TECHNOLOGICAL CHANGE AND INSTITUTIONS: THE ROLE OF PUBLIC SECTOR PROCUREMENT

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INTRODUCTION

As technologies become increasingly costly, complex and dynamic the traditional roles of public sector procurement agencies are being challenged. It is important to develop an understanding of the impact that such agencies can have on innovation and technological change and how they can address the changing nature of future technologies. Many studies of innovation management focus on the customer/supplier interface of firms within the private sector, particularly on reduction of cost and the delivery of value. In doing so, they often overlook the non-profit activities of public sector agencies and how these may differ from private sector firms' incentives to innovate.

The public sector affects innovation and technological change through its sheer size. In areas such as environmental protection and medical equipment, it accounts for a major share of the total market. The public sector can promote or hinder, and influence the direction of, technological change. The scale of demand will clearly influence decision-making within supplier firms, particularly with respect to investment in R&D since in many markets the public sector is often the

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initial user of innovations, patents and products (Dalpé & Debresson, 1989). Furthermore, the public sector is able to exploit its demand pressure, although this pressure may be diminished when there are many small, distributed pockets of users operating at a local level. Such fragmentation may lead to a lack of co-ordination and exchange of experience amongst users, undermining the potential interactive learning processes between public users and their suppliers (Gregersen, 1992). On the other hand, the alternative, institutionalised co-operation, may result in technical and organisational lock-in.

Adopting a systems-of-innovation (SI) approach, this paper shall investigate further the role of the public sector. Fundamental to the systems-of-innovation approach is the process of interactive learning, building on the inter-linkages that exist between production, use and learning. For studies of public sector procurement, this enables us to develop an understanding of the rationale of many purchasing decisions where social and political issues may override cost considerations and how this may influence the processes of innovation and learning.

Studies of innovation within the public sector highlight the importance of dynamic interactive learning between users and producers, looking to the role of qualified users. It is commonly acknowledged that competent users are important in the innovation process, particularly through direct participation (von Hippel, 1976; Lundvall, 1985). As formal institutions in the sense proposed by North (1991), public sector procurement agencies are significant in encouraging the development of new products and processes. However, they also have the ability to stifle, hinder and destroy potential technologies and, in some cases, sectors.

This paper shall consider how public sector procurement agencies undertake and support the process of interactive learning between themselves and users and producers, and how they maintain and renew this process in the face of technological change. Using an exploratory case study approach, we shall investigate how the English National Health Service (NHS) has confronted this issue, focusing on the adoption of a new medical technology, digital signal processing (DSP) hearing aids, and looking at the role of the NHS Purchasing and Supply Agency (PASA), a central procurement agency.

In considering technological change in relation to public sector procurement, this paper will first consider the role of public procurement

in relation to innovation and technological change before providing an overview of the systems approach to innovation (SI), discussing the process of interactive learning and the role of institutions. The paper will go on to present the case of purchasing and supply in the English NHS, outlining the functions of NHS PASA. Following this, it shall discuss NHS PASA's involvement in the adoption of a new medical technology, digital signal processing (DSP) hearing aids, into the English NHS.

PUBLIC PROCUREMENT AND THE INNOVATION PROCESS

Although the public sector is a major user of many technologies and innovations, its role and influence as a *procurer* of technologies has been poorly represented by the literature and consequently is not fully understood (Berggren & Laestadius, 2003; Edquist, 1998; Gregersen, 1992).

Traditionally, the 'free market' is perceived as the main source of innovation and technological change with competition and demand acting as the main drivers. However, such a view overlooks the role of government institutions and cooperative relations (Berggren & Laestadius, 2003). Attempts have been made to address this oversight, notably Granstrand (1984), Granstrand & Sigurdson (1985), and more recently Edquist (1997; 1998), centering on public procurement's position as a facilitator of technologies that has traditionally been overlooked by the private sector.

As Gregersen (1992) points out, through public procurement policies many nations attempt to play the role of technological 'pacer,' stimulating long-term innovativeness in both the public and private sector. However, such involvement in the innovation process may be inhibitive rather than enabling. An understanding of the influential role of the public sector's effect on innovation and technological change is essential if the inhibitory effect of public procurement is to be avoided.

