerly ASEA). However, it also recognises some positive effects of the procurement overall.

One of the main problems experienced by the X2000 was the failure of the train as originally designed to win a significant share of the export market for high speed trains. The analysis presented here indicates that a major reason for this failure was poor timing. The X2000 did not fare well in this market because of its late development and introduction. In Europe, at least, the X2000 lost possible foreign sales most consistently to a competitor, the Italian 'Pendolino', that had the advantages of much earlier development and introduction to the market. It is reasonable to hypothesise that the competitor's greater success has mainly been due to these advantages. This argument can be linked directly to the explanation of delay on the part of SJ as being the result of an initially low 'buyer competence'. There are, of course, counter-arguments to this explanation of the X2000's lack of export success. These are addressed in the analysis that follows in later sections.

The societal and industrial aspects of the X2000 procurement case will here be addressed in terms of three main kinds of criteria. These are criteria related to: 1) Innovation Policy, 2) Industrial Policy and 3) Costs, Benefits and Profits.

Evaluation in terms of 'Innovation Policy' entails establishing what kind of technology procurement this case represented and determining whether or not it was successful in altering the direction of technical change, increasing technical diversity, or influencing the pace of technical change. The X2000 procurement process was a case of 'adaptive public technology procurement'. Although adaptive public technology procurement can have significant effects on technological change, in this case it did not result in any radical change in the speed or direction of technical change. Most of the elements in the train system existed previously, and a high-speed train with similar functions – the Italian 'Pendolino' – existed well before the X2000 was developed (Agerberg, 1996a; Giuntini, 1993). Thus, the procurement was not altogether successful from an innovation policy point of view.

Evaluation in terms of 'Industrial Policy' involves establishing whether or not the competitiveness of the supplying firms was enhanced. It is true that the procurement of the X2000 did mean the development of a somewhat different train than the Pendolino – one drawn by a locomotive rather than consisting of motor coaches. However, this concept has not proven successful in other countries and the locomotive version of X2000 has not been exported to any other country.[1] This means that the X2000 procurement has not functioned well as an industrial policy instrument either.

The appraisal of 'Costs, Benefits and Profits' concerns whether or not the buyer and seller, respectively, 'gained' or 'lost' in strict accounting terms from the procurement process, and (if this can be established) whether or not there were any corresponding gains or losses in general economic welfare. The assessment presented here indicates that in these terms the X2000 procurement was for the most part successful.

The negative judgements given above can be qualified by an historical perspective. The X2000 case was far from a complete failure. Although the train itself did not prove to be a success on export markets, its development did result in significant improvements to the 'system competence' (i.e., capacity to design, build and maintain entire technical systems) of the supplier firm, AD Tranz (formerly ASEA). In this respect, it improved the firm's competitiveness. Moreover, the X2000 design incorporated some important technical innovations which have since been transferred to other, more successful, commercial applications. In what follows, we develop this perspective more fully and end our discussion by drawing some general conclusions and policy implications.

1. INDUSTRIAL POLICY

Although the X2000 procurement can be considered, overall, to have been a 'partial failure' in terms of innovation policy, it can be deemed to have been at least a 'limited success' in terms of industrial policy. There is general consensus among informed sources that the X2000 procurement improved the competitiveness of ASEA (now AD Tranz). This is certainly true so far as the development of the supplier firm's competences is concerned.

Historically, state railway companies (i.e., railway operators) in Europe have held the overall 'system competence' with respect to railway equipment. 'System competence', in this context, means the capacity not only to design but also to assemble and maintain or guarantee the operation of entire rail transportation systems. In contrast to the state railway companies, railway equipment manufacturers have tended to have only more limited – i.e., specialised – technical competences. That is, they have dealt primarily with the development of specific components for rail systems, and not with the systems as such. Yet at the end of the procurement process for the X2000 – the terms

[1] The train later sold by AD Tranz to Norway was a motor coach version of X2000 (Agerberg, 1996b: 44). So was the train sold more recently — in August, 1997 — by AD Tranz for operation on the future bridge now under construction between Malmö, Sweden, and Copenhagen, Denmark.

of which required the supplier to demonstrate such a capacity – ASEA (now AD Tranz) had acquired this kind of system competence (L. Pålsson, 1997, interview). In this respect, the competitiveness of the supplier was greatly enhanced (B. Andersson, 1997, interview; J. Lundgren, 1997, interview).

The acquisition of 'system competence' was particularly vital to the continuing survival and commercial success of the supplier, given that there is now a definite trend – in Sweden as elsewhere – toward deregulation and privatisation of the rail transport sector (B. Andersson, 1997, interview). This trend implies that equipment suppliers will have the primary responsibility for designing and maintaining entire systems in the future (J. Lundgren, 1997, interview; R. Persson, 1997, interview). Another implication is that there will be more operators and fewer suppliers of railway equipment, so that emerging 'system problems' within the sector will have to be addressed first by suppliers (Nilsson & Wallner, 1993). These aspects of restructuring in the rail transport sector have made the acquisition of 'system competences' crucial to firms like AD Tranz (formerly ASEA).

For these reasons, an important part of the story of the X2000 procurement process concerns the transfer of 'system competences' from SJ to ASEA. While the transfer was more or less successful, it was not without its problems. On balance, it can be regarded as illustrating both the strengths and the weaknesses of the conventional 'Swedish model' of public technology procurement, in which 'development pairs' such as SJ-ASEA have played a prominent part (Fridlund, 1993). As this case study shows, one of the strengths is the ability of development pairs to develop a high level of competence through interactive learning between buyer and supplier, even when both begin from a position of relatively low competence. However, one of the weaknesses is the inordinately long periods of time that may be needed to accomplish this. In this case, the competence of SJ remained problematic, even after a formal procurement process had been initiated. During this process, almost all functional requirements were altered (Flink & Hultén, 1990: 21). This would not have occurred if SJ had possessed the required competence in HST technology at the outset. The fact that SJ was slow to acquire this specialised technical competence had serious consequences, not only for ASEA, but also for Sweden. Arguably, the X2000 could have had greater success on export markets if procurement of a Swedish HST could have been accomplished more quickly.

