Evolving physical infrastructure to support open innovation in the digital age: case studies from the UK

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Abstract

This paper explores the design and evolution of publicly funded physical infrastructure projects specifically designed to support the implementation of open innovation. Our aim is to understand how the strategies and operations of these projects have evolved over time in response to contextual factors in order to draw lessons for others involved in providing support for open innovation in specific geographic locations in the digital era. We focus on the design and evolution of three open innovation infrastructure projects implemented in the UK in the period 2009-2016. Our key conclusions are focused on the contingent aspects of location; the different value offered by the physical and on-line aspects of the infrastructure; the gap between policy discourse and policy implementation for open innovation; the need for business model resilience and adaptability; the relative merits of specialisation versus generalisation; and the emerging dual focus on key infrastructure outputs being both innovation projects and the development of skills and capabilities for individuals.

Introduction

This paper explores the design and evolution of publicly funded physical infrastructure projects specifically designed to support the implementation of open innovation. Our aim is to understand how the strategies and operations of these projects have evolved over time in response to contextual factors in order to draw lessons for others involved in providing support for open innovation in specific geographic locations in the digital era.

Open innovation is a concept that continues to attract much interest from the academic, commercial and public sectors [1-3]. One gap in knowledge identified by academics and practitioners alike is in understanding the role of different types of physical infrastructure in specific locations in the successful implementation of open innovation [4]. Physical infrastructure for open innovation typically encompasses facilities that can be otherwise labelled as – or combine elements of – business incubators, shared workshops or labs, meeting spaces, *et al*. Examples of the development of physical infrastructure for open innovation can be seen in the activities of some multinational corporations that have sought to develop open innovation ecosystems based around their own R&D facilities (e.g. Philips in Eindhoven (Netherlands)[a], Unilever in Colworth (UK)[b], and Daikin in Osaka (Japan)[c] as well as those that have invested in new R&D activities within existing innovation clusters (e.g. AstraZeneca in Cambridge (UK)[d], SAP in Bangalore (India)[e] and BMW in Silicon Valley (USA)[f]). Research also shows that open innovation issues influence some small and medium sized enterprises (SMEs) when assessing choices of location for their businesses, and hence

[a] https://www.hightechcampus.com/
[b] http://www.colworthpark.com/
[c] http://www.daikin.com/about/corporate/tic/
[d] https://www.astrazeneca.com/our-science/cambridge.html
[e] http://www.sap.com/india/ms/sap-labs-india/about/overview.html
[f] http://www.bmwmagazine.com/int/en/node/2317

the role of supporting infrastructure for open innovation may be a factor influencing their location decisions [5, 6]. On the other hand, the widespread diffusion of digital networks and associated services has been predicted by many to lessen the need for geographic proximity to support collaborative innovative activities (built around the 'Death of Distance' concept as proposed by, amongst others, Cairncross [7]). Given the widespread diffusion of technologies to support on-line communication and collaboration, the case for investing in expensive and inflexible physical assets at specific locations to support collaborative innovation would seem to be weakening. Within this changing context, our research explores examples of different approaches taken to the design and evolution of physical infrastructure projects designed to support the implementation of open innovation. In particular, we focus upon projects that have received substantial public investment but with strong involvement of private sector and academic partners. We choose such projects as they present some of the most interesting issues to explore, given the complex, changing, and sometimes conflicting performance measurement and audit requirements of public and private sector investments. Our chosen projects are also examples of initiatives that have had to transform to respond to significant changes in the implementation of innovation policy in the UK.

The paper thus aims to answer the question: *How have three examples of jointly public and privately funded open innovation physical infrastructure projects in the UK responded to a changing innovation policy context in the digital age?*

Our paper is structured as follows. First we provide a brief overview of relevant literature structured around three themes: open innovation and location; infrastructure for open innovation; and business models to support the operation of open innovation infrastructure. Next, we describe the methodology chosen to capture, structure and analyse our data. We then provide a summary of the changing industrial and policy context within which our case study projects were launched and developed. This is followed by a description of our three

case studies, and a discussion of how their strategies and operations changed through three phases of their evolution in response to a changing innovation policy context. Finally, we present the conclusions emerging from this analysis.

