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An Evolutionary Analysis of the Development of the One North Innovation District in Singapore

Abstract

First conceptualised in Singapore's first National Technology Plan in 1991, the idea of creating a new integrated R&D and innovation hub in Singapore languished until it was incorporated into a broader Technopreneurship 21 (T21) strategy announced in 1998, and was officially launched in late 2001. In the 20 years since, the innovation district has made significant development progress, but not quite in the manner as presented in a number of prior studies that have adopted a "top-down rational planning" narrative. Taking an evolutionary view, we argue that the actual development of One-North was significantly shaped by a number of critical actors as well as external environmental factors, and its evolutionary trajectory deviated from its original plan. Our evolutionary narrative provides insights on the role of champions in large scale innovation projects, and the need to integrate physical space development within a comprehensive innovation ecosystem development strategy.

Keywords: innovation hub; Singapore; biomedical sciences; technology entrepreneurship

Una anàlisi evolutiva sobre el desenvolupament del districte d'innovació One North a Singapur

Resum

Conceptualitzada per primera vegada en el primer Pla Nacional de Tecnologia de Singapur del 1991, la idea de crear un nou centre integrat de R+D i innovació a Singapur es va frustrar fins que es va incorporar a una estratègia més àmplia de Technopreneurship 21 (T21) anunciada el 1998, i presentat oficialment a finals de 2001. Des de 20 anys ençà, el districte d'innovació ha fet un progrés significatiu en el desenvolupament, però no tal i com es presentava en una sèrie d'estudis previs que adoptaven una narrativa de "planificació racional de dalt a baix". Utilitzant una visió evolutiva, argumentem que el desenvolupament real de One-North ha estat format significativament per un nombre d'actors crítics, així com per factors ambientals externs, desviant la seva trajectòria evolutiva del seu pla original. La nostra narrativa evolutiva proporciona informació sobre el paper de les empreses exitoses en els projectes d'innovació a gran escala, i la necessitat d'integrar el desenvolupament espacial físic dins d'una estratègia de desenvolupament d'ecosistemes d'innovació integral.

Paraules clau: centre d'innovació, Singapur, ciències biomèdiques, tecnologia

Un análisis evolutivo del desarrollo del distrito de innovación One North en Singapur

Resumen

Conceptualizada por primera vez en el primer Plan Nacional de Tecnología de Singapur de 1991, la idea de crear un nuevo centro integrado de I+D+i en Singapur fue un esfuerzo frustrado, hasta que se incorporó una estrategia más amplia de Technopreneurship 21 (T21) en 1998, presentada oficialmente a finales de 2001. Desde hace 20 años el distrito de innovación ha hecho un progreso significativo en el desarrollo, pero no como se presentó en estudios previos que adoptaron una narrativa de "planificación racional de abajo arriba". Utilizando una perspectiva evolutiva, el artículo argumenta que el desarrollo real de One-North ha estado integrado básicamente por un número de agentes críticos, y factores ambientales externos, que han desviado su trayectoria evolutiva del plan original previsto. Nuestra narrativa evolutiva proporciona información sobre el papel de las empresas con éxito en los proyectos de innovación a gran escala, y sobre la necesidad de integrar el desarrollo espacial, físico, en una estrategia de desarrollo de ecosistemas de innovación integral.

Palabras clave: centro de innovación; Singapur; ciencias biomédicas; tecnología.

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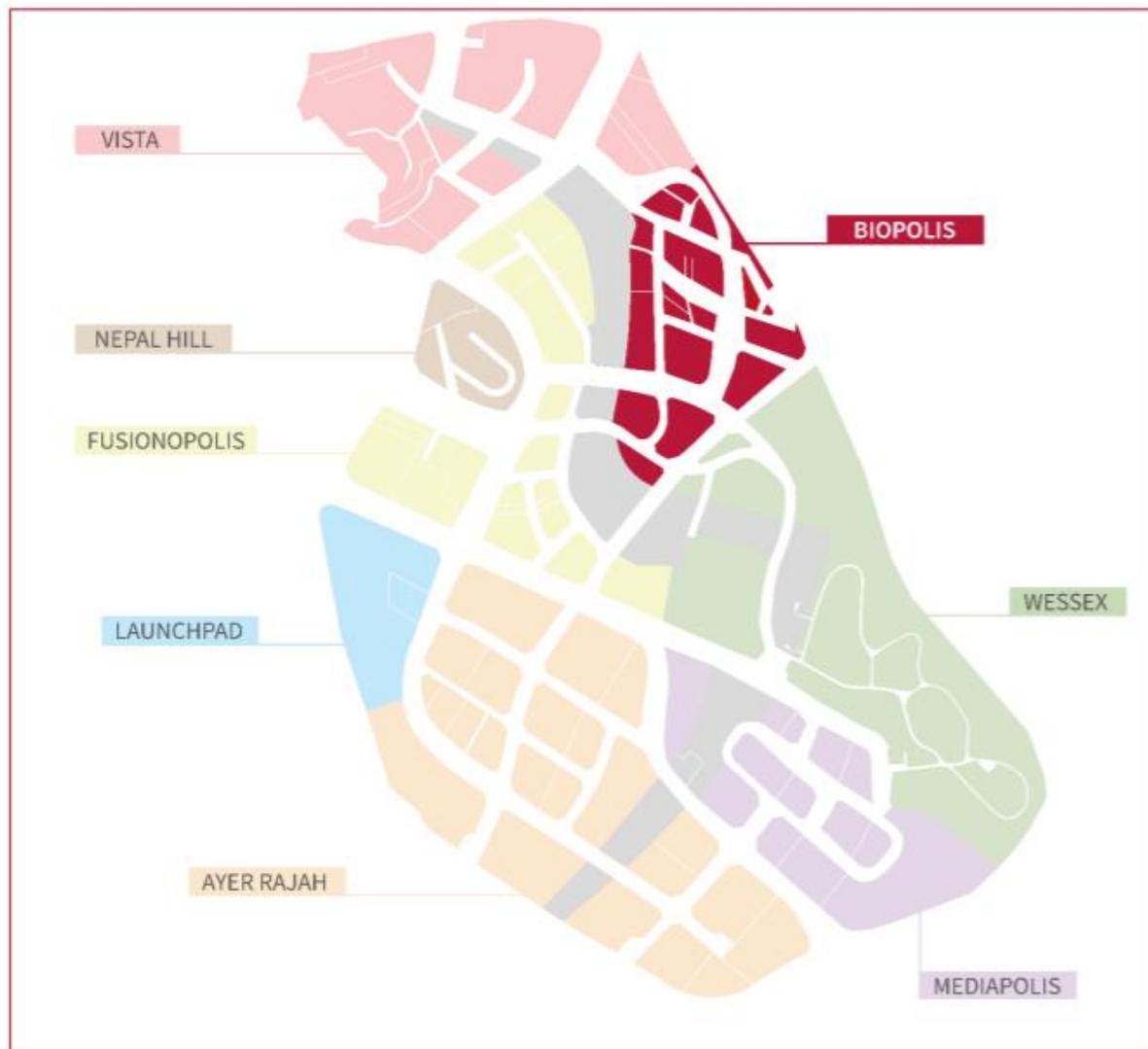
1. Introduction