There are reasons to believe that in the development of the X2000 the Swedish state railway company, SJ, might have had a preference for working with ASEA (now AD Tranz) because it was a Swedish firm. Part of SJ's traditional mandate was to 'care about' Swedish industry (E. Andersson, 1997, interview; A. Hörberg, 1997, interview). This meant caring about ASEA, since the Swedish market for railway equipment was characterised not only by buyer monopsony (SJ) but also by producer monopoly (ASEA) (Flink and Hultén, 1990; 1993). This situation – and the long history of 'collegial' relations and shared 'tacit knowledge' between SJ and ASEA that it entailed – gave ASEA certain competitive advantages in bidding on the X2000 procurement (E. Andersson, 1997, interview; A. Hörberg, 1997, interview). It may also have deterred serious competition from outside of Sweden (L. Pålsson, 1997, interview).

Moreover, the decision criteria of the first investigation into the possibilities of a Swedish HST gave priority to the development of domestic industry (SJ, 1969: 163).

Thus, it is not hard to discern some kind of protectionism in the initial phase of the procurement. Although at a later point the entire process of bidding and negotiation was open to foreign firms (J. Lundgren, 1997, interview; R. Persson, 1997, interview) and SJ was careful to evaluate all offers in 'a particularly honest way' (L. Pålsson, 1997, interview), there appears to have been lingering suspicion among potential foreign suppliers that 'they could not receive fair judgement' (A. Hörberg, 1997, interview). In other words, they were concerned that SJ's evaluation of tenders would be influenced by covert protectionism favouring the 'national' firm.

'Protectionism', however, does not fully account for SJ's highly 'professional' handling of the X2000 procurement through several rounds of bidding and procurement occurring between the first tender request in 1982 and the final contract negotiations in summer, 1986 (Flink and Hultén, 1990; Gunnarson, 1994; J. Lundgren, 1997, interview; Pålsson, 1987:8 - 10). In that process, a tender from at least one foreign supplier was apparently accepted and considered as an alternative to ASEA's offer even during the second round of bidding (B. Andersson, 1997, interview; E. Andersson, 1997, interview; R. Persson, 1997, interview; L. Pålsson, 1997, interview). This suggests that foreign competitors to ASEA *were* considered seriously.

Certainly, the legal and formal institutional context in which the procurement was carried out worked against protectionism. The law under which the procurement was conducted stressed the exclusivity of business criteria as the sole basis for evaluating tenders (SFS 1973:600, 1973). The law, which was scrupulously observed, emphasised openness, transparency and accountability in tendering and contracting procedures, and it insisted upon maintaining a 'competitive environment' (Linder, 1996: 13 - 14). Moreover, and not least importantly, SJ itself was never fully committed to a 'protectionist' solution – i.e., choosing a Swedish supplier in all cases and at any cost. SJ's first investigation of the options to acquire a high speed train ruled out *both* procurement of a complete train from abroad *and* procurement of a train originating from strictly domestic design, development and manufacturing (SJ, 1969: 163). The latter option was initially rejected because of the length of time expected. That it was later accepted and acted upon may have had less to do with 'protectionist' impulses on the part of SJ than with a reappraisal of ASEA's improving competence (R. Persson, 1997, interview). It may have had even more to do with SJ's attempts to remedy its own lack of competence.

SJ recognised, early on, that it would have to improve its own knowledge regarding high speed train systems and their various components in order to act as a competent procurer of high speed trains (SJ 1969: 171; A. Hörberg, 1997, interview; J. Lundgren, 1997, interview; R. Persson, 1997, interview). This thinking was in line with the responsibilities conventionally assumed by state railway companies for developing and maintaining 'system competence' (Flink and Hultén, 1990: 21; Pålsson, 1987: 3 - 7). The rationale was also consistent with the logic of 'best practice' in private technology procurement, where no 'political considerations' normally apply. In that context, too, effective procurement of new technology requires effective 'demand pull', and buyers must be not only strong enough to 'articulate demand' forcefully but also competent enough to make the correct demands. In this connection it has been noted that most potential suppliers were sceptical of SJ's competence (A. Hörberg, 1997, interview).

For these reasons, there was an imperative – not only in terms of 'industrial policy' but also in terms of 'innovation policy' – for SJ to develop its own lagging technological competence. There were limited options for doing this within Sweden, given the highly concentrated structure (monopsony/monopoly) of the Swedish market for railway equipment. Moreover, it is likely that SJ would have suffered serious disadvantages in trying to enhance its own knowledge by co-operating with foreign suppliers possessing technical expertise superior to its own. Under 'low trust' conditions, SJ would have had to pay a high price for the acquisition of competence from sources that it could have demanded little accountability from. Additionally, SJ might never have been able to develop truly superior expertise vis-á-vis potential suppliers. In the event of a formal bidding process, then, SJ would have remained unable to evaluate the offers thoroughly enough to arrive at the most rational decision regarding the award of a contract. It was therefore 'natural' for SJ to turn to ASEA as a development partner for the mutual upgrading of 'system competences' essential for the development of a high speed train. This was one main object of the lengthy collaboration between SJ and ASEA during the early and mid-1970s (Andersson, 1983; Flink, 1992; Flink and Hultén, 1993; Gunnarsson, 1994).