Literature review

Open innovation and location

The open innovation paradigm implies that firms of all sizes will come to rely more and more on external connections (with universities, suppliers, competitors, customers, *et al*.) for creating and capturing value throughout a value chain [8, 9]. This paradigm points to the need to consider not only the activities of the firm but also the broader environment in which these activities are embedded. This broader environment – or system of innovation – can be defined as: "*including all important economic, social, political, organisational, institutional, and other factors that influence the development diffusion, and use of innovations*" [10]. System boundaries can be determined in terms of sectors, activities, or location [10].

Location can be considered in terms of (a) absolute geographic location; (b) proximity to a specific resource; and (c) an organisation's position in a network [4]. An organisation's *geographic location* determines the system of innovation within which it operates, and that may qualify it to take part in certain activities (e.g. eligibility to apply for certain regional funding and innovation support programmes) [10] and access other infrastructure elements (e.g. engagement with local universities and colleges) [11, 12]. *Proximity* can be viewed in two ways: as relative geographic location or spatial distance, and as relative organisational/cultural compatibility or cognitive distance [11, 13, 14]. Cognitive distance is considered to be more important than spatial distance for knowledge transfer, assimilation and application [14]. Finally, an organisation's *position in a network* can both enable and constrain opportunities for access to external knowledge and new markets and influences the

likelihood of knowledge received being novel [15]. Moreover, it determines the relational/social assets and capabilities it can create or gain access to [16].

Infrastructure for open innovation

Infrastructure can be considered in terms of physical resources (e.g. buildings, equipment, transport and communication links) and virtual resources (e.g. networks of expertise, funding, and business support programmes). Physical infrastructure is sometimes viewed as a 'hygiene factor' for innovation [17], i.e. necessary but not on its own sufficient to support innovative activities [18]. The virtual resources encompass the underlying functional processes (including standards and IP agreements) that allow collaborative interaction to take place between organisations.

Research exploring the public policy aspects of the provision of support for open innovation covers a very wide canvas [19] and highlights the importance of considering policies beyond those targeting R&D and collaboration to include entrepreneurship, education, science, labour markets and competition [20].

Several areas of research provide insight on various aspects of physical infrastructure for open innovation. These include work on the role of universities in regional systems of innovation and the emergence of the 'impact agenda' for universities [21-24], the location and transformation of R&D activities of multinational corporations [25], the role of intermediate technology institutes [26], the design and operation of 'innovation laboratories' [27], and the operation of science parks, research parks, and business incubation facilities [18, 28].

For the virtual aspects of open innovation infrastructure, organisations need to ensure that their collaborative networks consist of a heterogeneous set of contacts and that there is a balanced mix of strong and weak, formal and informal ties in order for it to be able to access

diverse knowledge bases and resource groups, increasing the likelihood of being exposed to novelty [13, 15, 29, 30]. The management of inter-organisational network resources (social and relational assets) and the governance of inter-organisational relationships may be an explicit infrastructure function [31-33].

Business models to support the operation of open innovation physical infrastructure

The ways in which infrastructure to support open innovation can be delivered in a manner that is commercially sustainable and addresses the needs of diverse stakeholders has not been addressed in the literature in much depth. The literature on science parks, innovation centres and business incubators offers a view of the types of business models that are applied to maintain both the built environment and the underlying functional processes [18, 28, 34, 35]. This literature highlights four themes that relate to our research: (1) the physical and virtual aspects to the business models of science parks, innovation centres and incubators are essential to their success; (2) there are typically multiple stakeholders involved the funding and governance of such facilities; (3) the business model and operations need to fit with the characteristics of the local or regional innovation system within which the facilities are positioned; and (4) measuring performance is complex, given the differing viewpoints of the multiple stakeholders typically involved in such initiatives [18, 28].