The development of innovation districts, or more generally physical urban spaces designated to support innovation activities, has been on the rise over the last 20 years (Katz and Wagner 2014, Nikina and Pique 2016, Wagner, Katz and Osha 2019, Catapult,2021). While the majority of such innovation hubs are still in the advanced economies of North America and Europe, an increasing number have emerged in Asia.

Occupying 200-hectare (2 square kilometers), One-North — so named to reflect Singapore’s geographical location one-degree north of the equator — has emerged as the largest innovation district in Singapore and arguably one of the leading government-led physical hubs for innovation in Asia that seeks to integrate research, innovation and startup activities with educational institutes, residences, commercial and recreational amenities into an all-inclusive “work-live-play-learn” environment.

First breaking ground in 2001, One-North’s development has reached an advanced stage by 2021, comprising eight precincts (see Figure 1) that can be grouped into three distinct forms of land-use:

- a) Four Research/Innovation Parks – Biopolis, Fusionopolis, Mediapolis and Ayer RajahTech Hub
- b) One Startup Hub – Launchpad@One-North
- c) Three Mixed Commercial/Residential Areas – Vista, Wessex and Nepal Hill

FIGURE 1. Map of One-North

Source: Killen, Palladino and González (2021).

As of 2021, One-North was estimated to house 400 leading companies and global institutions in high tech and knowledge-intensive industries, 16 public research institutes, six institutes of higher learning and corporate universities, 50 incubators with approximately 800 startups, and 3,900 residents. Together, they have a working population of about 50,000. (JTC 2021).

By all accounts, both locally and internationally, One-North has been recognized as a relatively successful innovation district development. For example, in a recent review of innovation hubs around the world, Catapult (2021, 28) cited One-North as a successful example of suburban

innovation park development, highlighting its “masterplanning to accommodate multiple value chains”, and giving it “full or nearly full marks for anchor tenants, identity building, land development, and effective use of zoning and tax powers.”

Of the three major innovation clusters being promoted in One-North — biomedical sciences (BMS) in Biopolis, Physical Sciences/Engineering and ICT in Fusionopolis and Ayer Rajah, and Digital Media in in Mediapolis — it is Biopolis that has garnered the most international attention. For example, a recent study by Cambridge University (Killen, Palladino and Gonzalez 2021) credited the development of Biopolis as a major contributor to Singapore’s attractiveness as a biomedical innovation hub. The integration of commercial and residential spaces, and its proximity to the National University of Singapore (NUS) and the National University Hospital (NUH) were also cited as positive contribution factors.

2. Towards an Evolutionary Understanding of One-North’s Historical Development: Research Objectives and Methods

The aim of this paper is to provide a historical analysis of how the two most prominent innovation clusters of the One-North Innovation District — the Biopolis and the Launchpad@One-North start-up hub — came to be what they are today: how they were initially conceptualized, and how they subsequently developed over time. In contrast to prior historical research that has adopted a rational planning perspective, we adopt an evolutionary approach to studying the historical development of these two cases, highlighting the role of key actors and their dynamic interactions with changing external environmental factors at different stages of development. Besides drawing on similar publicly available archival documents as past historical studies, we incorporated additional public information sources, including

statements by the key actors involved and relevant independent media reports, that provided the evidence for our alternative interpretations.

The historical development of One-North has been examined earlier by several researchers from public policy and urban development perspectives (Chia 2018; CLC 2018). In particular, the recent study by the Centre for Livable Cities (CLC), a research centre within the Ministry of Sustainability and the Environment (MSE) of Singapore, has provided the most comprehensive review of One-North's development, with detailed historical development milestones, extensive archival references and interviews with leaders of the various government agencies involved (CLC 2018). Despite its comprehensive coverage, the study's narrative appears to be guided by a top-down, rational planning perspective, where developments occurred more or less in accordance with original plan, or where initial planning options were selected through relevant governance committees and pre-established decision-making processes. A similar top-down rational planning view is adopted by Chia (2018) in her review of the historical development of One-North, as well as by a number of less in-depth accounts (Prasad 2015; Hang, Low and Thampuran 2016).

The rational planning process as a 'top down' viewpoint has been challenged by a 'bottom up' viewpoint of actors 'on the ground' (Barrett and Fudge 1981), and the linear model of the rational policy making process has been increasingly challenged by conceptions of policy development as an interactive process, continuously evolving over time and drawing in different actors at different stages (Healy, 2001). In particular, we believe that an evolutionary analysis approach that focuses on the dynamic interactions of critical actors that often lead to unforeseen variations from original plan, or unexpected selections from initial planning options, is more useful in understanding how major public innovation projects like innovation district

developments actually happen on the ground (Aldrich, Ruef and Lippman 2020). In particular, the innovation literature has highlighted the championing actor role in radically new and risky innovation projects (Schon 1963; Howell and Higgins 1990).