The actual procurement of the X2000 experienced a long delay while SJ (together with ASEA) endeavoured to raise its level of competence to a level where SJ (and, presumably, ASEA) could participate credibly in a high speed train procurement process open to foreign bidders and aimed at the development of a technologically advanced high speed train. SJ first expressed interest in acquiring a high speed train in 1968 - 1969, but it spent the subsequent ten years improving its knowledge of high speed train technology in collaboration with ASEA, through development projects such as the X15 prototype (Flink, 1992; Gunnarsson, 1994).

In 1975, when the X15 project had been completed, the Swedish parliament passed a Bill for the speedy introduction of high speed trains (Flink, 1992). But SJ did not respond by trying to secure financing for such a project (E. Andersson, 1997, interview). Instead, its response was to undertake further preliminary investigations (SJ, 1980). Acquiring sufficient 'buyer competence' to procure a high speed train from a position of strength appears to have been a continuing concern for SJ. Conversely, SJ's reason for further delay is not likely to have been that it was concerned with the basic competence of potential suppliers.

The basic capability to build a high speed train existed in Sweden by 1975, due to the completion of the X15 project. It would also have been possible at this time to obtain from a foreign supplier a high speed train that fulfilled most of SJ's initial (1969) functional requirements – such a train, the Pendolino, had already been developed and came into full operation in 1976 (Agerberg, 1996a; Giuntini, 1993). However, even after 1981, when SJ received the necessary 'political support' for procuring the X2000 through a government decision to acquire and finance a fleet of high speed trains (Flink and Hultén, 1993: 98), SJ was still in the process of acquiring the necessary 'critical competence' to act effectively in procuring a high speed train (R. Persson, 1997, interview). Thus, for example, the X2 study was conducted by SJ in 1982, in order to test and develop newly acquired expertise in digital technology, control engineering and the techniques of 'Life-Cycle-Costing' (LCC) analysis to be used in the evaluation of alternative HST systems

(J. Lundgren, 1997, interview; Pålsson, 1987: 3 - 7). For its part, SJ is reported to have remained concerned at that time about the competence of ASEA (Flink and Hultén, 1990; A. Hörberg, interview) – with whom it was still collaborating as late as 1982.

Even after the X2 study had been completed and the formal bidding process for procurement of the X2000 had been initiated in 1982, the procurement remained a 'learning process' for SJ (B. Andersson, 1997, interview; A. Hörberg, 1997, interview). Nearly all functional requirements were changed during the bidding process, indicating that SJ did not initially have the competence required (Flink and Hultén, 1990: 21). Thus, one way of interpreting the result of the first round of bidding, where no suppliers were found capable of fulfilling SJ's functional requirements (Pålsson, 1987: 9), is to consider that SJ may not have been able at first to propose 'realistic' requirements. This problem took some years to remedy, and apparently was only resolved in 1985, when SJ sent out its supplementary request to the second invitation for tenders (Flink and Hultén, 1990: 21; Pålsson, 1987: 10). Subsequently ASEA (now AD Tranz) was awarded the contract in summer, 1986, and final contract negotiations were initiated (J. Lundgren, 1997, interview).

ASEA was clearly one of the main beneficiaries of SJ's learning, in much of which it had been a joint participant. Collaborative learning was most pronounced in the 1970s, when SJ and ASEA jointly developed and tested a tilting mechanism and 'soft bogie' and – later – the X15 train (Flink, 1992; Flink and Hultén, 1993; Gunnarsson, 1994). At this time, ASEA began to acquire extensive 'tacit knowledge' of SJ's requirements for a high speed train (E. Andersson, 1997, interview). Even at the outset of the procurement process that began in 1981 - 1982, ASEA and SJ continued to develop knowledge on a joint basis, and to share technical resources. For example, during the period when the X2 study was being conducted, SJ recognised, as a consequence of the study, that it lacked the necessary competence in digital control engineering (J. Lundgren, 1997, interview). SJ then hired a consultant expert in digital technology – who was subsequently hired by ASEA "in the last minute" before procurement (ibid.).

Once formal bidding on the X2000 procurement began in earnest in 1982, the formerly 'collegial' relationship between ASEA and SJ gave way to a more distanced kind of relationship. This shift in relations was a matter of policy for SJ, which was under political pressure to exhibit an arm's-length stance towards ASEA in order to develop credibility with potential foreign suppliers bidding on the X2000 procurement (J. Lundgren, 1997, interview; R. Persson, 1997, interview). The change in relations was accompanied by the requirement for LCC costing in all bids submitted on the X2000 procurement (Flink and Hultén, 1993: 98). Although SJ had developed knowledge and expertise in LCC analysis, it had not shared this competence with ASEA. Even in this context, however, SJ could be seen to have encouraged the development of ASEA by 'formalising professionalism', prompting the firm to acquire an important basis of 'competitive advantage', and instilling 'systems thinking' in ASEA (R. Persson, 1997, interview; Pålsson, 1987: 12).

Finally, even once it came to an end with the initiation of bidding, the earlier 'collegiality' between SJ and ASEA still had a continuing value for ASEA. While SJ was very strict in treating the procurement process as an open competition and was scrupulous about answering all requests for information, its reluctance to visit potential tenderers in order to explain its request probably favoured ASEA over other bidders (Pålsson, 1987: 8). Given that it had previously accumulated a large stock of 'tacit knowledge' about SJ's requirements, ASEA would have been able to understand SJ's request more fully than most, if not all, other tenderers (B. Andersson, 1997, interview; Andersson, 1983; R. Persson, 1997, interview).

A significant result of the X2000 procurement process was that ASEA developed full fledged 'system competence' as a designer and manufacturer of railway equipment (L. Pålsson, 1997, interview). SJ's fundamental requirement in this procurement was that the supplier could design, make, deliver and guarantee in all details the reliability of an entire system (J. Lundgren, 1997, interview; Pålsson, 1987: 3). ASEA (now AD Tranz) succeeded in meeting this requirement. Its accomplishment is encapsulated in the remark that "what SJ required in 1982 is what AD Tranz is just about able to accomplish today" (R. Persson, 1997, interview).

