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Socio-technical Transition of Singapore Public Housing Building Technology Innovation, 1960–1995

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Abstract

This paper reports on the research conducted on building technology innovation during Singapore's early decades of public housing development, 1960-1995. Taking an historical perspective, it traces the growth of innovation change in Singapore using a combination of data sources including archival materials and personal interviews. Framed by insights from Science and Technology Studies, in particular, the work of Geels on socio-technical transition pathways, it seeks to interrogate the development of technological innovation through a detailed examination of the evolution of HDB lift technology and how this responded to social needs around performance, satisfaction and security.

Keywords innovation, lift technology, socio-technical transition, public housing, Singapore

1. Introduction

Innovative urban solutions have become a part of Singapore's core framework to address urban challenges. Sitting at the heart of the history of that expertise is one particular Singaporean state institution, the Housing and Development Board (HDB), which was established to solve Singapore's housing shortage, develop public housing and improve the quality of the living environment for its residents. In this paper, we revisit specific aspects of the large-scale socio-technical transformation the HDB undertook through its mass housing programme, with a focus on the period 1960–1995, to gain insight into the processes of building technology innovation which underpinned that transformation. This period covers the post-independence formation of the HDB when almost all aspects of public housing design, delivery and management were handled internally by the HDB, apart from the expected procurement of some building components and construction services, which were tendered for private sector contracts.

An historical examination of the socio-technical work of the HDB offers insight into the emergence of innovation capabilities relevant to Singapore's contemporary place in the international urban solutions market. As Bruland and Mowery (2004) note, "innovative capabilities are developed through complex, cumulative processes of learning" (p. 1). They are also context specific, linked to distinctive moments of social transformation and spaces of possibility (Lazonick, 2002). Crucially, they often develop in circumstances that are far from the self-consciously labelled policies and places we imagine might be generative of innovation. As we shall see through the case study on HDB lift technology, the HDB's past of pragmatic problem-solving in its large-scale, centralised, housing delivery system laid a foundation stone for the nation's current capabilities in urban solutions. The role of the HDB in the foundation of Singapore's current innovative expertise was forged at a time when the motivation for generating "solutions" was driven, not by an aspiration of competitiveness in a global market place, but by public service concerns for resolving domestic housing needs and building national economic capacity.

The rest of the paper is organised as follows. The next section — Section 2 — briefly introduces the study background, including the mission of the HDB, the extant literature and our study approach. Section 3 uses Science and Technology Studies approaches and in particular the work of Geels on socio-technical systems, to discuss two key terms central to this study — innovation and technology. Section 4 offers a close analysis of the case of lift technology innovation in the HDB, analysing its evolution, effects and changes in user

practices, policies, cultural meanings, infrastructures and business models. Section 5 concludes the paper.

2. Study Background and Approach

The HDB's mission began within an emergency framework, motivated by the imperative to transition the population out of housing conditions judged to be of insufficient quality and quantity — the crowded, sub-divided shophouse or the attap housing of the kampungs (Malay word for 'villages') — and into modern, high-rise housing. Within the decade, the HDB's mission had expanded beyond mere emergency provision. By the end of the 1960s, it was providing multi-room, family housing and associated amenities as well as home ownership and estate management services to lower income households (Yeh, 1972). The radical transformation in housing that the HDB led depended on a number of political and economic facts.

Three, in particular, are worth mentioning as they speak to the very unique political and economic aspects of Singapore's public housing system. The first of these related to land supply. The long-term, integrated approach to land use planning in Singapore was supported by compulsory land acquisition, with limited market rate compensation. The process untangled colonial legacies in land management and secured sufficient and affordable land for housing development. The second was the introduction in 1964 of the Home Ownership Scheme, followed in 1968 by the provision to allow Singaporeans to release a portion of their Central Provident Fund savings (retirement fund savings) for public housing purchase. These changes transformed a "public" provision of shelter into a pillar of state capitalist development and household wealth creation. The third was Singapore's strong political commitment to affordable public housing provision, which established a covenant between government and people, and reinforced political stability (Castells, Goh, & Kwok, 1990; Chua, 1997; 2017).

There is a good deal of commentary and scholarship already on the HDB and its exceptional programme of mass housing construction and delivery by way of the high-rise typology. One category of commentary is provided by the HDB's own publications. Right from the start, the HDB has reported out on its achievements in formats that are intended for wider readership and which include its corporate magazines and annual reports. In addition to the HDB's own self-narration, there exists a range of external scholarship on the HDB and its achievements. Some of that work was done by academics who were effectively university based, but worked very closely with the HDB. An example here would be the social scientific scholarship of Professor Stephen

Yeh who, from late 1966, was Deputy Director of the newly established Economic Research Centre at the University of Singapore, and who, from that position, worked closely with the HDB to establish the Sample Household Survey and its Statistics and Research Department (S. Yeh, personal interview, May 21, 2018; Yeh, 1972). At the other extreme sits scholarship that applies a critical political economy lens to the HDB, such as the work of Manuel Castells (Castells, Goh, & Kwok, 1990). Mid-point between these examples is the work of scholars like sociologist Chua Beng Huat who, after working briefly for the HDB, went on to write a defining account of the political role of housing provision in Singapore (Chua, 1997).

The approach in our research is distinct from much of this existing scholarship. It offers, instead, an historical perspective on the question of "technological innovation" in the HDB building programme. Our method uses five key lenses. The first four of these are technological components central to the high-rise typology: prefabricated walls, lifts, waste chutes, and clothes drying poles. The last lens focuses on what might best be considered a software technique — feedback loops linked to the cultures of learning and knowledge transfer associated with the housing project.

These selected technologies deliberately range from the large scale and complex (the obvious example being prefabrication) through to the small-scale and domestic (such as clothes drying poles). Some of these technological lenses, such as the lift, were entirely necessary to the adoption of the high-rise typology. Others, such as wall prefabrication was a technological development, which both enabled and was enabled by the scale and repetition of the high-rise typology. Similarly, a technological lens such as the clothes drying pole enables us to follow how a traditional technology was scaled up into a modernist building project while the novel mechanism of the rubbish chute allows us to understand the specific imperatives of managing waste in tropical high-rise living. Finally, by looking at communication and information, what we dub "learning loops", we can understand something more of the culture of Research & Development (R&D) in the HDB during the study period. Such learning loops ranged from weekly team meetings to surveys and trial experiments, through to formalised processes of learning such as Quality Control Circles[1], in-house training sessions, and international study tours.

[1] Quality Control Circles were a quality improvement initiative adopted by the HDB in September 1982, which promoted employee participation in problem-solving performance. This method was used as a tool for workers to not only solve problems, improve work systems and promote teamwork, but also adopt positive work attitudes and acquire problem-solving skills.

3. The Innovation Zeitgeist in Context

An important part of the preliminary work of our study entailed better understanding of two key terms: technology and innovation. These might seem like entirely self-evident phenomena, but in both cases they can be subject to different conceptualisations and approaches. In the case of technology, while we might imagine that a technology is simply a thing, a Science and Technology Studies perspective demands that we see it as socially configured. Similarly with innovation: The questions and methods the economist might ask about the innovation process are entirely different to those that might be asked by the historian. Innovation is a term we nowadays assume as necessarily linked to economic growth. We also often, by default, link innovation exclusively to technological change. But, both assumptions are historically contingent.