Taking an evolutionary view, this paper argues that the actual development of One-North was significantly shaped by a number of critical actors in dynamic interaction with changing external environmental factors. To support our argument, we selected the two most widely recognized projects in One-North — Biopolis and Launchpad@One-North — for in-depth case studies using our method. Besides providing causal explanations for some unusual developments that were accurately chronicled but not explained in the rational planning narrative, our evolutionary analysis also highlights a number of developments that did not occur as originally planned. In particular, the abnormally fast pace of the early development phase of Biopolis would not have been possible without the extraordinary and entrepreneurial championing by a maverick senior government official who had the political sponsorship of the powerful former and founding Prime Minister. In addition, the transformation of part of One-North into the largest start-up entrepreneurial hub in Southeast Asia was actually off-script, and was the result of “bottom-up” championing by the leader of a government digital media start-up micro-funding program and the leader of a university entrepreneurship support organization.

3. Research Findings

3.1 Re-Cap of Findings from The Rational Planning Narrative

To better appreciate the contribution of the evolutionary perspective, we will first recap the key development milestones of One North as presented from the Rational Planning view by CLC (2018). Table 1, column 2 reproduces the major milestones provided by CLC (2018), while

column 3 highlights relevant information on several key actors that had significantly influenced some of the development outcomes listed in column 2, but their roles have been missing or glossed over in CLC (2018)'s narrative.

TABLE 1. Major Development Timeline of One-North

Date	Key Development Milestones in the Rational Planning Narrative	Relevant contributing factors in the Evolutionary Development Narrative
1991		<i>Concept of a tech corridor next to NUS included in Singapore Land Use Concept Plan 1991</i>
1998		<i>Technopreneurship 21 announced by DPM Dr Tony Tan</i>
1999	Buona Vista Science Hub (later renamed One-North) announced as a key thrust of the Technopreneurship 21 initiative.	
2000	The JTC appointed lead agency for developing One-North	<i>Philip Yeo was appointed chairman of NSTB and renamed it ASTAR, and he made the development of Biopolis ASTAR's top priority</i>
2001	Phase Z.Ro Technopreneur Park developed as a pilot. One-North officially launched by DPM Tony Tan. Zaha Hadid Architects appointed as master plan consultant. Groundbreaking ceremony of Biopolis in Dec 2001.	<i>NUS established NUS Enterprise and established an Incubator on campus and the NUS Overseas College (NOC) program to provide experiential entrepreneurship training in overseas tech start-up hubs</i> <i>Philip Yeo started recruiting top biomedical researchers from overseas to come to do research in Singapore, and started the ASTAR biomedical PhD scholarship program ("whales and guppies" strategy)</i> <i>Philip Yeo struck a build and lease agreement with JTC to begin construction of Biopolis, without seeking approval from MOF</i>
2002		<i>First NOC program launched in Silicon Valley</i>
2003	Biopolis Phase One opened [in Oct 2003]	<i>Media 21 Plan launched by MDA</i>
2006	<i>Biopolis Phase 2 (Neuro and Immunos) opened</i>	<i>The National Research Foundation (NRF) was established</i>
2007		<i>MDA launched the iJAM micro-funding scheme for digital start-ups</i>

Date	Key Development Milestones in the Rational Planning Narrative	Relevant contributing factors in the Evolutionary Development Narrative
		<i>Philip Yeo stepped down as ASTAR chairman and became chairman of SPRING</i>
2008	Fusionopolis Phase One (Connexis and Symbiosis) completed.	<i>Phase Z.Ro Technopreneur Park was demolished, after extended period of low occupancy and activities</i>
2009	Development of Mediapolis started	
2010	Fusionopolis Phase 2B (Solaris) and Biopolis Phase 3 (Synapse and Amnios) completed.	
2011	Development of Mediapolis Phase Zero (later renamed LaunchPad @one-north) and Fusionopolis 2A started one-north Mass Rapid Transit (MRT) station on the Circle Line opened.	<i>Block71 was initiated by MDA, NUS Enterprise and Singtel Innov8</i> <i>Philip Yeo (as chairman of SPRING) struck agreement with JTC to construct the one north MRT, after LTA refused as it was not in its original MRT station development plan</i>
2013	Fusionopolis Phase 3 (Nexus) and Biopolis Phase 4 and 5 (P&G Singapore Innovation Centre and Nucleos) completed.	<i>MDA asked the tenant startups in Block 71 to vacate before its 3-year lease with JTC expired. After social media protests by the tenant start-ups, this eviction decision was stopped by Minister-in-charge of Entrepreneurship</i>
2014	Official opening of LaunchPad @ one-north. Fusionopolis Phase 4 (Sandcrawler) and Phase 5 (Galaxis) completed. Infinite Studios at Mediapolis opened	<i>JTC reversed decision to redevelop the old Ayer Rajah industrial estate into high rise office buildings, and redevelop it into a start-up hub instead</i>
2015	Fusionopolis Phase 2A (Innovis, Kinesis, and Synthesis) completed. Mediacorp moved into Mediapolis as anchor tenant.	<i>Launchpad@one-north (covering Block 71, 73 and 79) was officially launched by Prime Minister in Jan 2015. Redevelopment of another three buildings (75, 77 & 91) was announced.</i>

Source: “Rational Planning Narrative” Column: extracted from CLC(2018); “Evolutionary Development Narrative” Column: by author.

In broad terms, the rational planning narrative of CLC (2018) started with the recognition that, as far back as 1991, when Singapore’s first National Technology Plan was launched, the idea of a new integrated R&D and innovation hub had been mooted (NSTB 1991). In the same year, a Land Use Concept Plan had identified a cluster of mostly government owned land in the vicinity of the then new Buona Vista Mass Rapid Transit (MRT) station and directly opposite the National University of Singapore (NUS) across a major highway, as a potential site for such

a new hub. However, the idea appeared to have stayed dormant, until a major new economic development strategy called Technopreneurship 21 (T21 for short) was unveiled in late 1998 by the then Deputy Prime Minister, Dr. Tony Tan. As part of the T21 initiative, the Buona Vista Science Hub (BVSH) project was also announced, with the mission to achieve three goals - positioning Singapore for high-tech industrial activities, creating a focal point for R&D and high-tech activities, and developing an innovation milieu in the country (CLC 2018).