As mentioned earlier, it turned out that the 'system competences' developed by ASEA (now AD Tranz) were fairly specialised in terms of market suitability. However, this might not necessarily have represented a great competitive drawback for the firm. The fragmentary structure of the international 'market for trains' leads to regionally specialised demands for 'tailor-made' solutions (Agerberg, 1996a: 13; Agerberg, 1996b: 45; J. Lundgren, 1997, interview). Subsequent sales to Norway – and, more recently, to the Malmö-Copenhagen bridge project – of a motor-coach variant of the X2000 suggest that AD Tranz (formerly ASEA) was at least able to compete in a 'regionalised' international market (Agerberg, 1996b: 44).

The fact remains, however, that – as further discussed in the next section – the X2000 design as a whole (a single-locomotive, tiltable, high speed train) has proven to have little if any potential for export. In this sense, it can be said to have 'lost out' in the international technology competition to develop high speed trains. The X2000's lack of commercial success beyond Sweden has meant that the world market impact of this innovation has been effectively limited to alternative applications of the innovative subsystems or components incorporated into the original product design (Flink and Hultén, 1993: 96; Gunnarsson, 1994; R. Persson, 1997, interview). These might have helped to establish a competitive position for AD Tranz (formerly ASEA), (J. Lundgren, 1997, interview). However, ABB's recent sale of its part of AD Tranz to Daimler-Chrysler implies that few such benefits are now likely to accrue to Sweden.

In sum, the joint development and 'transfer' of competence between SJ and ASEA can be considered to have improved the competitiveness of AD Tranz (formerly ASEA). There is consensus among informed sources that this has been the case. However, to the extent that exports are an indicator of competitiveness, the positive impact was not all that large. In this respect, and others (discussed below), the procurement of the X2000 may be regarded as having had only very partial success as 'industrial policy'. The question remaining is whether it would have enjoyed greater success – and perhaps also succeeded as 'innovation policy' – if the procurement of a Swedish HST could have been accomplished more quickly. The crucial problem in this regard appears to have been one of competence – not just that of ASEA, but also and more fundamentally, that of SJ. We will return to this question and a discussion of the trade-off between 'timing' and 'competence' in drawing conclusions and policy implications.

2. INNOVATION POLICY

The procurement of the X2000 did not fundamentally alter the direction of technical change in rail transport, and it resulted in only minor increases in technical diversity. The X2000 was not the first high speed train to be developed, nor has it come to be widely used outside of Sweden. On the whole, then, SJ's procurement of the X2000 from ASEA (now AD Tranz) must be regarded as a case of 'adaptive public technology procurement' rather than 'developmental public technology procurement'. There is a fundamental distinction between the former, 'diffusion-oriented', kind of public technology procurement, and the latter, 'creation-oriented', kind. In the latter, new products, processes or systems are created. In the former, the product or system procured is not new to the world but only to the country of procurement.

In the analysis of cases of adaptive public technology procurement, emphasis is placed on the fact that the system needs adaptation to local circumstances – not simply that it is new to the country. This adaptation may or may not bring about true 'branchings' in the development of existing technologies. In cases where this does occur, however, the buyer – and more broadly, the country that the buyer as a public or government agency represents – has the possibility of realising certain economic benefits and advantages.

Early adoption of an emerging technology can contribute to broader processes of economic growth and technical development. At a later stage of development, the further adaptation of the technology to local conditions can still involve real technological innovation and generate substantial economic benefits. Successful adaptation of this kind, however, requires exceptional capabilities for 'collective learning' and a strong bargaining position with suppliers. If buyers can meet these conditions, they can obtain favourable prices from suppliers and a leading position among competitor nations, due to improved infrastructure. And, if their timing is appropriate, they may also share in innovation 'rents' from the sale of the (adapted) technology to other national buyers occupying the same market segment.

By the standards outlined above, the X2000 was neither a complete success nor a complete failure. This evaluation is elaborated below.

As an adaptation, the X2000 did represent a diversification of high speed train technology – the design was in some respects unique and it incorporated some innovative components. The X2000 also met national requirements more or less successfully. It thus resulted in significant improvements to infrastructure – and, hence, the conditions for economic growth.[2]

[2] The actual contribution to economic welfare remains difficult to establish, given insufficient data, but see the discussion that follows this appraisal of the X2000 as a technical innovation.

Certain components of the X2000's design were new, or at least original, technological solutions to enduring problems in the development of high speed train technology. This was particularly true of the 'soft bogie' developed by ASEA on the basis of earlier collaboration with SJ (Gunnarson, 1994) – which, in and of itself, could be regarded as having constituted a successful case of developmental, or 'creation-oriented' public technology procurement. This innovation was transferred to other commercial applications, as well as being combined in the X2000 with supporting innovations from other sources – such as the specialised computer technology developed to control the tilting mechanism and the GTO-thyristor which made the asynchronous engine feasible (Flink and Hultén, 1993: 96). These developments represented 'a series of large, innovative steps' with considerable commercial potential (J. Lundgren, 1997, interview; L. Pålsson, 1997, interview).

For the above reasons, the X2000 should not be dismissed in terms of its innovative value. Rather than simply characterising it as an unspectacular case of 'incremental innovation' (refinement of an existing technology), it may be more appropriate to regard the X2000 as exemplifying 'modular innovation' (new technology in a familiar context) (Abernathy & Clark, 1985). At a subsystem level – e.g., the 'soft bogie' and its use in combination with supporting components – the X2000 could also be said to have entailed 'configurative innovation', which has at least the potential to generate new dominant designs (Hidefjäll, 1997: 43).