Develop an understanding requires a shift towards an approach that takes into account the participative role of the public sector. According to Berggren and Laestidius (2003, p. 94) "Much of the international literature on public procurement is in fact focused on the this [lack of] competition problem, rather than on the dynamic role of mechanisms that encourage shared technological investment and joint problem-solving. Theories of public procurement tend to assume a clear-cut division of labour between procuring agencies and supplying firms."

Conventional approaches to public technology procurement focus on the public sector as a *lead user*, particularly in sectors such as defence, telecommunications and transport. As a 'competent user' (Lundvall, 1985), the procuring agency outlines its requirements, exploiting its demand power to stimulate the innovation process amongst suppliers. However, government agencies may also act as intermediaries for the end-user (Edquist, 1998), supporting the development of technologies to fulfill a specific objective. Yet, how do such approaches function? If the neo-classicists are to be believed, the lack of both market forces and drive for profit that is apparently inherent to the public sector leads to dynamic deficiency and no innovative capability (Gregersen, 1992). Yet classic studies, such as those of space technology, demonstrate the ability of the public sector not only to stimulate a new technological paradigm as in space travel, but also to create new technological trajectories within existing paradigms, such as the development of Gore-Tex clothing which arose through such research (Edquist, 1997).

With respect to public procurement, policy-makers often view innovation in a mechanistic or linear manner that fails to take into account the intricate and interdependent relationships that occur between the users and producers of new technologies. This may result in policy instruments that focus too heavily on the supply side (Edquist, 1997). However, innovation is far from straightforward; firms do not operate in isolation but within a wider system of organisations and institutions. Through the exchange of knowledge and information, these organisations and institutions influence the innovative activities of the firm, and help determine which technological opportunities the firm may pursue.

In contrast, adopting a systems view allows recognition of the innovative role of demand-side instruments such as public technology procurement "when a government agency places an order for a product or system which does not exist at the time, but would probably be developed within a reasonable time period" (Edquist & Hommen, 1997, p. 65). As Edquist and Hommen (1997, p. 65) highlight, "public technology procurement is not only a matter of price signals and quantities anonymously sold and bought, but also involves interaction and learning processes that use other kinds of information."

Edquist's research into public technology procurement has contributed greatly towards recognition of the impact of public technology procurement upon the process of innovation and

technological change, particularly with respect to policy for the demand side. However, in doing so, Edquist overlooks the *nature* of the interactions that occur during the introduction and development of a new technology and also the difficulties faced by procurement agencies – a gap that this paper seeks to begin to address. In order to understand the dynamics involved, we need to develop an insight into the interconnections between institutions, organisations, groups and individuals during the procurement process, and how these influence the direction and pace of technological change. Adopting an SI approach, we demonstrate the interactive nature of the innovation process, using the introduction of digital signal process hearing aids into the NHS.

THE SYSTEMS-OF-INNOVATION APPROACH

The systems-of-innovation (SI) approach has become increasingly popular since its introduction by Lundvall in the 1980s (Carlsson & Stanckiewicz, 1991; De Liso & Metcalfe, 1996; Freeman, 1988; Lundvall, 1988; Nelson, 1993). An SI can be viewed as a set of interrelated sub-systems that may act independently but, by means of interactive learning, contribute towards the development of a technology. However, the various sub-systems may not act in synchrony. Some components of the same system may progress more efficiently than others (Hughes, 1992). These sub-systems will thus dictate the rate of development for the system as a whole and create the development potential for the rest (Andersen & Walsh, 2000), although the rate at which the system progresses is still limited by those sub-systems that are less advanced. Hughes (1983) refers to this in terms of "reverse salients": those components (or sub-systems) that trail behind the rest. If the system is to advance, these components must be improved. When this cannot be achieved, a radical solution may be adopted using ideas and principles from another sub-system.

This view also helps to explain the discontinuous nature of technological development noted by many historians of technological change; and the tensions that may develop between sub-systems acting as a catalyst for both continuous and discontinuous change (Leoncini, 1998). This is best explained using Dahmén's (1989, p. 11) notion of development blocks: "a sequence of complementaries which by way of a series of structural tensions, i.e., disequilibria, may result in a balanced situation." This is analogous to Dosi's (1982) notion of technological paradigms and technological trajectories, and Rosenberg's (1976)

"focusing devices." In other words, technological development within the system is limited by the system's existing knowledge, this knowledge providing the system with a technical logic or perspective on innovation. The firm's ability to find and locate technological opportunities will depend not only on its own outlook and capabilities, but also on its interactions with its external environment.