The Canadian science studies scholar Benoit Godin has recently charted the origins and development of the concept of innovation, including its use in conjunction with the term technology (Godin, 2016). Using google ngram, which can record the frequency of use of terms across a large body of published materials, Godin looked at changes in the use of the term over time. Several illuminating observations derive from his work. Firstly, he shows how the use of the term "innovation" waxes and wanes over time. There is a peak in frequency of use in the Early Modern era, another in the late 1800s, and a final peak in the latter part of the 20th century. Secondly, Godin explains that "innovation" in each of these periods was used in different ways. For example, the first peak in the Early Modern period reflects the discourse generated by the rise of the then controversial and "deviant" religious practices of the Reformation. In other words, innovation in this period was a negatively inflected cultural term not linked to technological change at all. The second peak, occurring from 1750 through to 1850, was again associated with a derogatory labelling, this time of social reformers by the status quo. It is only in the most recent peak in the use of the term "innovation", from the mid 20th century onwards, that it is linked to technological change, construed as a positive transformation.

Godin's study offers suggestive ways for us to think about innovation in different historical, geographical and institutional contexts. We might, for example, apply his method to Singapore to gauge the extent to which "innovation talk" has featured in the collective imagination. One, albeit merely approximate, way of doing this would be to track instances of the use of the term, and its derivations, in the primary English language paper of record, *The Straits Times*. That exercise indicates that the term "innovation" has increasingly become part of the discursive zeitgeist in Singapore (Figure 1).

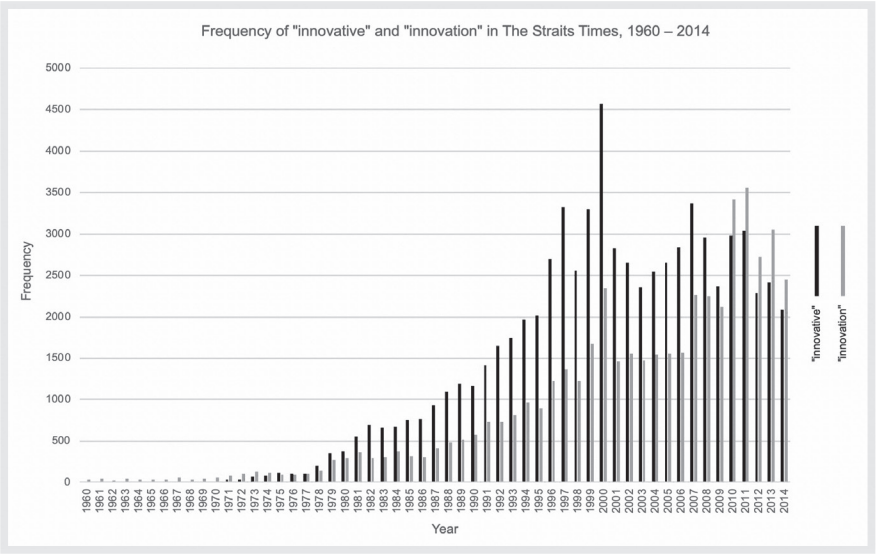

Figure 1: Incidence of "innovative" and "innovation" in The Straits Times, 1960-2014 (Source: NewspaperSG).

To add meaningful flesh to such a suggestive skeleton, it is necessary to look deeper into the specifics of the use of the term in relevant discourses. For example, an NVivo enabled analysis of the instances of the uses of the term innovation (and its variants) in the key self-reporting publications and reports of the HDB for our study period, shows that innovation is certainly a part of how the HDB effort is described, but only partly so. Indeed, and perhaps unsurprisingly, other terms like "efficiency" are more frequent descriptors (Figure 2).

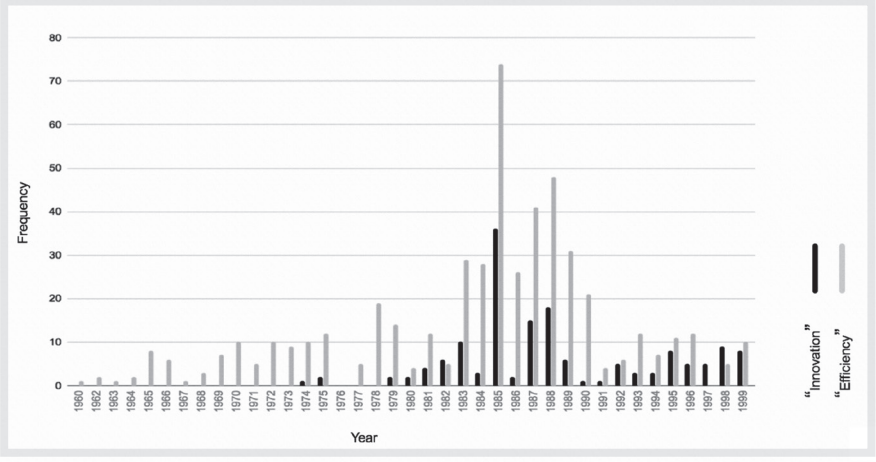

Figure 2: Frequency of "innovation" and "efficiency" (including derivatives) in key HDB published materials, 1960-1999.

This graph suggests that across the first decades of Singapore's dramatic housing transformation, the use of the term "innovation" was not consistent, despite this period involving the adoption of a novel built form and a range of associated local technological adaptations. In short, though radical change was happening in the housing construction and delivery sector, it was not always described by the concept "innovation".

When that term was used by the HDB, it was generally to describe subset technologies, and at specific, self-conscious moments of reflection. These included reflections on their effort associated with the HDB's 25th anniversary, as well as statements in Annual Reports of the time, and the publication of a special volume, *Housing a Nation* (Wong & Yeh, 1985). The late 1980s was also the lead up to the founding of the HDB Prefabrication Technology Centre (PTC), which housed the HDB's construction-related R&D efforts and capacity building programmes. As an engineering-led unit, the PTC was immersed in paradigms of experimentation, and routinely reported on their attainments through formalised training sessions and publications.

A closer examination of instances of the HDB's use of the term innovation across the 1980s and early 1990s indicates a growing organisational self-consciousness around all kinds of achievements. For example, the 1988/89 *Annual Report* ascribes improvements in flat design to "innovative design and construction details", and the launching of "a R&D programme to encourage improvements, innovations and technological breakthroughs in the Board's products and services" (Housing and Development Board, 1989, p. 16). In the mid-1990s, there was another minor rise in innovation rhetoric in the HDB, attributed to their starting a number of specialist journals directed towards the construction industry. Notably, *Technical Journal* and *Precastech* reported on "ingenious innovation[s] by HDB" (Yap, 1998, p. 10), and coincided with the 1995 establishment of the PTC, which had a focus on engineering-linked R&D and construction industry capacity building. The PTC embedded and formalised a culture of innovation. For example, the PTC's Product Talk Series offered seminars for the construction industry to "launch and market advanced technology and innovative products" ("Product talk series", 1995, p. 8). By 1998, on the occasion of the PTC's third anniversary, a seminar explicitly on "construction innovations" directed at industry carried the bold entreaty, "innovate or evaporate" (Yap, 1998, p. 1).