From its lack of success on export markets, it is clear that the X2000 failed to establish a new 'dominant design' – the single-locomotive, tiltable, high speed train – in the international market for high speed trains. Instead, as indicated in the introduction, the main demand in this market has been for 'motor-coach' designs, and as reiterated in the preceding section, all export sales of the X2000 have been for a motor-coach variant, not the original design. In this sense, the original X2000 'lost' a technology competition. In so-called 'technology-competitions' markets tend to 'lock in' on one of several options in technology, due to positive feedback effects of initially influential choices (Arthur, 1988; Foray, 1989). However, as the case of the X2000 demonstrates, it remains important to consider the nature and extent of the competition.

We have noted that, as with railway equipment in general, there is no true 'world market' for high speed trains. Rather, there is a very fragmented and diverse market consisting of a series of national or regional markets that are essentially 'custom' markets demanding 'tailor-made' systems (Agerberg, 1996a: 13; Agerberg, 1996b: 45; J. Lundgren, 1997, interview). Thus, even though the Italian Pendolino out-competed the X2000 in parts of Europe and may thus be considered to have 'won' a limited technology competition (R. Persson, 1997, interview), this competitor still appears to have fallen well short of establishing a new 'dominant design'. For example, an altogether different competitor – the Canadian firm, Bombardier – managed to secure a significant part of the largest North American market (Agerberg, 1996a: 12 - 13: Agerberg, 1996b: 45). Accordingly, the fact that the X2000 'failed' in past competitions with the Pendolino did not necessarily imply that it would lose in future competitions (B. Andersson, B., 1997, interview; E. Andersson, 1997, interview; A. Hörberg, SJ, 1997, interview). Given the nature of the market, all such competitions are 'limited' and some might well favour the X2000 or its descendants.

In addition to the above mentioned characteristics of the 'market for trains', there is also an apparent trend towards increasingly fragmented national markets (B. Andersson, 1997, interview). In these markets the manufacturers of trains and railway equipment will be required to assume a much greater share of the responsibility for designing, delivering and maintaining – perhaps even operating – entire systems (J. Lundgren, 1997, interview; Nilsson and Wallner, 1993; R. Persson, 1997, interview).

In this context, it may be particularly significant that the X2000 was fairly successful in meeting national requirements. The X2000 may also be considered to have been at least a partial success in terms of winning national markets within its region – despite significant differences in national requirements within the region. The recent sale of a motor-coach version of the X2000 to Norway is reported to have been for a 'completely different' train (R. Persson, 1997, interview). This might nevertheless indicate that the excessive customisation that may have prevented the X-2000 from capturing markets elsewhere in Europe (ibid.) could also have been a source of regional advantage. That is, the high degree of customisation involved might have enabled the supplier to develop a design well suited to its own region, as well as the capability to modify this design (or to develop others) for specialised national markets.

In addition to the commercial viability of the X2000 on export markets, the question of whether genuine societal needs were met should also be considered as a criterion for evaluating the X2000's successfulness as an innovation at the national level. These criteria will be considered in more detail below. Here, we will only refer briefly to the estimations of possible societal benefits that formed part of the second (1980) investigation into the costs and benefits of building a Swedish high speed train (SJ, 1980: 9). The investigation projected socio-economic benefits due to decreased travel time of around 300 million SEK/year, decreased energy consumption on the roads resulting in savings of about 30 million SEK/year, plus additional improvements to social conditions and savings in infrastructure costs also related to decreased use of automobiles (ibid.). It has not been possible to ascertain whether all of these projected benefits have been realised, but they would not have had to have been met completely in order for one year's societal 'savings' to compensate for the actual development cost of the X2000, which turned out to be about twice the originally quoted figure of 100 million SEK (E. Andersson, 1997, interview). This does not take into account the benefits (versus costs) for either SJ or ASEA, which will be addressed subsequently.

A final issue for consideration is that of whether or not the procurement of the X2000 increased the speed of high speed train development. Formulating an answer to this question depends on the frame of reference. From an international standpoint, the answer is probably 'no'. Indeed, from an 'outsider's' perspective, it even appears that the pace of technological development may actually have been slowed down within Sweden, given the length of time it took to produce the X2000 after the X15 had already been developed and the first generation Pendolino had come into operation.

From a national viewpoint, however, the answer to this question may be different. The question might be restated as follows: Would SJ have saved time by buying the Pendolino? It is not clear that this would have been the case. Buying the Pendolino for use in Sweden would have involved an extensive adaptation of the existing design to local conditions, including differences in the electrical power supply that would have required, among other things, a major redesign of the train's propulsion system (E. Andersson, 1997, interview; R. Persson, 1997, interview).

Related to these technical considerations, there is a fundamental issue of cost – or, to be more precise, uncertainty about cost. Assuming that the Pendolino could be successfully adapted to Swedish conditions, could this have been done for a substantially lower cost than developing a Swedish train? We can not answer this question on the basis of the available data. We have, however, reviewed extensive evidence concerning the procurer's lack of adequate competence until a very late point in time. Given these circumstances, it is arguably the case that SJ was unable to make a proper evaluation of the costs until the time that the procurement process was formally initiated, and possibly for some time afterwards. Under these conditions, it would have been rational for SJ to minimise uncertainty by preferring a 'known' supplier with whom a relationship of 'trust' had been established. This point was also made in the preceding section.

3. COSTS, BENEFITS & PROFITS

We will now consider the strictly economic costs and benefits for SJ and ASEA – and Sweden. If it did not succeed entirely at the level of innovation policy, the X2000 procurement was at least minimally successful at the level of industrial policy. This procurement was effective in extending the life of a nationally based industry and enhancing the competitiveness of the leading national firm in that industry – even though it did not lead directly to export sales. But at what cost – or profit – to the procurer was this accomplished? What was the extent of the economic benefit to the supplier? And what losses or gains were there for Sweden as a whole?