We can see that there are many strands of research that contribute different aspects of understanding related to our research question. However, much of this work tends to be at either a very broad level, or focuses on very specific elements of the issues we are seeking to understand. Little work has been targeted at addressing the evolving strategic and operational challenges of delivering physical infrastructure projects to support open innovation in an era

when such tangible, inflexible and expensive assets would seem to be ripe for replacement with digital solutions not tied to a specific location.

Methodology

The type of issues we are addressing (multiple stakeholder, multiple levels of analysis, complex interactions, evolution over time, etc.) and the lack of prior research point to the use of case studies as an appropriate form of data collection [36]. However, the use of case studies in organisational research carries a number of well-recognised drawbacks, among which generalisation is often perceived as one of the most significant [37]. We recognise that the details of some of the insights revealed through the case studies will have limited generalisability. However, we believe that our the cases deliver insights on how emerging management theories may influence innovation policies, reveal some of the complexities of managing changing multi-stakeholder interests in relation to an approach to open innovation support, within an evolving economic and political context, and provide a basis for further research.

We selected case studies of jointly publicly and privately funded regional infrastructure programmes in the UK that were targeted at supporting innovation through collaborative activities. This focus aligned with a specific aim of UK regional innovation policy in mid- to late-2000s, i.e. supporting regional resilience [38] through capital investments that encouraged collaborative approaches to innovation, developed and delivered in partnership with private sector partnerships [39, 40]. For this exploratory research, our cases studies were selected to encompass a broad range of scale of public investment (from UK£2-40m per project).

The three projects selected for investigation are summarised in Table 1. Evidence to support our analysis was captured from a combination of primary and secondary sources. Primary

sources included semi-structured interviews with managers within each organisation, representatives of the funding and partner organisations and tenant companies carried out in the period 2009-2016, and participant observation with one author as an unpaid member of the steering committees for two of the case study organisations (ideaSpace Enterprise Accelerator and Colworth Park). Secondary sources included practitioner reports, corporate presentation materials, published cases studies, publicly available documentation relating to the projects accessed from the UK National Archives[g] and the Internet Archive[h]).

Table 1: Summary of case study organisations at time of launch

	Manufacturing Technology Centre (MTC)[i]	**Colworth Park[j]**	**ideaSpace Enterprise Accelerator[k]**
Self description	"[..] *providing collaborative partnerships that take the ideas coming out of academia and look to develop them into commercial reality within industry*."	"[..] *a facility to support growing businesses and facilitate open innovation*."	"*A regional resource for enterprise and open innovation*"
Key elements	Development and demonstration facilities and support for innovation related to advanced manufacturing technologies	Office space, lab space, scientific support, conference and meeting facilities, connections to academic partners	Office space, supporters network, membership programme, events, sponsorship
Scale	12,000m^2	5,000m^2	Initially 300m^2
Sector focus	Manufacturing technologies	Food > health and wellness > science	No explicit sector focus, though majority of firms ICT-related
Partners (at launch)	University of Birmingham, Loughborough University; University of Nottingham, TWI, Rolls-Royce, Aero Engine Controls, Airbus, Advantage West Midlands and East Midlands Development Agency	Unilever, Goodman, EEDA, Cranfield University, University of Cambridge, University of Nottingham, Institute of Food Research	Hauser-Raspe Foundation, EEDA, University of Cambridge, Babraham BioScience Technologies, Institute of Directors
Public funding received	UK£40m	UK£4.4m	UK£2m

[g] http://www.nationalarchives.gov.uk/
[h] https://archive.org/
[i] http://www.the-mtc.org/
[j] http://www.colworthpark.com/about/
[k] http://www.ideaspace.cam.ac.uk/

Case studies

Context

Before presenting the detailed description of our case studies, two important aspects of the context within which these initiatives were launched and developed needs to be provided. Firstly, there is the changing context for industrial innovation. During the period of observation for our case studies, firms in many industries were undergoing substantial transformations in their approaches to innovation. As has been widely documented elsewhere (e.g. [8, 9, 41, 42]) a number of factors aligned to change the way in which companies innovate. By observing and reflecting on these factors and on the lessons provided by the examples of success and failure in leading corporations, a coherent model for describing and operationalizing this emergent approach to innovation – *open innovation* – was articulated by Chesbrough [8]. This open innovation model showed firms how they could access and absorb external knowledge, combine it with internal knowledge and consider a variety of potential outlets for its exploitation.