De Liso and Metcalfe (1996) describe the structural tensions that build up within a system in terms of imbalances, linkages and constraints. Within each system there must be some degree of compatibility (linkage), although each subsystem will be following their own design configuration or, in other words, technological paradigm. Systems not only enable interactive learning, they may also create "interrelatedness constraints" (De Liso & Metcalfe, 1996) on what may be achieved. The degree of compatibility between the subsystems will strongly determine the nature and rate of technological development of the system.

The Institutional Environment

In contrast to the neo-classical view, the SI approach recognises the important role of institutions. According to North (1991, p. 97): "Institutions are the humanly devised constraints that structure political, economic, and social interactions. They consist of both informal constraints (sanctions, taboos, customs, traditions and codes of conduct), and formal rules (constitutions, laws, property rights)." This suggests that an institution can act in one of two ways: either as a governing body through, for example, well-defined policies and law, or less formally, along a set of behavioural norms, such as routines and culture.

It is commonly agreed that institutions provide a framework upon which the 'players' may plan their strategic activities (Edquist & Johnson, 1997; Leoncini, 1998; Lundvall, 1992). Edquist and Johnson (1997) perceive institutions as serving three basic functions: to reduce uncertainty, to manage conflicts and co-operations, and to provide incentives. Innovation cannot occur without some degree of uncertainty, but there are means by which institutions can decrease the risk that 'players' face when undergoing any innovative activities. For instance, patent laws, fiscal policies, and the provision of relevant information all play a significant role in maintaining the dynamic efficiency of an economy (Carlsson & Stankiewicz, 1991).

Institutions' influence upon the process of innovation may be both positive and negative. Although institutions provide the stability, co-ordination and incentives to innovate, they can also act as a brake, slowing the whole process down. Freeman and Perez (1988) refer to 'techno-economic' paradigms and suggest that, in some cases, the introduction of a new technology has such an impact that it brings about a 'major structural crisis of adjustment.' Such adjustment requires social and institutional changes in order to align 'the system of social management of the economy (regime of regulation)' (Freeman & Perez, 1988, p. 38) and the new technology. Freeman and Perez highlight the important interacting roles played by the dominant technology and the economic selection which helps to shape and develop this technology into a tangible product or process. As disparity grows between the evolving techno-economic sub-system and the old socio-institutional set-up, there is a period of "experiment and search and political debate and conflict leading ultimately to a new mode of regulation for the system" (Freeman, 1988, p.11).

Although organisations are dependent upon institutions for stability and support, it would appear that institutions are equally dependent upon organisations to inform them of the latest technical advances. By doing so, they are able to develop, or rather, co-evolve, and so continue to support economic growth and technological change. This is akin to a symbiotic relationship whereby each component benefits from the other's existence, and it is unlikely that either structure would survive without each other.

An interesting feature of this relationship is how the nature of the dependency alters throughout the development of the technology. Initially, organisations are reliant upon institutions not only for stability, but also for the co-ordination and reproduction of knowledge. This is particularly apparent during the early phases of technological development or with technologies that have an ever-changing knowledge base (Metcalfe, 1995). However, as a technology develops, there is a shift in balance. Organisations still remain dependent upon institutions for the efficient distribution of knowledge, but as organisations become familiar with the technology, knowledge accumulates and the institutions begin to depend upon the organisations to keep them up to date with the state of play. In fact, the depth of knowledge built up by one organisation may be such that it may be able to influence institutional change. In Sweden, for example, the establishment of a stable

institutional set-up promoted technological development in mobile telecommunications, and as a result, saw Ericsson switch from fixed to mobile telecommunications. As Ericsson expanded, it began to globalise, building a truly international R&D infrastructure and becoming an expert in the field of mobile telecommunications. Consequently, when Ericsson moved from analogue to digital technology, it played a major role in establishing digital technology standards. In other words, it had helped to create an institution.