3.1 Societal and Industrial Results

In the investigation of 1969, several calculations were made. A Swedish express train set of 1969 was running about 275,000 km a year or about 750 km a day. This is the same as today since not much has happened regarding the speed for express trains (SJ, 1969: 158).

If a high speed train was going to be used 300 days a year, it would probably have reached a usage of 600,000 km a year or about 1,600 km a day. This increased production capability of each train set would have allowed SJ to diminish the size of the train sets and increase the frequency of departures with a constant demand (SJ, 1969: 158).

An express train has a capacity of 450 passengers, while the predicted high speed train would have carried 200-250 passengers. The investigators also thought that this would require less personnel, since a high speed train only would require a crew of two persons, while an express train needs a crew of 4 persons. Therefore they thought, in the investigation of 1969, that if the current train sets were replaced by the same number of high speed trains astonishing results would emerge:

- the same number of passengers could be transported.
- the travel time could be cut to 50%.
- the frequency of the departures could be doubled.
- the need for personnel could be reduced to 50%.

(SJ, 1969: 158)

The investigation of 1980 did not make calculations similar to those above, but the travel time in 1980 was about the same as in 1969 (SJ, 1980: 23). SJ made corresponding calculations, to which we do not have access. However, we think that the above discussion was of relevance in 1980 as well, since actually not much had happened since 1969 with regard to travel time and maximum speed.

3.2 The Cost

Each train, consisting of five coaches and one locomotive, of X2000 that ASEA started to deliver to SJ in 1990, had a cost of about 100 millions SEK (Agerberg 1996: 16). The final sum of the contract in 1986 was about 1,5 billion SEK (Pålsson, 1987: 3). SJ bought 20 trains in 1986 and have by now had a total of 43 trains delivered. The first 20 trains were used on major passenger routes. The remaining 23 trains were used on routes supported by rural cities and regions (B. Andersson, 1997, interview).

3.3 Benefits & Profits

As the high speed train reduces travel time between cities, the real time distance decreases. Round trips to neighbouring cities that it was formerly not possible to make within one day are now possible. In Japan this has allocated business activities to other cities than Tokyo. It has furthermore enhanced business activities between cities and led to overall economic growth as well. For the hotel industry in places that have become closer to Tokyo in real time distance, the impact of the 'Shinkansen' in this respect has meant fewer guests, since it is not necessary to stay over night any more (Hultgren, 1981: 6).

We are unable to determine whether the X2000 has had similar effects in Sweden. However, such effects would be plausible.

There are some indications that the X2000 has enabled the procurer, SJ, to compete successfully with air and highway transportation. Between Stockholm and Gothenburg – the first and second largest cities in Sweden, respectively – the X2000 has reduced journey times by 25 per cent. This gain in efficiency has "increased rail's market share on the 285-mile route from 41 to 55 per cent" (Batchelor, 1996).

It appears, then, that at least on major routes the X2000 has met the expectations of SJ. By doing so, moreover, it will also have realised to some extent the societal benefits projected by the second (1980) investigation into high speed trains. These included not only increased commercial profitability for SJ but also reduced infrastructure costs for the building of roads and traffic routes, lower energy consumption costs from decreased use of automobiles, benefits due to shorter travel times, and reduced costs in terms of the accidents and pollution caused by highway traffic (SJ, 1980: 9). However, we can not quantify the extent of these benefits on the basis of data currently available.

It is hard to determine whether the X2000 project as a whole has been profitable for AD Tranz (formerly ASEA). However, according to Bernt Andersson, ASEA did not make any profit on the first 20 trains and, at best, the total was probably break even (B. Andersson, 1997, interview). Despite this, it has been important for AD Tranz from a strategic point of view. As argued previously, the X2000 project enhanced the general level of competence at AD Tranz (E. Andersson, 1997, interview).

4. MAIN CONCLUSIONS

In our introduction, we suggested that the procurement of the X2000 was not altogether successful as an instrument of industrial policy, due to the train's failure to win export markets. We also suggested that the X2000 was not a particularly successful example of innovation policy, since it resulted in little or no radical change to the speed or direction of technical change. Subsequently, we have reviewed evidence and arguments to support these statements. Here, we will offer further conclusions that follow from salient features of the case.

An important inference that can be drawn from the history of the train's development and its consequences concerns the management of the procurement process. It is a plausible interpretation of the evidence that the requirement of SJ that X2000 should be a locomotive-drawn train pushed the supplier, ASEA (now AD Tranz), into a dead-end street. In other words, the demand from SJ was perhaps not appropriate or visionary enough to function well as industrial policy. Although the new motor- coach version of the rapid train is partly designed on the basis of experience with the X2000, the locomotive requirement might, at the same time, have delayed the development of the motor coach. It might have been better if SJ had been looking more closely at the Pendolino design at the outset of the procurement.

One of the main problems faced by the X2000 in capturing a significant share of export markets for high speed trains was simply that of timing. The X2000 was a very late arrival to the international 'market for high speed trains', and fared poorly. In contrast, the competitor to which the X2000 lost possible foreign sales most consistently – the Pendolino – was one of the early arrivals. It is reasonable to consider that the greater success of the Pendolino may have been due, in large part, to better timing – i.e., earlier development of a viable, marketable train.

There is, of course, a counter-argument to this position. It has been explored at some length here. According to this counter-argument, the failure of the X2000 to gain export sales in Europe and elsewhere can be attributed largely to the highly fragmented and nationally or regionally divided nature of existing markets for railway equipment.

There is no true 'world market' for high speed (or other) trains – only a series of 'custom' markets, the differences among which are often exacerbated by political conditions. For these reasons, the counter-argument holds, the X2000 can not be considered to have lost a truly international technology competition. Moreover, the X2000 proved the supplier's competence as a 'custom' manufacturer of high speed trains. The manufacturer, if not the train, subsequently began to make foreign sales, and will likely continue to do so.