That said, talk of innovation in the HDB was never far from the enduring concern with efficiency, as this 1987/88 *Annual Report* statement on the introduction of the Total Quality Control Management System by the Administration and Finance Division suggests: "The Division continued its

ongoing efforts to further improve the efficiency, cost-effectiveness and promote innovativeness of the Board's operations." (Housing and Development Board, 1988, p. 15). Efficiencies, in this instance, were a desired output of innovation. This kind of organisational emphasis was also evident with respect to innovation in computerisation. The HDB saw "computer networking" as important because it offered "linkage[s] with other bodies" and "result[ed] in greater operational efficiency that will benefit the public" (Housing and Development Board, 1988, p. 16). By the 1990s, the HDB could report that its operations "at all levels of the organization" were extensively computerised, which transformed and lauded the shortened processing time for "improving efficiency." (Housing and Development Board, 1993, p. 58)

It is clear from the evidence that although there was a radical technological transition underway in housing provision, that transition was only occasionally described in terms of innovation. Furthermore, any talk of innovation was justified by recourse to the goal of efficiency. Interviews undertaken with former officers give an on-the-ground, standpoint perspective on the place of innovation in the HDB across the latter decades of the study period (1970s to 1990s). Those officers confirm that "innovation" was rarely how they framed their work effort. The officers do describe a working life full of instances of applied research, experimentation, invention, test-bedding, piloting and "product" development, but this was more usually thought of as the expected requirements of "problem solving" operational issues or "adapting" off the shelf solutions. As the then CEO Liu Thai Ker reflected: "I don't want to use the word innovation […] It is badly abused. It's a history of problem solving." (Liu Thai Ker, group interview, May 8, 2018).

Framework for Understanding Innovation and Technological Change

The HDB story of technological transformation fits uncomfortably into many of the established frameworks we have for understanding innovation and technological change. For example, hagiographic origin stories that place innovation in the mind and hands of a sole inventor-innovator, operate at the wrong scale and with an emphasis on the individual that does not accommodate a complex bureaucracy with its often anonymous public servants. The HDB story also deviates from interpretations of technological transformation that emphasize a single technological attainment, in and of itself. The HDB technological transformation in housing comprised a complex assemblage of many different component parts; some borrowed,

others invented, some novel, others not. Even the more process-oriented frameworks for thinking about innovation, such as the staged model that is commonly used to represent the process of product innovation in market-linked sectors, does not have the complexity for thinking about innovation and technological transformation in housing in Singapore in the post-independence period (Figure 3).

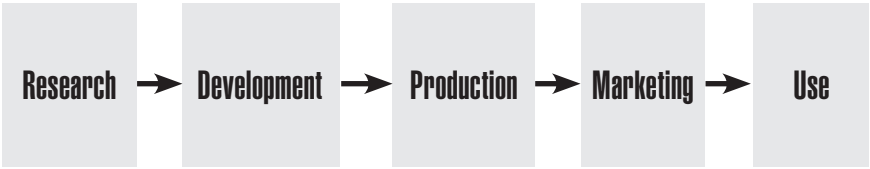

Figure 3: A simplistic, linear 6-stage model of innovation (Source: Kline & Rosenberg, 1986, p. 286).

In such models, the pathway is simplistic and linear, moving from basic research through to applied research, leading to product development and production, and on to the diffusion of an innovation through the market to users. Again, this way of conceptualizing innovation is not particularly relevant to a bureaucratically-based, housing delivery programme where the focus was the production of housing, not only as a welfare-linked shelter *but also* a market-linked commodity that was *designed to* support community development and the cultivation of "lifestyle". The shortfalls of linear models of innovation such as that in Figure 3 are now well recognised and there are a range of alternative models that speak more to the distributed complexity of invention and adaptation that operates around technological transformation. These alternative frameworks acknowledge that innovation does not always (or only) relate to "product innovations." It also relates to a wide range of changes "designed to resolve, circumvent or eliminate technical difficulties" in everything from manufacturing to services. It may also be realised in the service of a range of desired outcomes, from improving productivity or efficiency, to changing the conditions of work and life (Fischer, 2001; Bienaymé, 1986; Malecki, 1991). Conceptual models of innovation nowadays better reflect the ways in which R&D-dependent innovation happens through activities that are distributed across firms and other institutions and facilitated by a range of feedback loops. One conceptual model that reflects such a complex process of relations and collaborations is the "chain-link" model (Figure 4).

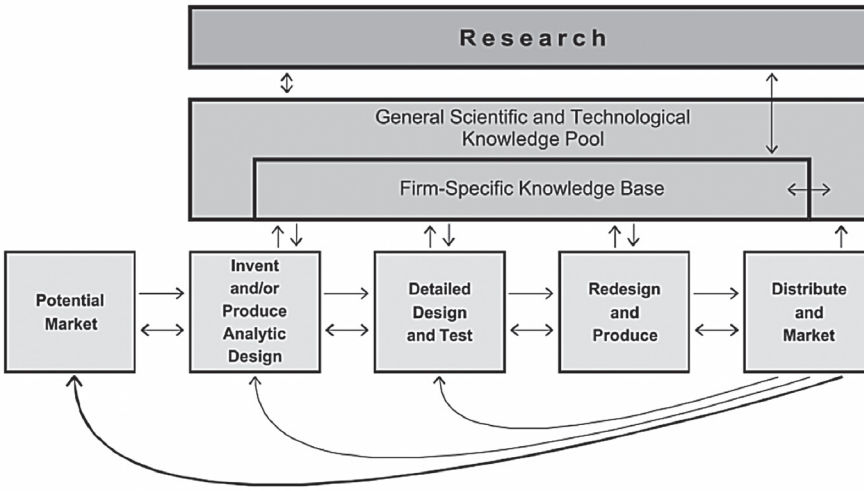

Figure 4: A chain-link, interactive model of product innovation, showing feedback loops and interactions (Source: Fischer, 1999, p. 15).

The scholarship on innovation increasingly emphasises such relational complexity, showing how innovation is embedded in networks of association that involve "the creation, combination, exchange, transformation, absorption and exploitation of resources within a wide range of formal and informal relationships" (Tijssen, 1998, p. 792). In short, innovation happens in a relational system or assemblage (Freeman, 1989; Lundvall, 2010; Nelson & Rosenberg, 1993; Edquist, 1999). According to Morton, when innovation is conceptualised as relational, it is clear that it is not simply a process of technological substitution but a transformation entailing a whole range of creative acts — from research, to product development and delivery, to service and diffusion (use), all of which come to act "together in an integrated way toward a common goal" (as cited in Godin, 2016, p. 542). Increasingly, it is understood that innovation is the outcome of assembling and aligning social institutions, markets, technologies and users in such a way that problems are solved and goals fulfilled, often using whatever means available and appropriate, and in a range of settings far more distributed than the pristine research laboratory or the purified transactional space of the market. Geels (2005) refers to this as an innovation system, and argues that it is the establishment of such systems that enables socio-technical transitions (Figure 5). Relational thinking such as this reminds us that new technologies alone do not generate technological transitions. The wider challenge of technological transition