The narrative went on to identify the formation of a Steering Committee for the project, comprising of representatives from the various key government agencies and ministries, to provide strategic direction and to resolve policy-related issues and inter-agency conflicts. It was chaired by the Minister for the Environment and its members included the chairmen of the Economic Development Board (EDB) (the government agency responsible for attracting foreign investments), SPRING Singapore (the government agency responsible for local SME development), as well as the CEOs of the Urban Redevelopment Authority (URA) — in charge of land-use planning—, and the Land Transport Authority (LTA) — in charge of urban land transport.

The narrative then pointed out that a decision was made to appoint a government agency, Jurong Town Council (JTC), as the master-planning and development agency, given its track record in industrial estate development for the last 35 years, and the fact that the land in the One-North was mostly public. A number of operation-level committees were subsequently set up to provide inter-agency coordination (One-North review committee), to select the master planning architect firm (Master Plan Selection Committee) and to tap advisory inputs from relevant experts (Resources and Advisory Panel).

In line with the rational planning perspective, the subsequent major developments of One-North were narrated as largely being decided and executed through these governance structures and planning/implementation coordination mechanisms. The key physical development stages of each of the three major innovation clusters were then separately narrated in their chronological order, starting with Biopolis (ground-breaking in late 2001), then Fusionopolis (around 2006) and lastly Mediapolis (2009), with the implicit assumption that this was a deliberate strategic sequencing decision. The development of Biopolis and Mediapolis were presented as being directed by their respective designated lead government agency — the National Science and Technology Board (NSTB, later renamed Agency for Science, Technology & Research (ASTAR)) for Biopolis, and Media Development Authority (MDA) for Mediapolis. For Fusionopolis, no lead government agency was mentioned, but JTC itself appeared to have taken the lead role in earlier phases, while later phases were opened to private sector developers.

There was little inkling of major policy debates or conflicts in this rational planning narrative. While some disputes among the different government agencies were noted on a number of occasions (e.g. Urban Redevelopment Authority (URA), which had general policy oversight on permissible commercial space allocation in land use, initially objected to JTC's plan for commercial space in some mixed use precincts in One-North, these did not appear to be major, and were resolved through the above mentioned planning coordination mechanisms (CLC 2018). Indeed, throughout the narrative, it was implicitly assumed that broad consensus were achieved on most if not all major decisions through these rational planning processes, and actual development outcomes were implicitly interpreted as planned outcomes, with little mentioning of mistakes being made and recognized, and that resulted in subsequent policy changes or reversals. Thus, while the use of One-North as a test bed for new policy innovations was

mentioned quite a few times, there was virtually no mentioning of any new policy ideas that were trial-tested and failed.

3.2. Findings from the Evolutionary Analysis Perspective

While comprehensive in its review, the above rational planning narrative appears to be inadequate in two ways. Firstly, by glossing over possible debates and conflicts among key actors, that could have arisen as part of the development process, we have little insights on how the eventual development policy choices were arrived at. Secondly, by implicitly attributing the development outcomes to be the original envisioned outcomes, we are not able to assess how much the eventual development outcome actually deviated from original intent, whether positively or negatively, and what roles individual actors or other unforeseen factors could have contributed to this difference.

Using the analytical lens of evolutionary theory, and adopting an actor-level analysis, we provide an alternative historical narrative on two major developments in One-North that offers substantially different explanations and interpretations from the rational planning perspective.

a) The Genesis and Initial Development of Biopolis

As the first innovation cluster to be developed in One-North, Biopolis is strikingly unusual in terms of its remarkably fast development from ground-breaking to a very substantial hub with near full occupancy in its first two phases (2000-2006). This remarkable achievement was the result of one key championing actor — Philip Yeo—, widely recognized as the brainchild and champion of Singapore's strategy to become a leading Biomedical Sciences (BMS) hub in the world. The development of Biopolis was an important part of his overall BMS strategic thrust,

and cannot be understood without taking into consideration the vital contribution of the other key elements of this strategic thrust.

After completing his engineering degree overseas on a government scholarship, Yeo returned to serve in the Singapore Administrative Service from June 1970 to March 1999, taking on various appointments in the Ministry of Defence (MINDEF), including Permanent Secretary for logistics, technology research & development and defence industries. During his time in MINDEF, he became known to, and highly trusted by, the then Prime Minister Lee Kuan Yew, deputy prime minister Goh Keng Swee and Defence Minister Howe Yoon Chong through his outstanding, if maverick, track record of taking on challenging assignments and getting things done, including creatively breaking rules if necessary (Peh 2016). The trust of the top political leaders, coupled with his reputation for integrity, had protected him from being sanctioned for repeated rule-breaking. From 1980-87, he also served as the first Chairman of the National Computer Board (NCB), and is credited for his leadership role in formulating and executing Singapore's first national computerisation plan. In 1986, he was appointed as chairman of Economic Development Board (EDB), the lead government agency responsible for attracting foreign investment into Singapore to generate economic growth and create high value adding jobs. Through his leadership, EDB successfully shifted the focus of investment attraction from more established industries to new areas of business, including internationally exportable services, semiconductors, aerospace, speciality chemicals, and pharmaceutical manufacturing. Yeo is credited with making Singapore a leading global petrochemical processing hub by merging seven small islands through land reclamation to form an integrated complex, as well as pioneering Singapore's participation in overseas infrastructure development projects such as



those in the Bintan Industrial Estate in Indonesia and the Wuxi-Singapore Industrial Park in China (Peh 2016).