In extremes, lack of feedback may result in "rigidity" or "institutional sclerosis" within the system (Johnson, 1981). In contrast, North (1991), Edquist and Johnson (1997) and Leoncini (1998) all focus on the ability of institutions to adapt and change. Like technologies, institutions can be subjected to both radical and incremental change. This may be stimulated by a variety of social, political and cultural factors as well as by technical innovation. In many ways it is easier for informal rather than formal institutions to make this change, since formal institutions have to be altered by means of policy and strategy (Edquist & Johnson, 1997), yet the means by which formal and informal institutions interact may influence this process to some degree.

Networks, Public Procurement and Systems of Innovation

Although the institutional set-up strongly affects the process of interactive learning, formal and informal networks also play a significant role (Carlsson & Jacobssen, 1997), affecting the nature of knowledge and information that a firm is able to access. Depending on the nature and size of an SI, it may be made up of several interlinked networks, including 'vertical' trade networks or 'horizontal' knowledge networks. Through network analysis, the principal components of an SI can be identified and the various linkages investigated.

Building on development block theory, the SI approach highlights the existence of structural tensions that stimulate the development of linkages between the users and producers of innovation. According to Edquist and Hommen (1999), development block analysis allows the early translation of user needs into tangible products.

An efficient SI is built upon mutually beneficial relationships between the constituent parties that make the diffusion and development of technologies a collective, as well as individual, activity (Carlsson & Jacobssen, 1997). Such co-operation and interaction, however, may

result in inertia and path dependency, and it becomes difficult to introduce new technologies. This may require establishing a new SI and the development of new networks. Doing so may require the involvement of public agencies to develop innovative networks, bringing together firms that have previously had little interaction.

SI's focus on the interdependency between institutions and organisations makes this approach particularly appropriate for understanding the influence of public procurement upon the rate and direction of technological change. The SI approach places a heavy emphasis on the interactive learning between the different actors that make up an SI, suggesting that the *quality* rather than quantity of demand plays an important factor in influencing the innovation process. Underlining the importance of the institutional set-up, it is suggested that during periods of rapid technological change, institutions such as government agencies must overcome inertia and develop markets that are conducive for innovation. Public agencies may be required to pave the way for technological development, particularly where the technology is complex and resource intensive, and where there is little or no entrepreneurial activity.

Recognising the importance of networks, the SI approach identifies the role of public agencies in developing innovative networks, and in some cases, developing a market where a technology may have significant social or economic benefits (Edquist & Hommen, 1999). Without existing users, this may require a clear communication of requirements. For emerging technologies, it may be necessary to establish a 'focal organisation' that is able to organise and bring together the developing market.

The next section shall present case material that investigates this further examing how, as a part of an SI, a public procurement agency (NHS PASA) has influenced the process of technological change. Focusing on both the inhibitory and enabling effects of institutions, we aim to identify the implications that this has for practice and the significance that this has for policy-makers.

CASE STUDY: DIGITAL HEARING AIDS AND NHS

This case looks at the introduction of a new technology, digital signal process (DSP) hearing aids, into the English National Health Service (NHS). The case is unusual in that a systemic approach was

adopted that involved participation of all the main actors that made up the SI for this particular technology. The case highlights the importance of understanding and exploiting these interactions if a new technology is to be successfully introduced and adopted.

NHS Audiology Services in the Late 1990s

In the UK, hearing impairment is the second most common disability (after mobility), affecting 8.7 million individuals; 55% of individuals over 60 yearss of ages are affected, rising to 93% of individuals over 80. As with other disabilities, hearing impairment can lead to social isolation and loss of independence. Various reports were published in the late 1990s which were highly critical of NHS audiology services. GPs [General Practitioners] were often ill-informed and failed to make appropriate referrals. Once referred, in many parts of the country, waiting lists were very long. A significant proportion of service users did not achieve satisfactory outcomes. Of the five million people who would benefit from hearing aids, only two million were fitted with an aid and only 1.4 million actually wore one. An estimated 30% of users used their aids ineffectively. Almost all users were prescribed highly visible, behind-the-ear, analogue hearing aids, even though smaller, less visible, digital hearing aids were being widely used in other countries. English people could obtain these more modern aids, but only if they could pay for them personally.