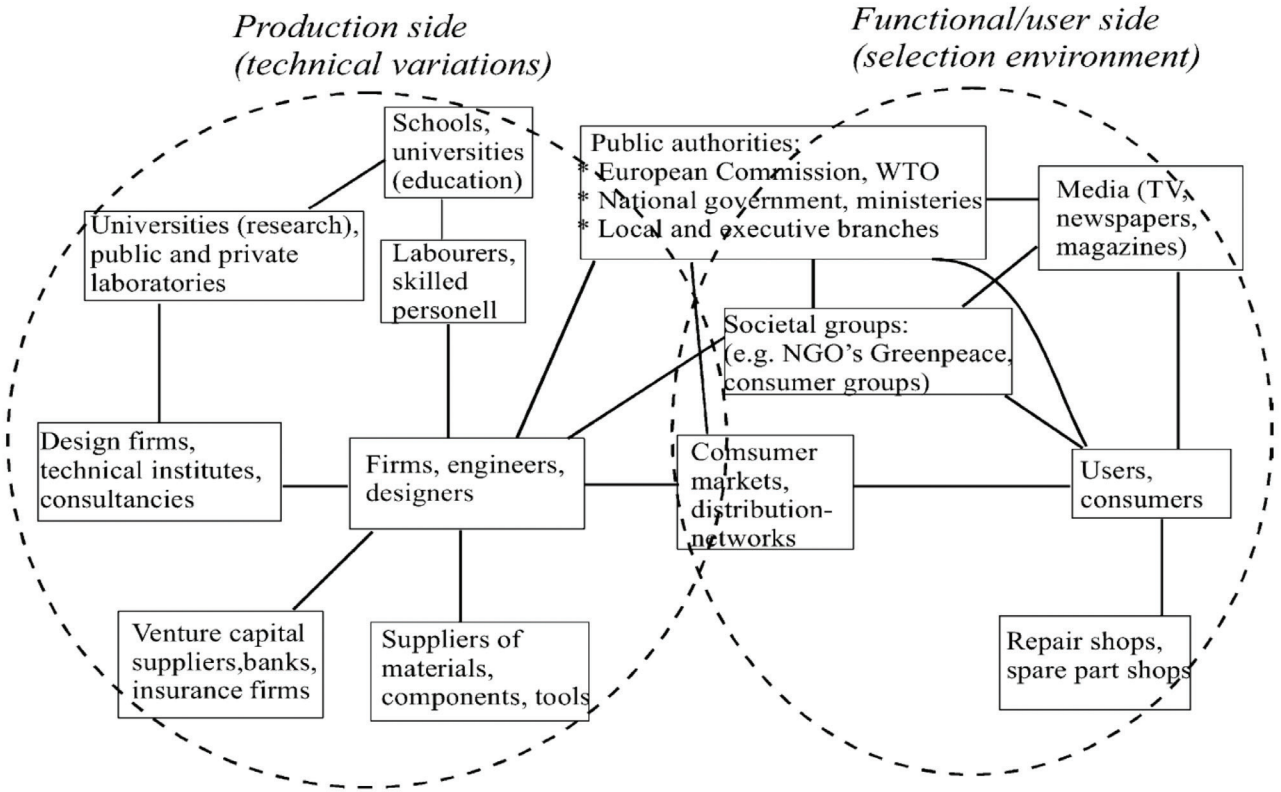

Figure 5: Social and institutional agents that carry and reproduce a socio-technical system (Source: Geels, 2004, p. 900).

requires innovation embedded in "networks of agents interacting in a specific technology area under a particular institutional infrastructure" (Carlsson & Stankiewicz, 1991, p. 111).

That the models depicting technological innovation should be complex is supported when we think more deeply about what "technology" is. Science and Technology Studies explain that marketed technologies often come to the user as wholly competent artefacts, the inner workings of which need not be known or understood for them to function successfully, what is called a "black box". In other words, they come as stable technologies and any of the controversies or challenges that might have been associated with them reaching this stable state of functionality is "closed off" (Latour, 1987, p. 3). The intellectual project of Science and Technology Studies is to prise open the "black box" of technological artefacts. One tool for doing this is the lens of social construction, which emphasises how technologies are embedded within social frameworks, be that the institutions of production (firms, laboratories, government departments), the norms of society (as expressed in, say, regulatory frameworks), or the cultures of consumption (such as taste, aspiration or welfare). These social aspects of technology shape its form, social meanings and trajectories. Furthermore, technologies are taken up and used — we might say translated or diffused — into society in complex and unexpected ways. This means that technologies, rather than being stable artefacts are subject to "interpretative flexibility" (Pinch & Bijker, 1984).

Indeed, Science and Technology Studies demand that we see technology in a socio-technical dialectic in which technology and society are mutually constitutive and co-evolving (MacKenzie & Wajcman, 1999). Importantly, within Science and Technology Studies there has been a long tradition of thinking beyond "specific isolated technologies or technical artefacts", and about what Thomas J. Hughes (1987) dubbed "large technological systems", including large infrastructure projects like that of the HDB housing programme. Hughes' work on Large Technological Systems draws attention to the ways in which they are spatially extended and functionally integrated socio-technical networks, often assuming a focal role in processes of social development and transformation.

Much of the initial work on large technological systems focused on self-evident technology networks, such as transport, communication and information systems, as these were readily conceptualised as systems. But, other large socio-technical achievements that were not so self-evidently systems or networks have been increasingly analysed through this lens. Our study contributes to this scholarship, and conceptualises the HDB housing construction and delivery programme as an instance of one such large socio-

technological assemblage. It uses the concept of large technological systems to render in more nuanced complexity the radical socio-technical transformation that the HDB oversaw across the first decades of its operation.[2] We illustrate this with the HDB lift technology.

4. The Socio-technology of HDB Lift System

In his 2014 cultural history of the elevator in Europe and America, Andreas Bernard reiterates a self-evident fact: the invention of the elevator by Otis in 1854 facilitated a new linear vertical extension in buildings. But, he reminds us too that the elevator also immediately gave rise to worries and concerns about safety. This is because it was a closed box that moved vertically through a building by way of a shaft, working both with and against the law of gravity. Bernard notes that in the early history of the adoption of elevator the "possibility of an accident served repeatedly as a catalyst for both technical improvements in the apparatus and the development of legal ordinances" (Bernard, 2014, p. 23). Furthermore, the closed box elevator generated new opportunities for users to behave in socially unacceptable ways — to violate other users, or to vandalise the lifts themselves. Many of the things we take for granted today with respect to elevators (e.g. inner and outer automatic doors, door locking in motion, and the ceiling trap door) were technological responses to incidents and accidents that had human consequences.