In the late 1990s, Yeo became convinced that Biomedical Sciences (BMS) innovation was the next big high value creating industry that Singapore needed to shift towards, and became a passionate champion for greater government investment in this new area. Prior to 2000, while Singapore had already become an important manufacturing hub for global pharmaceutical companies, there was little private sector biomedical R&D activities being performed in Singapore. Although NUS Medical School had some applied biomedical research activities, and a number of public research institutes in life sciences (Institute of Molecular & Cell Biology, IMCB) and Bioprocessing Technology Institute (BTI) had been established prior to 2000, the overall scale of biomedical research was small, and little commercialization resulted from it yet (Finegold, Wong and Cheah 2007, Wong 2007).

Following the first public announcement of the Technopreneurship 21 strategy in late 1998, the plan to establish a Science Hub in Buona Vista area (the land area near to the National University of Singapore) to provide new space for integrated research, innovation and entrepreneurial start-up activities was unveiled in 1999. While biomedical sciences was highlighted as one of several key innovation clusters to be promoted in this new Buona Vista Science Hub (BVSH), few details were provided at that stage.

Through Yeo's championing, the government unveiled an ambitious strategy to make Singapore a leading global hub for Biomedical Sciences (BMS) innovation in June 2000 (Beh 2004). The strategy involved three prongs: industrial development (to be led by EDB's Biomedical Sciences Group, EDB BMSG), strategic investments in companies (to be led by EDB's new \$1 billion venture capital fund Bio*One Capital) and substantially increasing

funding of public sector and university research in BMS (to be led by NSTB's Biomedical Research Council, BMRC).

Integral to this BMS strategy was the creation of a major BMS innovation cluster in BVSH (which by then has been renamed One-North), to be led by NSTB's BMRC. Yeo, who as chairman of EDB had been championing the attraction of BMS manufacturing investment by foreign pharmaceutical MNCs, got himself appointed as chairman of NSTB just before the BMS strategy was unveiled, while still retaining a co-chairmanship role at EDB overseeing BMSG and Bio*One Capital. Through this joint appointment, Yeo was thus able to assume a holistic leadership role over the entire BMS innovation strategy. Upon taking on NSTB's chairmanship role, Yeo promptly renamed the organization as Agency for Science, Technology and Research (ASTAR), and made the development of Biopolis its top priority. In effect, although the overall T21 initiative was led by the other co-chairman of EDB, Teo Ming Kian (who reported to the then Deputy Prime Minister), and was not primarily about BMS, Yeo had seized upon it to advance his BMS agenda.

Yeo's championing role not only made BMS the first innovation cluster to be built in One-North, but also explained the extraordinary speed at which it got built. Firstly, rather than the traditional route of writing an elaborate plan to seek funding from the Ministry of Finance (MOF), Yeo struck an unusual build-and-lease deal with JTC, the government agency in charge of One-North development master planning (Peh 2016). As part of the inter-agency agreement, ASTAR was initially given 60% ownership of the public land lease for Biopolis, with JTC owning the other 40%. Yeo offered to transfer ASTAR's share to JTC as construction payment, and convinced JTC (as the landlord) to construct the building and lease it back to ASTAR (as the tenant) for a 10-year lease (Peh 2016, 156). Through this creative arrangement, Yeo not

only bypassed the lengthy process of seeking funding approval from MOF, but also the associated lengthy tender process for public construction projects.

Besides speeding up the commencement of construction, Yeo also pushed JTC hard to speed up the construction process, resulting in the completion of Phase 1 of Biopolis, comprising of a cluster of seven interconnected buildings, within 14 months (Aw 2015), and the full commissioning of the buildings for occupation by October 2003, less than 2 years from the initial ground breaking in December 2001.

In parallel, as chairman of ASTAR from 2000, Yeo quickly funded the establishment of three new BMS-related institutes (Genome Institute of Singapore, GIS, in 2000, Bioinformatics Institute, BII, in 2001, and Institute of Bioengineering and Nanotechnology, IBN, in 2003). Together with the two existing research institutes IMCB and BTI, these five new public research institutes (PRIs) became the first anchor tenants of Biopolis. Leveraging his leadership position in EDB-BMSG, Yeo was also able to simultaneously deploy EDB's various investment incentives to attract a strong pipeline of global BMS companies to move into Biopolis as soon as it was ready. These included Novartis Institute for Tropical Diseases, Vanda Pharmaceuticals, Illumina, Paradigm Therapeutics, Waseda-Olympus Bioscience Research Institute and Johns Hopkins University Medical School. In addition, the Health Sciences Authority (HAS), the regulatory body for healthcare sciences and services in Singapore, also moved into Biopolis (Beh 2004).

As highlighted by Killen, Palladino and Gonzalez (2021), the co-location of major BMS PRIs within Biopolis provided the initial critical mass to enable the continued attraction of major global biomedical multinationals. The high initial occupancy rate of Phase 1 also bolstered JTC's confidence in attracting more players to Biopolis, and led to the early follow-on



development of Biopolis Phase 2 (Neuros and Immunos, opened in 2006), as well as Phase 3 (Synapse and Amnios, opened in 2010). As can be seen from the timeline in Table 1, the first Fusionopolis building did not get completed until 2008.

In parallel with funding new PRIs and attracting foreign biomedical companies, Yeo also created and executed an audacious program to attract the critical talents to staff these organizations. Calling his two-prong talent attraction strategy “Whales and Guppies”, Yeo sought to attract top scientists in the world (the “whales”) to head up the PRIs in Singapore, and simultaneously recruiting many young researchers (the “guppies”) to work with and be trained by them.

Leveraging a relationship he had earlier developed with Nobel laureate Dr. Sydney Brenner, Yeo convinced Brenner to be an advisor to his BMS strategy. With Brenner’s help, Yeo compiled a list of 100 top biomedical scientists in the world and personally went to meet most of them to try to attract them to come to Singapore to lead major BMS research programs (Hang, Low and Thampurant 2016). The first top scientist he attracted was Dr. Edison Liu, former director of clinical sciences at the U.S. National Cancer Institute, who became founding executive director of Genome Institute of Singapore. Other prominent catch followed within the next 3 years, including Dr Sir David Lane, from the University of Dundee, Scotland to become the Executive Director of IMCB; Dr Alan Colman, formerly from UK-based PPL Therapeutics, to become the Chief Scientific Officer of ES Cell International, a biotech start-up funded by EDB Bio*One; Dr Jackie Ying, an MIT professor, to become the Executive Director of IBN; and Dr Yoshi Ito, from the University of Kyoto in Japan, to become a Principal Investigator at IMCB (Beh 2004).