The total NHS service cost was estimated as £100 million, with hearing aid equipment and direct audiology staff accounting for £50 million. Of the £50 million, one third was taken up by new users, with the balance for aftercare (repair and maintenance) for existing users. The NHS provided around 450,000 hearing aid units each year. In contrast ,the private market was also estimated to be worth £100 million but provided only 150,000 units. The technology gap between the public and private sector was growing, and the private market was starting to expand rapidly. The average price paid by the NHS for analogue aids based on 1970s technologies was £40, including the cost of fitting a user would pay £90. In the commercial sector, an audiologist would pay the manufacturer about £600 for the aid, and the user would pay the audiologist a total price of £1,500-£2,000 for the service.

There were several obstacles to radical change towards adoption of DSP aids, the first of which relates to suppliers. Worldwide, 6 million hearing aid units are sold per year, with UK purchases accounting for

almost 1 in 10. There are more than 12 suppliers worldwide with various brands. There are five major suppliers and five key markets, (UK, USA, France, Germany and Australia). Unless the 'NHS brand' was applied to the product, the industry was apprehensive about providing the NHS with commercially available products at considerably lower prices, for fear of damaging their private markets, UK and world markets.

Second, prescribing practices were firmly established. Using an audiometer, audiologists categorized patients according to level of hearing loss and then selected an appropriate aid from a standard NHS range. Many audiologists did not have access to equipment needed to programme digital hearing aids, or the skills to use it. Some audiologists split their time between NHS and private practice; they would have the necessary skills, but no incentive to bring them into the NHS.

Third, supply practices were also firmly established. The standard range of aids was specified by a national group, the "Commodity Advisory Group" (CAG), that was organized by NHS Supplies, a national purchasing agency and logistics service provider. CAG members represented organizations, including professional groups, from across the audiology network. NHS Supplies' buyers then organized tendering exercises. Over the years, some developments were incorporated into the NHS range. However, digitally programmable and other innovative aids were not available. When bidding, suppliers could offer a product designed especially for the NHS, or rebrand and possibly downgrade a product distributed through commercial outlets. One of the factors in sourcing decisions was ensuring competition within the UK market.

Fourth, the necessary funding was not available. Funding was provided to hospital trusts via ENT (ear, nose and throat) commissioned services (i.e., hearing aid services were rarely separately identified) and audiology service budget levels were subsequently set by trusts. Funding was usually calculated on a historical basis. This did not encourage a high quality service dedicated to minimising patient visits. Services were particularly vulnerable to cost cutting exercises. It was very difficult to maintain funding levels and pay for small increases in aid prices for small improvements in product. Through the introduction of some improvements at slightly higher prices and getting rid of the practice of recycling aids, NHS Supplies was attempting to upgrade the NHS. Audiology departments were given time to make their cases

locally with their host hospitals (or even their local health authorities in some cases) for the necessary increases in funding, but this nevertheless caused some friction between NHS Supplies and the NHS. No local audiology service could hope to persuade commissioners to fund widespread use of DSP aids.

A Project for Modernising Hearing Aids Services

Following several reports highlighting the ineffectiveness of the hearing aid services (RNID, 1999), John Hutton MP, Parliamentary Under Secretary of State for Health, announced in January 2000 that the British government would invest £9.7 million to fund a series of NHS pilot sites to assess the implications of adopting digital hearing aids. This initiative subsequently became known as the Modernising Hearing Aid Services project (MHAS). Within four years, the NHS moved from prescribing no digital hearing aids to prescribing the technology to all users for whom it was appropriate.

The MHAS project had several key objectives: to ensure the provision of leading edge DSP technology; the introduction of standard service protocols; the delivery of measurable benefits, the introduction of *compatible* IT systems; an increase in resources available with the parallel reduction of waiting lists; and a revision of the existing supply chain. It was recognised that this would require working closely with both new and existing organisations if the modernisation initiative were to be delivered. In other words, a new SI needed to be developed. The main actors involved in this project included the Royal National Institute for Deaf People (RNID), a charitable organisation led by Mr. James Strachan; the Department of Health (DH); the Medical Research Council (MRC) and the Institute of Hearing Research (IHR), scientific and research organisations that are primarily funded by the government; and the NHS Purchasing and Supply Agency (PASA), the national purchasing agency that replaced NHS Supplies in April 2000.