This counter-argument, however, ignores the fact that the X2000 usually lost export markets to the Pendolino. This is particularly true of competition within Europe. Thus, it appears that, at least in Europe, a 'bandwagon' was formed around the Pendolino and not around the X2000. This would not be possible in a completely fragmented European market. For this reason, the counter-argument is not fully convincing. Additional explanations must be sought, and of the other possible explanations available, the one concerning 'timing' is the most powerful.

In the preceding discussion we identified late development as a main flaw of the X2000, in terms of both innovation and industrial policy. We also referred to the theoretical argument, made elsewhere, that adaptive public technology procurement can alter the diversity, direction or pace of technological change. To do so, it must be conducted by a 'buyer' that is capable of developing exceptional competence through learning – thereby becoming able to deal with 'suppliers' from a position of strength. If the buying agency, moreover, can exercise good timing, both the public agency and the country it represents may also be able to benefit from subsequent sales of the (innovatively adapted) technology in other countries. Under these conditions, adaptive public technology procurement can achieve successes both in terms of innovation policy and in terms of industrial policy.

These conditions were not met in Sweden, with the result that the X2000 procurement can not be regarded as a 'success story'. As we pointed out above, it seems from an international perspective that the X2000 procurement actually slowed down the pace of technological development in Sweden, instead of speeding it up. Earlier, in our discussion of industrial policy, we reviewed extensive evidence indicating that one of the main causes of this effect was the initially low competence level of SJ, the state railway company, and the length of time it took for SJ to raise its competence to a level where it could function effectively as the 'buyer' in procuring a high speed train for Sweden. We returned to this theme in the discussion of innovation policy, when considering the poor export performance of the X2000. We have suggested, throughout, that in the case of the X2000 procurement there had been a trade-off between 'timing' (earlier development, increasing the probability of greater success on export markets) and 'competence' (in particular, the competence of SJ).

Closer scrutiny of the available evidence indicates that SJ executives involved in the procurement of the X2000 were quite conscious of this trade-off. From the mid-sixties onwards, SJ was aware that it was under considerable economic pressure to acquire a high speed train (Flink and Hultén, 1993), and the leadership of SJ contributed on several occasions to increasing the political pressure to make such an acquisition (Flink, 1992). Despite this, the development process headed by SJ before the procurement was initiated, as well as SJ's actual procurement of the X2000, proceeded very cautiously and slowly. SJ was concerned from the outset to acquire and demonstrate to potential suppliers 'a certain critical competence', and it remained unable to do this satisfactorily until the very late stages of the procurement process. After SJ became fully capable of 'matching' its functional requirements with the technical capabilities of potential suppliers, the procurement proceeded smoothly. However its conclusion had suffered a lengthy delay, even in terms of the schedule that SJ had originally set for itself (SJ, 1980: 25).

5. POLICY IMPLICATIONS

The evidence suggests that an insufficiently high level of 'user competence' was one of the primary reasons for the poor 'timing' of the X2000. What, then, are the main policy implications to be drawn? We can begin to answer this question by first considering the orthodox view.

According to this prevailing wisdom, the main problem with public technology procurement as it has been conventionally practised in most countries is that government involvement has tended, for political reasons, to interfere unduly with the operation of market forces. The main remedy, as conceived and enacted by the EU, has been to institutionalise in the legal and administrative regime governing public procurement a 'free market' orientation, based on classical economic efficiency principles and emphasising the exclusive priority of commercial criteria in the awarding of contracts (Martin, 1996: 41).

The stated goals of the EU policy regarding public procurement, including public technology procurement, have been not only to broaden competition and thereby achieve public savings, but also to bring about restructuring and adjustment leading to economic growth. The policy has sought to eliminate protectionist procurement practices on the part of public agencies with monopsonistic powers within nationally 'closed' sectors such as rail transport. Such practices were considered, in analyses that informed the current EU policy, to have resulted in supply-side overcapacity, an excessive number of firms, the duplication of research and marketing efforts, and inadequate scales of production. The solution recommended (and since attempted) in order to meet the challenges of increasing international competition, was (and remains) to create "viable producers" in Europe by widening competition. It is expected that more open competition will both enable and encourage existing firms "to merge, rationalise and invest in new technology" (WS Atkins Management Consultants & Associates, 1988: 14 - 15).

The orthodox view, it can be seen, focuses primarily on the supply side. Insofar as it is concerned with issues of competence it addresses only questions about producer competence. With respect to the demand side, there is only a preoccupation with opening markets and increasing the extent of demand. This is a perspective that takes little real account of user competence. Its main prescription, in the case of Sweden's acquisition of a high speed train, would have been for SJ to purchase an existing high speed train at the best possible price, as soon as possible.

We considered this proposition, when we posed the question, 'Would SJ have saved time by buying the Pendolino?'. Reviewing the evidence indicating that a major overhaul of the Pendolino would be required in order to adapt it to use in Sweden, we could not state that the answer to this question was a definite 'yes'.

We also drew attention to the issue of cost. Assuming that an adaptation of the Pendolino to Swedish conditions could have been made within a shorter period of time than it required SJ to take delivery of the X2000, would it also have cost less to buy the Pendolino? Our answer to this supplementary question was that SJ, because of its lagging technological competence, was in no position to know whether this would have been the case or not. There is ample documentation to show that, at least until a very late stage in the procurement process, SJ found itself unable to evaluate properly the costs, benefits, capabilities, and inadequacies of the Pendolino and, for this reason, felt itself to be at a considerable disadvantage in negotiating a contract with its producers.