For the second prong of his talent attraction strategy, Yeo launched an ambitious ASTAR scholarship program to fund bright Singaporean undergraduates or recent graduates to pursue PhD education in BMS fields in leading universities around the world. The generous scholarship not only covered all tuitions and living expenses, but included an additional monthly cash top-up to compensate for their forgone earnings while doing their PhD studies. In return, the young PhDs were to be bonded to work in Singapore's BMS sector (especially in Biopolis) for several years. Such unusually generous scholarship was not only unheard of among public sector organizations, but Yeo actually did not have an approved budget in ASTAR to do so. Without asking for approval, Yeo diverted ASTAR's research budget to fund the scholarship instead. Yeo deliberately offered the scholarship to only Singaporeans, as he was concerned that many of the researchers in his BMS research institutes were foreigners, and he wanted to groom a future generation of Singaporean BMS scientists and innovators.

Yeo's orchestrated, multi-prong approach to BMS innovation cluster development, by complementing the physical infrastructure development of Biopolis with public-private sector co-location, investment incentives, public research funding and venture capital, and the recruitment of top scientists and young PhDs, significantly accelerated Singapore's move towards becoming a leading global BMS innovation hub. The creation of Biopolis in One-North benefited significantly from, but also contributed significantly to, his overall BMS strategy: Besides the physical infrastructure, Biopolis also provided an early iconic brand for the whole BMS strategy, as well as a credible signal of Singapore government's long-term strategic commitment to BMS (Killen, Palladino and Gonzalez 2021).

Yeo's imprint is manifested in the distinctive physical form of Biopolis itself as well. Inspired by what he learned from highly innovative places he saw in Silicon Valley and elsewhere, Yeo

wanted the physical layout and design of Biopolis to facilitate physical connectivity and social interactions among the building occupants, and this requirement was well reflected in the distinctive architectural and landscape design made by the architect Zaha Hadid. The seven buildings of Biopolis Phase 1 are interconnected with sky-bridges, and share a common underground carpark and a continuous roof carpet. To maintain vibrancy at street level, the buildings were built closer together than conventional setback standards, with reduced road reserves and narrow streets. The height of kerbs was also reduced to make it easy for pedestrians to cross roads, and the curved road layout created enclosed and walkable spaces that maximize outdoor, street-level social interactions (CLC 2018). In contrast, because the same insistence on connectivity among buildings was not made in the later development of Fusionopolis and Mediapolis, the physical layouts of these two precincts reverted back to conventional setback standards for typical business parks (CLC 2018).

In summary, our actor-level analysis strongly suggests that, absent a strong entrepreneurial champion like Yeo, it is highly unlikely that a committee of senior civil servants from multiple government agencies could have developed and executed a similar strategy in an equally short time. The significant imprinting of dominant actors on the early growth trajectories of business organizations and industries has been extensively documented in the business research literature.¹ Our analysis of Biopolis in One-North suggests a similar dominant actor imprinting, albeit in the public sector context.

¹ See e.g. Marquis and Tilcsik 2013

b) The Genesis and Development of Launchpad@one-north

In contrast to the Biopolis case where a dominant actor exerted extraordinary influence on the early development of a plan, our analysis of the development of the tech start-up hub in One-North suggests what may happen when such a dominant champion is absent.

As its name suggests, the Technopreneurship 21 (T21) initiative's primary goal was on promoting technology entrepreneurship in general, rather than start-ups in specific technology sectors. Indeed, the key impetus for the T21 initiative was the dotcom boom in the US in 1997-98, which led to heightened interest in the "Silicon Valley" model for wealth creation through tech startups and venture capital investment among the political leadership of Singapore, particularly Dr Tony Tan, the then Deputy Prime Minister (Wong 2001). Tan chose to announce the new T21 initiative at the annual Techventure Conference in 1998, an event for the tech startups and venture investment community that was started by NSTB to promote technology startups (Tan 1998).

The subsequent prioritization of three technology clusters — biomedical, physical sciences/engineering/ICT, and digital media — occurred to facilitate the delegation of lead responsibility to different government agencies, and in the context of One-North's initial concept plan, to guide strategic spatial clustering —Biopolis, Fusionopolis, Mediapolis— (CLC 2018). In spite of such sectoral prioritization, however, the core policy focus of T21 remained on promoting technology entrepreneurship in general, as can be seen from various new policies that Tan subsequently announced in 2002 (Tan 2002). These range from promoting interest in entrepreneurship among university students, promoting angel investments for early stage startups, a Technopreneur Home Office (THO) Scheme to allow technopreneurs to use public housing as home offices, a Technopreneur Pass scheme that relaxed immigration rules to allow

foreign entrepreneurs to stay in Singapore without a confirmed job, and making it easier for directors of bankrupted businesses to start new businesses.

Unlike the case of BMS hub strategy, however, the implementation responsibilities of technology entrepreneurship promotion under T21 was fragmented among different government agencies. While NSTB was designated the main agency to lead the multi-agency T21 initiative when it was first launched in 1999, that role was transferred to EDB in Jan 2001 (Tan 2002). However, EDB's lead role also diminished over time. For example, a business angel co-investment scheme was launched by EDB in 2002, but it was later shifted to SPRING, the government agency in charge of SME promotion (Wong and Singh 2012). A \$1 Billion Technopreneurship Investment Fund (TIF) was created as a fund-of-fund to invest in venture capital funds, but it reported to the Ministry of Finance and invested mostly in venture capital funds overseas, with minimal impact on the local venture capital industry. Modest funding was channelled to the local universities and polytechnics to promote entrepreneurship education and start-up activities among tertiary students, but the institutions were free to develop their own programs as they saw fit.