The scheme was centrally funded over four years. During the first wave (2000-2001) 20 pilot sites were set up. Focusing on adult patients, the sites tested new service protocols and implemented new technologies, covering both DSP hearing aids and IT systems and equipment. The research partners collated data from each of the sites. In December 2001, a further investment of £20 million was made. This second wave (2002-2003) involved a further 47 sites. A choice of service protocols was introduced and also a significant increase in children's services. In

February 2003, an additional £94 million was allocated to adopt the new technology across the entire NHS. By wave 3 (2003-2004), over 400 sites were involved and a Public-Private Partnership (PPP) initiative was started. Through direct referrals identified by the NHS, users are offered the option of PPP or NHS. The PPP arranges appointments, but NHS protocols are followed and the NHS provides the product to the PPP. Following sign off, the user returns to NHS care.

Roles and Sub-Systems

The MHAS project was a systemic process that involved identifying the parties involved and their different roles. Several key activities took place in initiating and running the project: the issue of the introduction of DSP aids in England had to be framed; funding had to be found and committed to the initiative; products were evaluated and specifications prepared; negotiations took place and contracts were awarded; finally, implementation – local service provision was re-organised and personnel trained. The RNID represented the needs of the patients and, in an arrangement which was unusual, formally acted as the lead organisation, managing the project and leading the process of implementation. DH sponsored the project. The MRC and IHR oversaw the research and collated the evidence. NHS PASA was responsible for all procurement activities.

From 1998 into early 1999, the various parties began sharing their knowledge of the situation and learned about each other's competencies and abilities to take the technology forward. Under pressure from the findings of the critical reports and campaigning from the RNID, the presumption that NHS provision of state-of-the-art DSP aids was unaffordable was challenged. It was recognized that NHS buying power would lead to prices much lower than those in private practice. Initial inquiries suggested manufacturers would offer DSPs for £250 – still far beyond NHS affordability. Strachan, however, argued that £80 per unit was achievable, and he was able to convince Ministers to start the MHAS project.

Early differences of perspectives and goals from various stakeholders in the project led to power struggles, but these were dealt with through firm leadership from Strachan, whose business and campaigning skills and status as Chief Executive of the RNID were complemented by his personal experience and stake in NHS audiology

services, since he is hearing impaired. Working as a collective enabled the different actors involved to influence policy. The RNID regularly met ministers and the DH, and with advice from MRC and PASA, briefed ministers and made the case for further investment.

Through the MRC and IHR, it was possible to assess and compare the broad clinical aspects and cost-effectiveness of hearing aid technology. Various actors were involved in evaluating products. Through discussion, an agreed listing of essential and desirable features was drawn up. NHS PASA took responsibility for evaluating commercial aspects; the MRC and IHR oversaw IT and software compatibility; clinicians and users assessed the aesthetics and ease of use of the products; and the scientific community looked into the issues relating to quality. Through involving different actors, NHS PASA ensured that product evaluation was not based primarily on cost, and that user needs and quality were taken into account.

This had important implications for procurement and more specifically for NHS PASA. By reaching agreement on a 'leading edge specification,' it was possible to go to the suppliers and negotiate for the supply of digital hearing aids. It also enabled the RNID to convince Ministers that for a relatively small investment they could secure a positive and transparent agreement, affecting millions of people but it required investment in the system as a whole.

Agreements with suppliers were negotiated according to the different waves of the project. The first wave only needed small volumes to serve the needs of the research. Four suppliers were involved and the price of the units varied from £140 to £205. The second wave saw an extension of the original agreement. A joint negotiating team was formed, led by James Strachan and supported by NHS PASA. Prior to tendering, strategic discussions were carried out with the CEOs of all contracted suppliers, informing them of the intended reduction of the supply base and expected purchase volumes. Suppliers faced some difficult choices in deciding how to respond. Their approach to the NHS could have fundamental implications for their global business strategy, relating particularly to branding and pricing. Only one supplier needed to respond to MHAS' aims, and others would have to follow or withdraw from the UK market. Eventually, agreements were extended with two of the suppliers, and as a result, the price of units went down to £70 - £75. A new, four and a half year agreement has recently been implemented through partnership between the RNID and NHS PASA. Again, this

involves two suppliers with volume commitment and also the introduction of an upgrade programme, the development of strategic alliances, and the development of shared vision amongst all actors involved.