During its procurement of the X2000, SJ was subject to a procurement regime similar in its essential features to that now in force in Sweden as a member state of the EU. SJ also acceded to political pressures to 'widen competition' to an international level. Yet SJ still confronted a fundamental problem of uncertainty due to insufficient knowledge. SJ remedied this problem by building upon a relationship of trust with a known domestic supplier, which it enlisted as a 'development partner' in acquiring the needed competence. This was a lengthy and difficult process and its eventual outcome was that the domestic supplier gained considerable competitive advantage over foreign rivals and, largely for this reason, won the procurement contract from SJ.

In this case, then, the simple 'widening of competition' provided no immediate solution to the fundamental problem of developing a sufficiently high level of 'user competence'. It is also questionable whether the current trends towards deregulation and privatisation in the rail transport sector will, over the longer term, result in a restructuring of the supply and demand side of 'the market for trains' that would eventually mitigate problems of 'user competence' such as those which held back development of the X2000. The apparent trend is towards consolidation and concentration of equipment manufacturers on the supply side of the market, and a proliferation of smaller-scale railway operators on the demand side. 'System competence' will no longer be held by the users, but rather by the producers. This is a potentially very negative scenario for the future of innovation in rail transport. As observed elsewhere, in markets dominated by producers there is a strong tendency towards "unsatisfactory innovations" arising out of deviation away from user needs in innovative activities that are producer-led (Freeman, 1982; Lundvall, 1988).

This possible trajectory of development would contribute to an emergent overall 'system problem' in the railway industry. Mainstream economic analysis does not fully recognise or appreciate all of the dimensions of such problems, including the one which is most fundamental from a Systems of Innovation perspective – namely, the *quality* of demand (Lundvall, 1988). Addressing this problem effectively in cases where users are dominated by producers and possess little capability to articulate their needs forcefully or well enough requires some form of public intervention, direct or indirect, aimed at establishing or restructuring user-producer relationships. Somewhat ironically, therefore, the current trend to institutionalise a 'free market' orientation in public procurement and elsewhere, which has been justified in part by arguments about 'non-market' barriers to innovation, may, over the longer term, generate strong demands for public intervention, justified by arguments about 'market-based' barriers to innovation. In the case of rail transport (and similar sectors) in Europe, however, the level of public intervention required may well be supra-national, rather than national.

If the EU finds itself called upon to restructure the demand side of the rail transport sector, the type of solution required might well be that of overcoming a 'low level equilibrium trap' by constituting a focal organisation capable of (re)creating an organised market through the development of an appropriate form of vertical linkage between users and producers (Teubal, Yinnon, & Zuscovitch, 1991). In that (admittedly hypothetical) case, the main focus of public activity would not be to consolidate demand by acting as an end-user, but rather to resolve the co-ordination problems involved in market creation by organising and, to some extent, leading existing end-users. This would involve an organisation or articulation of demand resulting in, or equivalent to, the formation of a core of innovative users sufficiently large to overcome the problem of otherwise inadequate 'critical mass'. The key requirement for the responsible public agency, in the role of a 'catalyser' or 'focal' entrepreneur, would be to represent both the broad range of diversity in user demand and a high level of sophistication in 'user competence'.

These are very general policy implications, based on the most general aspects of the Swedish experience in procuring a high speed train. With regard to more specific issues, connected with more detailed considerations about the case, it seems to us that the experiences accumulated in Italy by the Pendolino case could have been used more intensively in some way. Drawing upon the Italian experience could have decreased the long time period it took Sweden to develop the X2000.

We would add to this that the Swedish state railway company, SJ, and the Swedish government might also have studied the Italian case more carefully from the 'buyer's' perspective. What, for example, were the key features of user-producer relations in the Italian 'market for trains' that contributed to the early development and subsequent international market success of the Pendolino? What organisational aspects of the Italian state railway company, FS, contributed to its apparently superior capabilities for 'collective learning' in preparing to procure the Pendolino? And how did public policy operate in relation to these and other features of the Italian case? We can not, of course, answer those questions here. They are, however, of more than 'historical' interest. As we note above, there are reasons to believe that national – or supra-national – public technology procurement in rail transport has 'a future' in Europe.

INTERVIEWS

Andersson, Bernt – General Manager, Swedrail (interview, April 28th, 1997).

(B. Andersson was the Director of Technique within the Engineering Department at SJ between 1984 and 1988. From 1988 until October he was the Director of the Engineering Department at SJ.)

Andersson, Evert – Professor KTH & AD Tranz (interview, April 28th, 1997).

(E. Andersson entered the high speed train project in 1973 and worked half-time until 1981 with high speed train project. He was a specialist in mechanical systems. In 1981 he became the director of the office for mechanical system technique. He continued to work with the high speed train until 1990.)

Hörberg, Agne – Currently Director of Technique within the Engineering Department at SJ (interview, April 28th, 1997).

(A. Hörberg entered the high speed train project after the first tender request. He was project leader for the project at SJ.)

Lundgren, Jan – Director of The Service Division, ABB Atom (interview, May 12th, 1997).

(J. Lundgren took part in the final negotiations towards SJ in 1986. As the contract was written by midsummer 1986, he took over as the overall project leader. He was responsible for the development and the total delivery of 20 train sets. He left the high speed train project in 1992 when the trains worked satisfactorily and ASEA had delivered 10 train sets.)

Persson, Richard – AD Tranz (interview, May 12th, 1997).

(R. Persson entered the high speed train project in 1982. He made, e.g., calculations regarding the life-time of the train. From 1986 until 1993, he was responsible for the tilting mechanism and the coaches themselves.)

Pålsson, Lars – System Purchaser, SJ (interview, April 28th, 1997).

(L. Pålsson entered the high speed train project in 1982. He started at the finance and accounting department. Pålsson introduced LCC [the Life Cycle Cost concept] in SJ. He was a member of the group that defined the functional requirements in the technology procurement of the high speed train, X2000.)

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