In this decentralized policy environment, JTC started a pilot project called "Phase Z.ro" in 2001 to provide temporary office space (made out of ship containers) for early stage tech startups at the northern corner of One-North. Occupancy rate was initially high due to its low rent (CLC 2018), but in later years it appeared to have declined significantly (TheUnchartedWater 2016), and the facility was demolished in 2008.

In 2006, a new National Research Foundation (NRF) was created under the Prime Minister's Department to provide central coordination of research, innovation and enterprise startup policies, and T21 was quietly disbanded. By then, a number of the T21 tech startup promotion

programs had completed their gradual transfer to SPRING. Nevertheless, technology entrepreneurship policies continued to be fragmented. As an example, SPRING had an early stage startup funding program called SEEDS, but MDA also launched a seed funding program (called iJam) in 2006 for digital media startups, while NRF launched a Technology Incubation Scheme (TIS) in 2009 that co-funded 16 early stage investment groups to invest in startups. All three funding schemes ended up overlapping substantially, as most of the tech start-ups during that period were in the internet/mobile/IT space (Wong 2019). In contrast, there was little public co-funding support for early stage venture investment in “deep technology” start-ups, because these types of start-ups entailed higher risks and higher quantum of investment even at the seed stage, and required venture investors with specialized technical domain knowledge that Singapore lacked (Wong 2019; World Bank, 2021).

Despite the growing amount of public seed funding for tech start-ups from the second half of 2000s, the number of funded tech start-ups remained relatively small throughout the decade of 2000s, because the supply of tech entrepreneurs was actually still quite limited. An initial wave of tech start-ups in the late 1990s in tandem with the global dotcom boom was followed by a big drop in start-ups in tandem with the dotcom crash in early 2000s. In this regard, by the time that T21 policies were rolled out, the global environment for tech start-ups had turned negative, making it harder for these policies to have substantial immediate impacts. We suspect Phase Z.ro was adversely affected for this reason as well, leading to its closure in 2008.

It was only from early 2010s that a second wave of tech start-up emerged (Wong and Ho 2017; Wong 2019). While the increase in seed funding in the second half of 2000s may have contributed, a more important driver was the growing number of university students and young graduates, especially from NUS, choosing to become tech entrepreneurs. A decade earlier,

NUS had set up an entrepreneurship support program called NUS Enterprise (Wong, Ho and Singh 2007 and 2014). Right from the start, NUS Enterprise launched an experiential entrepreneurship education program called NUS Overseas Colleges (NOC), through which it sent two cohorts of undergraduate students each year to do full-time internship at early stage tech start-ups for up to a year in leading entrepreneurial hubs across the world to learn first hand about tech entrepreneurship (Wong, Ho and Ng 2019). Starting with around 50 students in Silicon Valley in 2002, the program was progressively expanded over the years to over 300 students per year spread across 9 locations covering Silicon Valley, New York City and Toronto in North America, Shanghai, Beijing and Shenzhen in China, and Israel in the Middle East, Stockholm and Munich in Europe. Returnees from these programs were found to have much higher propensity to engage in start-up activities than normal graduates from NUS (Wong, Ho and Ng 2019). As more and more of these students returned, the number of start-ups by such NOC alumni began to climb, contributing a disproportionate share of tech startup formation in Singapore from the late 2000s onwards. A study in 2018 found that NOC alumni founded start-ups accounted for over 8% of tech start-ups in Singapore that have received external funding, even though such alumni accounted for less than 0.5% of graduates from local institutions of higher learning (Wong, Ho and Ng 2019). In 2020, the three most successful NOC alumni start-ups were estimated to have accounted for over 40% of the total value of start-ups in Singapore (NUS Enterprise Academy 2021).

In the first decade (2000-2010), NUS Enterprise operated an incubation support program, including co-working space, within its campus (Wong, Ho and Singh 2014). With growing demand, however, the CEO of NUS Enterprise, Dr. Lily Chan, started to look for additional incubation space outside the campus. Coincidentally, Michael Yap, the director of MDA's iJam

program, also started to look for space to accommodate the increasing number of start-ups it funded. Although Mediapolis would have been an ideal place to accommodate these start-ups, its development had been repeatedly postponed, and was expected to be opened only in 2014. Being well acquainted with each other through their active role in the start-up community (as well as through Yap's iJam funding of several NUS Enterprise incubated start-ups), the two decided to join force to find a larger common space.²

As it so happened, JTC owned an old industrial estate comprising of several somewhat run-down multi-storey factories for SMEs within the Ayer Rajah precinct of One North, just a short distance away from NUS campus. Coincidentally, beginning in 2000, JTC started to terminate the leases of these SMEs en-masse with a plan to progressively demolish the vacated buildings to make way for building new high rise offices and retail spaces, as an extension of Fusionopolis. Sensing the opportunity, Yap offered to take a 3-year lease for one of the 7-storey buildings that was only slated for demolition in 2014, and invited Chan to share the leased space and cost. Around that time, a common acquaintance of both, Yvonne Kwek, was heading up a new corporate venture capital (CVC) fund (Innov8) of Singtel, the largest telco in Singapore, so they persuaded her to join in taking up part of the space. After some minimal renovations (to keep cost low), the building was opened in 2001 as a no frill, affordable space for start-ups. Although officially named as Phase Zero of Mediapolis, the place became widely known instead as Block71 (its original building block number) (Chew and Neo 2017).

Serving as anchor tenants, the three founding organizations (MDA iJam, NUS Enterprise and Innov8) were able to fill only about half of the spaces with their own offices and about 120 of

² Chan, personal communication.

their incubatee start-ups. To fill up the remaining spaces for another 160 startups, NUS Enterprise extended most of its own on-campus start-up events, training workshops and networking meet-ups to Block71 to create buzz and to market the place to start-ups, investors and incubators from across Singapore. Within a year, Block71 began to reach near full occupancy, and became widely known as the most vibrant start-up hub in Singapore. Block71's growing popularity as a start-up hub prompted the Economist magazine to dub it "the world's most tightly packed entrepreneurial ecosystem" (The Economist 2014). A recent study suggests that start-ups that grew out of Block71 accounted for almost one-quarter of the total value of start-ups in Singapore in 2020 (NUS Enterprise Academy 2021).