Having committed to the high-rise typology, lifts were essential to the successful realization of the HDB's planned housing transition. The risks of vertical travel in an enclosed box were embedded into HDB housing. The HDB soon discovered that lifts alone were not enough to make high-rise housing make sense. Their lifts had to also be safe, reliable and efficient. In other words, their lift technologies had to be translated into a *proper lift service,* and for this to happen it had to be a part of a wider system of operations. This systemic integration required alignment between a range of actors, processes,

[2] In delving into this history of socio-technical transformation, we have systematically sourced all already publicly accessible sources on the efforts of the HDB. This includes: a range of in-house publications, from technical journals to resident-directed publications; secondary reports and scholarly works; interviews with former officers, both conducted by our team as well as those already deposited with the National Archives of Singapore; and, government papers available through Government Records held in the National Archives of Singapore. We have subjected these sources to systematic qualitative analysis using Nvivo software. In our analysis, we seek to create veracity in findings by: triangulating between sources; exercising impartiality, by using a symmetrical approach, which does not just seek out innovation "success" stories, but also failures, as well as controversies that arise in relation to technological development; generating thick descriptions, by way of the up-close focus of the case study lenses, and the animating detail offered by the voices and visual language of the period.

institutions, infrastructures and technologies. Furthermore, to do this in a large housing system where, for example, during the accelerated period of housing delivery in the 1980s there were nearly 10,000 lifts in operation, was especially challenging (Wong & Yeh, 1985). Not least, it required that the HDB bring into line the building layout, residents and other users, regulatory authorities, other departments such as the Public Utilities Board (which supplied power), as well as the suppliers of lifts and related components. Each of these component players in the socio-technical achievement of a proper lift service had to fit in with the high-rise typology as well as the HDB's goal to deliver quality and affordable housing that performed as expected, and so was worthy of living in and taking an ownership stake in. In other words, to create a proper lift service the basic lift technology is necessarily overloaded with mission statements, user expectations, performance standards, social survey data, safety innovations, maintenance regimes, and much more (Figure 6).

We can start to see something of the complexity of the lift in the HDB's larger technological system if we map its social and institutional context, following Geels' generic system diagram (Figure 7).

Figure 6: The HDB lift was overloaded with more than people (Source: "Please do not overload the lift", 1978, p. 5).

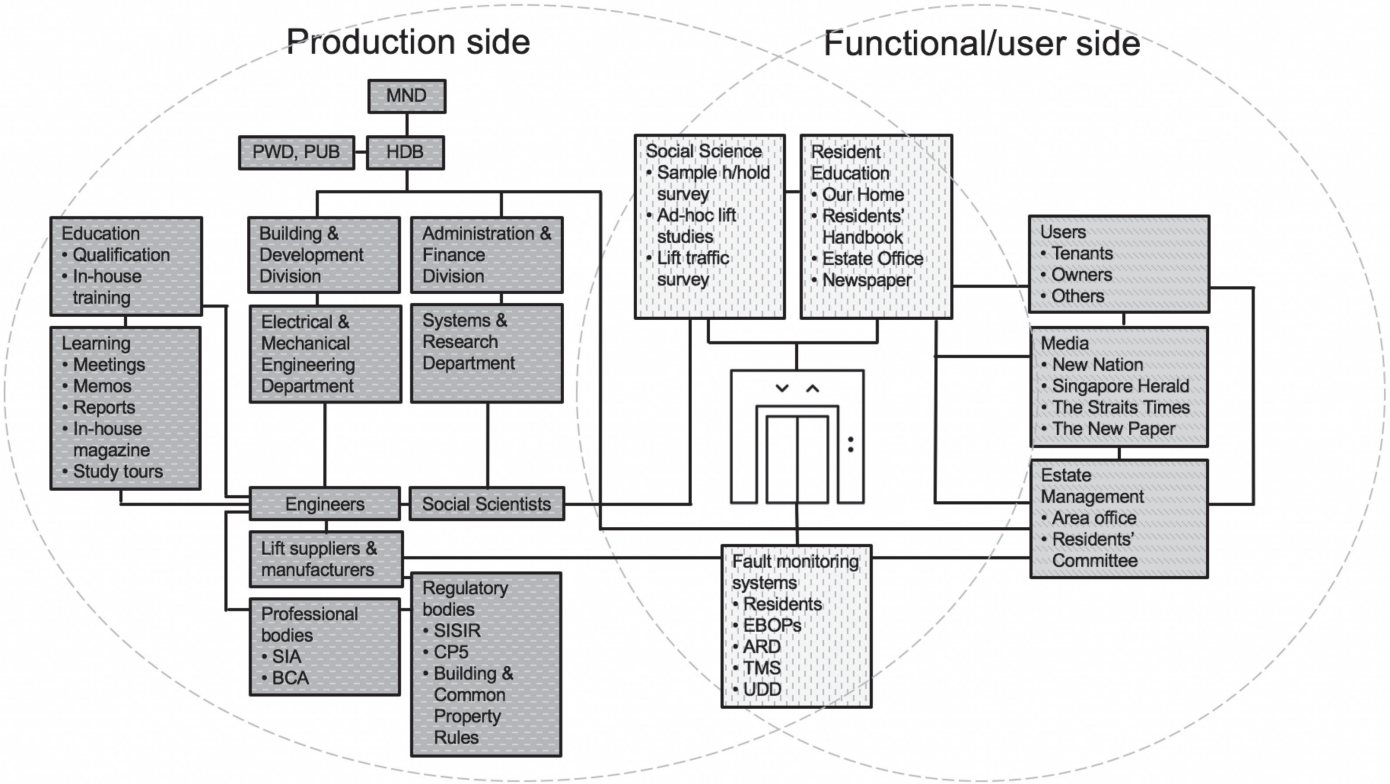

Figure 7: The HDB lift in a social and institutional system (Source: Authors, after Geels 2004).

As Figure 7 shows, on the production side of the lift system are various government agencies, including of course the HDB and its Building and Development Division, within which sat the group directly responsible for lifts, the engineers of the Electrical and Mechanical Engineering Department. Also involved in the production side of the lift service were other parts of the HDB. This included the architects of the Building and Development Division, who designed lift shafts and placed lifts into the layout of the building, and the social scientists of the Systems and Research Department, who collected information on resident satisfaction and helped shape resident education materials. The production side of the lift system importantly also included industry partners in the form of lift supply and manufacturing companies, as well as other suppliers of off-the-shelf components (such as emergency alarm systems). It also included regulatory bodies, which set and policed compliance on a range of building, safety and other professional standards. Finally, the production side of the lift service system included what we might think of as knowledge-based sectors and processes, including the ways in which the HDB built the skill capacity of its officers through credentialization, in-house training, study tours, or knowledge and technology transfers facilitated by industry partnerships.

The Function/User side of this diagram depicts those who use or support the use of the lifts, including residents, tenants and other users, as well as the problems they encountered and the controversies these problems created. Such controversies were readily reported upon in the media, and certainly generated work for the HDB Area Office, which was the first stop for resident complaints. The use of lifts also generated HDB discourses and actions directed at residents, including educational campaigns on how they should use lifts, and institutional protocols of action in the local HDB Area Offices. The proper lift service that the HDB sought to deliver across the study period sat as a socio-technology at the centre of this assembled system: part hardware, part systems of safety and rescue, part resident behaviour and attitude. If we zoom in on specific parts of this system we can see in greater depth and empirical richness the challenges faced by the HDB, and how those challenges seeded a collaborative effort of socio-technological transformation and innovation.