The impact of the MHAS on the NHS has been very positive. Over 200,000 DSP hearing aids have been fitted. Seventy-five percent of NHS sites now fit DSP hearing aids. A typical unit now costs c£60. Other benefits have included the development of equipment that is now fit for purpose, increased staff morale, reduced waiting times, and fundamentally, more satisfied users.

It seems likely that eventually DSP hearing aids would have been introduced into the NHS. Through the MHAS, though, the rate of adoption of digital hearing aids in the NHS was dramatically increased. The RNID was the driving force throughout the case. As this case demonstrates, product specification involved a range of actors from users and procurement specialists to experts in the scientific community. Through interactions, the NHS was able to ensure that the DSP hearing aids met the requirements of users, going beyond the simple consideration of price. However, the collective power of the SI resulted in a marked reduction of cost per unit that had an impact on both a national and global level.

DISCUSSION AND CONCLUSION

Innovation is an interactive and systemic process that is governed not only by the knowledge and capabilities of the individual constituents, but also by the interrelations between them. Consequently, in understanding the relationship between technological change and public procurement it is essential to understand both the system surrounding a technology and the interactions as well as public procurement's position and influence within such a system.

In particular, it is important to appreciate the institutional aspect, principally the ability of institutions to constrain as well as support technological development. In this study, service users were victims of institutional sclerosis or inertia, cost pressures, and outdated specifications inhibiting the introduction and adoption of DSP hearing aids. This resulted in structural tensions as the technology gap between the public and private sector grew. The public sector was acting as a

reverse salient, trailing behind the private sector and limiting the rate of technological development with respect to DSP.

Consequently, as Freeman and Perez (1988) suggest, a major structural adjustment was required in the form of the MHAS project and the development of a new SI. With respect to the DSP SI, this was built on both horizontal integration as a means of sharing knowledge and information within the system as well as on vertical integration as a way of creating demand pressure.

In this light, public procurement is not simply governed by price mechanisms, but also by exchanges of knowledge and information that occur between different actors within an SI, highlighting the importance of the *quality* of demand. In the case of DSP hearing aid technology, the main actors were the RNID, MRC, IHR, DH, and NHS PASA. As this study demonstrates, co-ordination mechanisms must be developed that facilitate interactions between the various elements of an SI that generate and support technological development.

The success of the MHAS project required a shared 'vision.' Initially, it would appear that each element of the system had a clear but different perception of the nature of the problem. Without interacting, they would have each pursued their own paths that could have potentially inhibited the adoption of DSP hearing aids into the NHS and also hindered technological development in this area. Through the strong influence of the RNID and James Strachan, cohesion was brought about. This ensured that all the actors understood their roles and responsibilities and contributed towards the development of a shared vision. It also highlights the importance of a 'focal organisation,' the RNID, and a 'champion', James Strachan, who could not only co-ordinate this process but also assure that the nature of the problem was understood, that the user needs were articulated, and that the demand was formulated.

For NHS PASA, interactions with other members of the DSP SI enhanced their capabilities. Through their relationship with the RNID, they were more influential at both a political and industrial level. Through the DSP SI, NHS PASA was able to effectively articulate specifications that addressed the needs of the user, but that were both technically and economically realistic.

Public procurement can influence the rate of technological change. This case study demonstrates how institutions such as the NHS have the ability to constrain technological development. However, through the

development of linkages between the different constituents of a technology's SI, it is possible to support technological development. It is difficult to assess public procurement's influence on the direction of technological change as it is not possible to foresee the direction in which a particular technology might progress. However, through the MHAS project, the NHS was able to close the gap between the private and public sector, clearly articulating specifications that addressed the needs of society.

Academically, this paper highlights the need for researchers in the field of public procurement to adopt a systemic view to innovation that considers the role of other actors and the position of a government procurement agency within that system. Although public procurement has the ability to influence the rate and direction of technological change, it is not in isolation and is dependent upon the nature of the interactions and mechanisms that link it to other actors within an SI. Consequently, the focus should not be simply on the demand pull of procurement agencies, but also on the systems that surround them -- such as other institutions, firm and non-firm organisations -- all of which influence technological development.

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