Besides its low cost and the critical mass of diverse start-ups, investors and incubators co-located in one dense building, the attractiveness of Block71 was also boosted by the opening of a mass rapid transit (MRT) station at nearby Fusionopolis Phase 1 in 2011, making it much more accessible by public transport. This development was actually not according to plan, and was the result of an intervention by Philip Yeo, who had stepped down as Chairman of ASTAR in 2007 and moved to become chairman of SPRING, which moved into Fusionopolis in 2008. The original plan for a new MRT line (Circle Line) by LTA was to connect the existing Buona Vista Station at the northern end of One-North to the new station at NUS Medical School, with the line running through One North but no station in between. Yeo felt strongly that an MRT station should be built within One-North, but LTA refused as it did not have the budget for the extra station, so he negotiated with JTC to pay for the cost of construction (Peh 2016).

Three months before the 3-year lease for Block71 expired in Feb 2014, MDA notified the early tenants of Block71 to move out by the expiry date. This created an uproar among the affected tenant companies, and the social media storm led to a prominent coverage of the issue in the

mainstream media (Chng 2014). This caught the attention of the then Minister-in-Charge of Entrepreneurship as well as the leadership at JTC and SPRING. After a series of inter-agency deliberations and dialogue with the wider start-up community that voiced their strong support for maintaining and expanding the Block71 hub, JTC announced a major decision to reverse its earlier plan to demolish the old Ayer Rajah industrial estate to make way for a new extension of Fusionopolis; instead, it would turn the entire industrial estate into a low-cost start-up hub, by renovating the blocks adjacent to Block71 — Block 73 and 79 — to accommodate more start-ups, investors and incubators. The new expanded start-up hub was officially launched by the Prime Minister in January 2015 under the new name of Launchpad@one-north, and a further expansion of the hub to include the remaining buildings in the old estate (Block 75, 77 and 91) was announced (Chew and Neo 2017). Fully completed in 2019, the hub was estimated to have a total floorspace of 600,000 sq ft and accommodated over 800 startups and other start-up ecosystem players (JTC, 2021).

From an evolutionary perspective, the T21 initiative that catalysed the One-North Innovation District development did not actually realize its initial plan to incorporate a vibrant technology start-up ecosystem within One-North until a decade later, and in a manner that was not as originally envisaged: JTC's initial start-up hub Phase Z.ro was abandoned in 2007, only to re-surface several years later in a different location that it had originally slated for other purposes. To its credit, JTC leadership responded well to the new, unplanned development at Block71, and managed to change course to co-opt the externally championed initiative into its fold.

4. Conclusion and General Implications for Innovation District Development

Taking an evolutionary view and using an actor-level analysis of the development process of two major innovation clusters in One-North, we have offered proximate explanations of the

timing and evolutionary trajectory of these two clusters that differ from, or are missing/glossed over in the rational planning narrative of prior work (CLC 2018, Chia 2018). In the case of Biopolis, the key development milestones and their timing are not in dispute, but the pivotal role of a dominant actor was glossed over or downplayed, leaving its extraordinary development outcomes unexplained. In the case of Launchpad@One-North, the (implicit) inference that the start-up hub was a pre-planned outcome in terms of choice of location and development timing was at significant variance with the actual evolutionary process.

Our actor-level analysis findings are consistent with considerable prior entrepreneurship and innovation research that show that the passionate championing roles of key individual actors often exert disproportionate influence on the outcome of new, uncertain undertakings (Schon 1963, Howell and Higgins 1990); Schon's early observation that "new idea either finds a champion or dies. No ordinary involvement with an idea provides the energy required to cope with the indifference and resistance that change provokes" (Schon 1963) appear to be valid for public innovation projects as well.

Unlike many other governments where political factional fights and bureaucratic gridlocks are rife, Singapore has a dominant political party and a relatively efficient state bureaucracy with a generally pro-business regulatory regime, a meritocratic civil service ethos and a well-functioning multi-agency coordination approach to policy making and implementation (WEF 2020). Nonetheless, our analysis of One-North has found that, even with such an efficient and meritocratic civil service, top-down rational planning still has its limits when it comes to radically new public innovation endeavours, and the roles of individual champions with passionate vision are still critical to overcome bureaucratic roadblocks. In more complex environments where power is more decentralized and factional interest groups are more

entrenched, it is all the more important for researchers to adopt an actor-level analysis to analyse the evolution of major new, innovative public projects such as innovation district development.

Our analysis findings on Biopolis development also clearly highlighted that the development of physical spaces for innovation must be part of a holistic innovation ecosystem development policy that includes other complementary support elements such as talent development, risk financing, and investment incentives for private sector actors. In contrast, our analysis findings on the development of start-up hub suggests that fragmentation of policy implementation, while empowering a larger number of actors and experimentation, could lead to less coherent evolutionary outcome, if no strong champions emerge to act as a strong selection mechanism on the greater variations generated.

In closing, we acknowledge a number of limitations of our research on Singapore's One-North development history that in turn could suggest possible future research directions. Firstly, our research has relied almost entirely on secondary data and archival records that are available in the public domain. Future research could benefit from additional primary data gathering, including in-person interviews with the various actors concerned to corroborate, or to add nuance to, our reported findings. Another limitation of our research is that it has focused on studying only two of the innovation clusters in the broader innovation district development plan. Future research should therefore broaden the scope of study to cover the other innovation clusters as well. Last, but not least, future research could apply our actor-level, evolutionary analysis methodology to develop more case studies of major public innovation projects, in Singapore or elsewhere, thereby enabling comparative research on the role of key actors and their championing process in radical public innovation.

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