The users in the lift system, comprising tenants, residents and others, is a good place to start this closer examination. In the first decades of HDB housing development, we can see that when lifts and users came together things did not always go smoothly. This is well recorded in newspaper coverage on HDB lifts between 1960–1995. Across that period, we found some 450 English language

media reports on lifts in HDB. Those reports include news articles, feature articles and letters.[3]

Coverage across this period confirms that residents encountered many different problems with the lifts, from crime (including molestation), vandalism (including graffiti and urination in the lifts), accidents (including fatalities), as well as technical breakdowns, some relating to local and island-wide power outages, others a result of misuse by residents or other users, such as forcing doors to hold open. Negative news reports would intensify in frequency and in tone if compounded by serious accidents or crimes, such as molestation or theft. For example, a *Singapore Herald* article of 1970, which reported on the tragic accidental death of two small boys in a lift shaft, concluded that complaints about lifts were the "biggest single grievance of HDB tenants" ("HDB plan for safer lifts", 1970, p. 2).[4] Residents routinely wrote to papers complaining of lift failure, often because the localised systems for receiving and responding to complaints and breakdowns were inadequate or failing. This is evidenced in the following selection of quotes:

> I would like to draw the attention of the Housing and Development Board to the workings of the two lifts at Block 4, Syed Alwi Road. These new lifts were installed about two months ago but breakdown often occurs at least three or four times a week. Sometimes people have been trapped inside the lifts. ("Breakdown of HDB lifts", 1972, p. 6)

[3] The English language papers we reviewed were The Straits Times, The Business Times, Singapore Herald, Singapore Monitor, and New Nation.

[4] That lifts, and how residents interacted with them, could prove a troublesome node in the HDB housing system was anticipated, based on earlier experiences of the Singapore Improvement Trust (SIT). In the final years of its responsibility over multi-storey housing in Singapore, the SIT experienced a spate of vandalism in its lifts. Government Records from 1957 and 1958 show extended debates among the Building Committee and Estate Committee about how best to respond. The employment of "jagas" or lift attendants was discounted as too costly. A press exposé was contemplated but set aside. Instead, the SIT imposed a time-limited blanket restriction which meant that for some weeks all SIT lifts only ran from level 2 upwards, effectively ceasing ground floor access. This was supplemented by an education campaign on the "proper use of lifts". In this late colonial approach the options deployed to place the lift service back in alignment were very limited. The resident/user bore the brunt of effort for the creation of the problem and the solution. (Government Records available in the National Archives of Singapore. Singapore Improvement Trust. (1958). Memos on the operation of lifts from 2nd floor (SIT334/52 Microfilm No. HDB1257). Singapore: SIT; Singapore Improvement Trust. (1958). Discussion on the engagement of lift attendants (jagas) (SIT334/52 Microfilm No. HDB1257). Singapore: SIT; Singapore Improvement Trust. (1958). Memo on conducting of courses for tenants on proper use of lifts from estates manager (SIT) to lift companies (SIT334/52 Microfilm No. HDB1257). Singapore: SIT)

> One Saturday afternoon on Nov. 8 both lifts in the 16-storey Block 18 of Jalan Sultan went out of order. In spite of repeated phone calls to 913333, nothing was done until late Sunday evening when one lift was made partially serviceable. ("Fright of life in jammed lifts", 1975, p. 6)
>
> On behalf of the residents of Blocks 100 and 101 Whampoa Drive, I write this letter in the hope that something positive will be done to the lifts in these blocks. For more than a year, the lifts have been breaking down more frequently than we can tolerate. Despite innumerable verbal complaints, and letters to the Area Office, the problem has so far not been resolved. ("Inefficient lifts", 1984, p. 18)
>
> I believe many Housing Board lifts have expired lift maintenance certificates, and it is surprising that no authority seems to be concerned whether they are in good working order. For example, Lift B in Block 13, Teck Whye Lane, has a lift maintenance certificate which expired on Dec 31 last year. ("Lifts have expired certs", 1983, p. 17)

Being aware of resident opinions about the lift service (and other aspects of housing) was an early concern of the HDB, as was being seen to be responsive. This was particularly so from 1964 onwards, when the HDB moved on from emergency housing provision to flats that could be purchased through the Home Ownership Scheme.

One component in the HDB's effort to build a systematic approach to user dissatisfaction with lifts was the HDB Sample Household Survey. This Survey was introduced in 1966 to gauge needs and satisfaction among residents with their new housing. From the outset, the Sample Household Survey included specific questions about lifts and user satisfaction. In the 1966 Survey resident responses to the question on the efficiency of lifts showed that, out of 3,403 households in all areas living in blocks of flats being served by lifts, only a little more than one-third of households rated the efficiency of lifts as either satisfactory or acceptable. Most of those respondents lived on lower floors. Some 61% of households were not at all satisfied with the efficiency of lifts, and the level of dis-satisfaction increased with floor level (Yeh, 1972, p. 59). Technical faults, accidents and vandalism, along with resident dis-satisfaction, contributed to a collectivised problem, which was coloured by the fact that the HDB operated to the publicly shared goal of delivering social welfare and economic development in and through housing. We might usefully dub this

collective problem as *the unreliable lift*.

Science and Technology Studies have a way of conceptualizing such problems within larger socio-technical systems. They refer to them as "reverse salients". A reverse salient "appears in an expanding system when a component of that system does not march along harmoniously with other components" (Hughes, 1983, p. 79). They are usually the result of things that cannot be foreseen or, if foreseen, are unable to be countered in an expedient way, for whatever reason. In other words, as the HDB's evolving housing system was marching towards the goal of affordable housing, efficiently delivered, for the majority of Singapore's population, a lift that broke down, or hid a crime, or attracted vandalism, had fallen out of line with that trajectory, or defected from that larger project by being defective. To get the lift back in line, some kind of remedial action was required. This field of remedial action is important for, as the work of other scholars in Science and Technology Studies has shown, "innumerable (probably most) inventions and technological developments result from efforts to correct reverse salients" (Hughes, 1983, p. 80). In other words, in an operational socio-technical system like that of HDB housing, an unreliable lift was an impetus for innovation.

In what ways, exactly, was the unreliable lift a reverse salient in the wider HDB housing project? There is, of course, the obvious matter of access: without the vertical mobility all the flats in the high-rise housing system could not be accessed easily. Also, market forces were starting to work inside the HDB's housing system as a result of the Home Ownership Scheme. Poor lift performance would reduce the desirability of upper floor flats and depress value. Lift breakdowns were also considered by the government to be a security risk, especially if the breakdowns were across many blocks, such as was the case in the early decades of the HDB when there were island-wide or area-wide power outages. HDB engineers took such risks very seriously, not least because of the number of lifts that could be compromised and, as a result, the number of people who could be trapped and needing to be rescued. The seriousness of this issue was communicated by this recollection from a HDB Senior Principal Electrical Engineer:

> That time, [it] so happened [we] got a few island-wide [failures]- that's frightening - island-wide power failure or partial power failure. And then people were trapped in the lift. People trapped in the lift! And there's so many people trapped and to do the rescue for them [was] terrible. Because [if there were so many] people trapped in the lift [it might take] maybe one day

> to rescue… because there are so many lifts. If it's peak hour, every lift [on island] could be stalled!" (Former HDB Senior Principal Electrical Engineer, Mr M.K. Swee, personal interview, November 22, 2017)

It is clear that an unreliable lift service was a central concern for the HDB. This was given succinct expression in the 1985 HDB publication *Housing a Nation*, where it was concluded that: "[the] importance of the residents perceiving HDB lifts to be reliable cannot be over-emphasized. It is crucial to their acceptance of high-rise living as a way of life" (Wong & Yeh, 1985, p. 139).

The HDB pursued a range of corrective efforts to transform the unreliable lift into a proper lift service. One response was information-based and involved the targeting of user behaviour. The responsibility for this work lay primarily with the social research and information management parts of the HDB, working in collaboration with Area Offices, Resident Committees and individual residents. The lift-related questions in the Sample Household Survey was a foundational element in this information sub-system. Letters from residents that were published in the newspapers was another, and the HDB usually responded directly and promptly to such letters. It even used its responses to such letters as an opportunity to flag planned or recently launched technical and service interventions, as the following examples illustrate:

> Please refer to the letter by Mr Richard Wee who suggested that every HDB lift should be installed with a security alarm system connected directly to the HDB Lift Maintenance Department (SM, Aug 17). The writer may not be aware that the board is working on a Telemonitoring System which has been successfully tested in some lifts in Ang Mo Kio and will be extended to all lifts. (Tan, 1983, p. 15)

> I refer to the letter "Lift robberies: Maybe HDB can install cameras at lifts" by Ms Leow May Inn (ST, Sept 13). The writer suggested that cameras be installed in or outside lifts in HDB estates to prevent lift robberies. HDB would like to assure the writer that security in lifts is one of HDB's primary concerns when installing lifts in HDB flats. To this end, all HDB lifts are fitted with an anti-crime siren, which will sound automatically if an attempt is made to jam the lift. (Yeo, 1995, p. 38)

The HDB also developed educational campaigns, communicated primarily through the *Residents' Handbook*, which was given to residents on take-up of their flat, as well as the pages of *Our Home*, a magazine that was delivered free to all HDB households from 1972 to 1989. These campaigns emphasized, on the one hand, modifying bad behaviours (such as urination in the lift or vandalism) and, on the other, educating residents in the role they could play in keeping the lift service working (Figure 8). In the early years of the HDB if a lift broke down it had to be reported by phone to the lift suppliers, who provided a maintenance service as part of the supply contract. A timely repair or rescue response depended upon rapid reporting of problems. Usually the lift contractors got that information about a lift problem from the HDB via the estate-based Area Office, or directly from residents in an affected block.

Figure 8: Examples of educational campaigns designed to change resident behaviour. (Sources: "Don't get caught with your pants down", 1989, p. 22; "Do-it-yourself lift rescues? Don't!", 1983, p. 30).

This was not a foolproof system of detection and the HDB struggled with ensuring timely repair and rescue responses. Area Offices checked blocks routinely but not continuously. Residents were most likely the ones to first detect a fault, but they were unreliable reporters of such faults. For a start, if residents witnessed a lift break down they did not always interrupt their activities to report it in a timely fashion. Furthermore, residents could intensify lift problems. For example, residents might try to intervene in a breakdown themselves by, say, forcing open a door to effect a rescue or prizing a button that was stuck in the hope of repairing the fault themselves. As such, the resident/user in the HDB's lift system was just as likely to create or intensify technical problems, as be a victim of them.

Increasingly, the HDB needed technological as opposed to resident-based solutions to deter and detect lift faults. From a technical point of view, the

original HDB lifts were very basic.[5] They did have some safety features, such as trap doors in the roof and a localised alarm system that could be triggered manually by users if they needed rescuing in the event of a breakdown. The HDB's technical responses to the problem of resident dissatisfaction with lift services went in two key directions. One direction was to change the policy with respect to the number of lifts supplied per block in future designs. From 1969 onwards, all HDB blocks constructed were supplied with two lifts. In specifying this the HDB ensured the social impact of a breakdown in one lift would be compensated for by other working lifts. But, even redistributing risk could not remedy the problem of unreliable lift performance. A solution of increased lift supply certainly addressed the resident's experience of the problem of lift breakdown by giving them another lift option. However, it intensified the engineer's problem by enlarging the lift system, and increasing the scale of the challenge of rescuing residents in the event of an island or area wide power failure.

The other direction of the HDB's technical response was to change the engineering and functionality of the lifts themselves, a project that needed to incorporate the lift suppliers and contractors. Through the 1960s, lifts were procured by the HDB from a range of suppliers and manufacturers who were contracted to provide off-the-shelf lift units, as well as after service maintenance and repair. As early as 1962, the HDB is recorded as contemplating whether it should bring repairs and maintenance processes in-house, though it did not act on this. By the late 1960s, this matter was being revisited in response to the evident resident dissatisfaction with lifts uncovered by the first Sample Household Survey, a finding that had attracted the attention of the Prime Minister. In 1969, the Estates Department of the HDB did a follow-up study that focused not on the performance of lifts themselves, but of the contractors who supplied and maintained them (Housing and Development Board, 1969). That study reported that the repairs of lifts by suppliers were prompt enough but were hindered by the fact that they did not always become aware of breakdowns in a timely fashion. Further, the quality of replacement parts could not always be guaranteed. Around the same time, the HDB set up another *ad hoc* committee to inquire into how best to respond to the "persistent complaints on the poor performance of lifts" (Housing and Development Board, 1970, para. 1). That inquiry resulted in a restructuring of the process

[5] The lift cars had opaque doors, often limited indicator systems to show where a lift was in the building, non-illuminated buttons that could not indicate a request was recorded, basic painted metal interiors, and only one speed, and so stopped suddenly.

by which residents reported breakdowns. Instead of directly contacting the lift company, residents were required to report via their respective Area Offices, enabling the Area Office to monitor contractor performance on response time and quality of repair (Housing and Development Board, 1970, para. 2). Across this period lift performance also became the concern of authorities beyond the HDB. The Singapore Institute of Standards and Industrial Research, a subset of the Economic Development Board, established a review into "the absence of a central scheme of quality and inspection control" for lift repair and maintenance in Singapore generally (Singapore Institute of Standards and Industrial Research, 1969, para. 4).

Concurrent with such reviews and revisions, the HDB once again evaluated if it should have its own lift department, deciding for a second time against that course of action. Instead, the HDB's lift contractors were put on notice to both improve their response times to lift breakdown and use compliant parts in repairs (Housing and Development Board, 1970, para. 3). From 1971 onwards, lift emergency repair was incorporated into an expanded 24-hour Essential Maintenance Service Unit (EMSU) managed by the HDB (Wong & Yeh, 1985, p. 385). Even with these changes, the HDB's goal to offer an efficient and reliable lift service faced the persistent issue of the delay in time between a lift failure and its reporting. Figure 9 summarises HDB

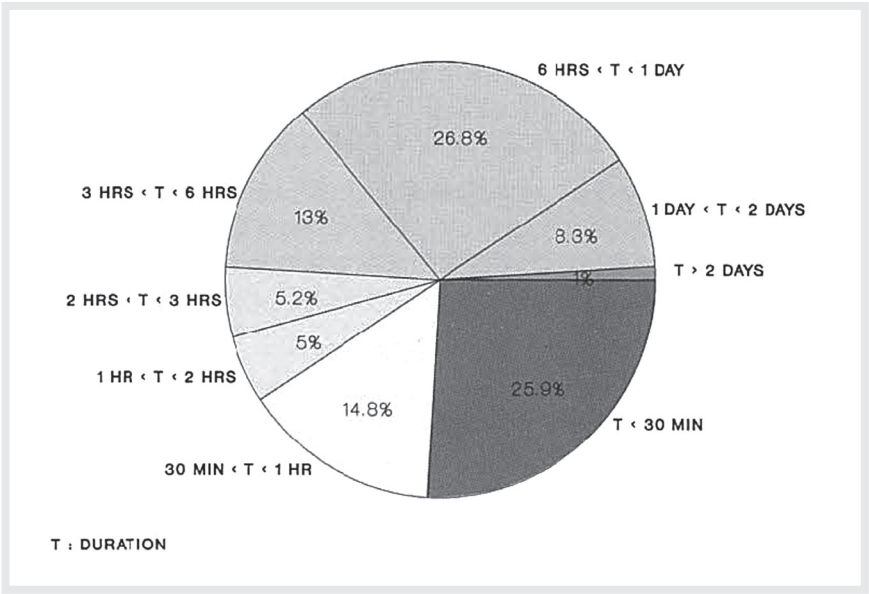

Figure 9: Duration between occurrence of lift breakdown and receipt of complaints (Source: Seah, Swee, & Yeo, 1990, p. 5).

research on this matter from the late 1980s, and shows how human-based detection and reporting generated an unacceptable duration between when a breakdown occurred and when those able to respond to the breakdown were informed.

The next decade and a half in the HDB was a period of intense lift-related innovation by HDB engineers, who understood the resolution of poor performing lifts depended on better controlling them through technological means. The HDB strategy was a mix of restructuring lift procurement and maintenance responsibility, as well as in-house research and development. With respect to procurement, the HDB increasingly sought or required that suppliers adjusted their products to technical specifications it set. And because of the size and length of contracts, many manufacturers were willing to do this.

A small-scale instance of this was the 1979 introduction of the Automatic Rescue Device, an off-the-shelf product from Europe which in the event of a break in electricity provision self-activated and brought passengers to the nearest landing and released them. An Emergency Battery-Operated Power Supply was also retrofitted to existing lifts. The largest scale instance of a procurement adjustment was the HDB's arrangement with Fujitec, which was awarded a pioneer status contract to establish a lift manufacturing factory in Bedok and become a primary provider of lifts for the HDB. Significantly, the Fujitec contract allowed a newly formed Technology Development Unit within the Engineering Department to collaborate on technical innovations for improved lift safety, reliability and performance. Through this collaboration the HDB was able to improve lifts by introducing vision panel doors and Light Emitting Diode indicators, among other things.

With more control over product supply, the HDB Technology Development Unit set about inventing a range of in-built automated detection systems, including its Anti-Crime (alarm) Device, the oft-cited Urine Detection Device, a Lift Monitoring Device and, most impressively, an integrating Telemonitoring System. Devised in 1981, and trialled for a year,[6] the Telemonitoring System was a microprocessor based system that continuously monitored lift operations, including the detection, transmission and receipt of messages relating to unauthorised stoppages, forced opening of landing doors, trapped passengers and failure of the Automatic Rescue Device. It could also generate maintenance

[6] It was trialled from May 1982-May1983 across 20 monitoring devices connected via telecom cabling to an Area Receiving Station.

reports, and report on breakdown response times. Costed at S$9.5 million, the initial system comprised a centralised master station at the Essential Maintenance Service Centre, 33 area stations and over 4,864 lift monitoring devices (Housing and Development Board, 1985, p. 49). [7]

Each of these systems is an example of the HDB taking a lead in problem-solving through internal research and collaborative product development or adaptation of off-the-shelf products. They used this R&D network to establish automated fault detections systems that melded emerging capabilities in micro-computing with existing analogue systems of circuitry, and to-order hardware production. Across the 1970s, the HDB invested heavily in developing a range of detection devices, what we might think of as technologies of transparency, which effectively did away with the risks generated by the lift being a mobile room that could not be seen into and a technology that could only be monitored through on-site labour or cooperative residents. The effort of the HDB was to transform the lift from an opaque space of "uncontrolled disappearance" (Foucault, 1977, p. 143), to a transparent space in which social and mechanical events that might take the lift out of service (and so out of alignment with the wider goals of the HDB) could be reliably detected.

The automated detection devices simplified and integrated the previously unreliable and dissipated systems of breakdown detection and response, which were spread across the service contracts of many lift providers, were vulnerable to power failures that were out of the hands of the HDB, and relied on unpredictable human detection and reporting. In every respect, this was innovation in the service of the resident client and the conjoined goals of comfort, safety and efficiency. It was also innovation enabled by the scale of the HDB's operations at that time. Scale not only intensified the imperatives to have a reliable and secure lift service in HDB flats, it also enabled large scale-procurement contracts to be put in place that, in turn, served as conduits for knowledge and technology transfer and structures for experimental collaboration.

5. Conclusion

Technology innovations in response to urban and social challenges take place in many different ways. Such innovations are not merely a technological matter. They also require political frameworks, rules, regulations and collaborations.

[7] This is a period of technological innovation reached into the 1990s when a camera based Lift Surveillance System was installed in 1994.

This historical examination of the lift technology within an instance of housing transition to the high-rise form offers insight into the formation and workings of a large technical system, including how that larger system depended upon innovation in relation to sub-technological systems. This multi-scaled system of technological innovation, in turn, was reliant upon the cultivation of learning capacities among engineers, supply companies, HDB Area Offices and residents. These learning loops and collaborations were drawn on by the HDB to generate a reliable lift service.

The first decades of the HDB were a period during which there was rapid adoption of an international housing typology — the high-rise building — followed by incremental adaptation of that typology to local circumstance. The lift technology gives us insight into how this borrowing and adapting happened. A proper lift service for Singapore's emergent high-rise housing system was the result of a network of collaborations that enabled adaptation and innovation. The quest to create a proper lift service and system generated a cluster of ever-improving technical solutions created through emergent collaborations between the HDB, suppliers and residents. Although patents were not pursued at this time[8] in relation to the technological detection and monitoring devices, the period did deliver to the HDB a symbolic, proprietary claim over that type of building technology innovation. It led to an era of self-conscious publicizing and expertise transfer from the organisation out to local industry and beyond.

The HDB's lift innovations remind us how historically contingent and socially relational innovation is. Across the study period, the central goal of the HDB was attaining the requirements for resident (and so societal) wellbeing through improvement of efficiencies in fault detection. A key building block in that success was the work culture of the professionals involved. These HDB officers saw themselves as doing localised "problem solving", but that work and the innovative detection devices they generated reverberated across the sector and associated industries. With reference to how we might think of innovation and technological transitions, we can see that this was innovation-in-action.

Inventions were not forged in a laboratory but in the complex space of collaboration that involved the state agency of the HDB, residents (users), as well as suppliers managed through the process of procurement. What is critical

[8] One of the earliest legal conversations about patenting of HDB outputs, specifically around the detection devices developed. As a comparative endnote, it is worth reflecting that the HDB ultimately decided not to patent these innovations. Why that is is not entirely clear, but we do know from our conversations with former officers that patenting products was only then emergent in the mindset of the HDB, who still saw its primary responsibility is to provide housing, not patented devices.

to innovation in this hybrid system, as the Singapore experience demonstrates, is the ability to envisage the potential role and application of foreign-derived technology, the facilitation of its transfer and, necessarily, the adaptation of off-the-shelf solutions to local needs, often across the spectrum of low and high-tech components. As Singapore continues to hone its expertise in building technology innovation and better understand the kinds of new ideas that work in public housing, a focused historical study such as this offers a useful comparison point. Singapore's effort to house its nation, although unique, is an important instance of socio-technical transformation, deserving to be understood in all of its richness.

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