The management of many leading firms recognised that open innovation presented a potential solution to addressing the diminishing competitiveness of their current innovation infrastructure and used open innovation as the model around which they could transform their approach to innovation.

The shift towards openness in innovation had been gradual and examples can be traced back long before the publication of Chesbrough's initial articulation of the open innovation model in 2003 (e.g. [43]). However, the widespread diffusion of the core open innovation concept gave firms an explicit model for planning, communicating and implementing open approaches to innovation. Historically, firms who developed open approaches to innovation prior to the publication of the book were led by an 'effectual' decision process [44], i.e. as a

result of particular contingencies such as the need to respond to major crises, many forms of openness were experimented with to help the companies survive. The articulation of the open innovation model in 2003 provided some firms with a language to describe activities already on-going. Other firms were thus able to direct efforts to establishing and deploying open innovation programmes based on Chesbrough's model and visible examples of other firms. Thus approaches to the implementation of OI can be seen as having two phases – one characterised by effectual implementation logic, the other by causal implementation logic – separated by a 'discontinuity' in 2003 [45]. For the period of observation for our case studies, the organisations involved in these initiatives were operating within this second phase.

The visibility of the open innovation model also affected public policymaking. Our review of policy documents related to our case studies showed clear evidence of the influence emergence of open innovation on the design of regional and national innovation policies. This leads to the second contextual element that needs to be described: the changing approach to regional and national innovation policy in the UK.

The perception of UK politicians and policymakers of the role of innovation on the performance of the UK has passed through a series of clear phases since the 1950s [46]. Within each of these phases, different innovation policy approaches and instruments have been deployed. For the initial period of our observations, much of the justification for public support for innovation was based upon the 'New Labour' government's perception of the growth of the UK being based around the development of a strong 'knowledge-driven' economy; and innovation and entrepreneurship were key strands in the achievement of that objective [46]. This was coupled with a desire to devolve key aspects of innovation policy implementation to regions, rather than have these centrally managed, to reflect the differing needs of different areas of the UK. One important manifestation of that strategy was the establishment of Regional Development Agencies (RDAs). RDAs were launched in eight

English regions in 1999, with a ninth established in 2000 in London. The RDAs' agenda included: "[..] *regeneration, taking forward regional competitiveness, taking the lead on inward investment and, working with regional partners, ensuring the development of a skills action plan to ensure that skills training matches the needs of the labour market*" [47]. The Conservative / Liberal Democrat coalition that came to power in 2010 decided to reverse this approach and in 2012 all RDAs were abolished. One result of this was the return of responsibility for innovation to the national government and specifically the Department for Business, Innovation and Skills (BIS). As all three of our case study organisations had received their core public sector funding from their respective RDAs, these changes in the political and innovation policy landscape presented them with substantial challenges to the implementation of the strategy and operations. One example of a challenge faced by all of our case studies was that of targeting their activities to the achievement of metrics provided in the RDA 'Tasking Framework' as shown in Table 2. Failure to achieve the agreed targets in each of these headings could result in a funding 'claw-back' (i.e. funds returned to the government). As such, the strategies and operations of each of our case study projects were focused upon achievement of these clear targets (even if they were, at times, in conflict with commercial goals). However, with the abolishment of the RDAs shortly after our case study initiatives were launched, and the return of responsibility to national government agencies, the operational oversight and monitoring of these targets became very uncertain and unclear.

Table 2: RDA Tasking Framework

Core output area	Core output indicator
Employment creation	Number of jobs created or safeguarded
Employment support	Number of people assisted to get a job
Business creation	Number of new businesses created and demonstrating growth after 12 months, and businesses attracted to the region.
Business support	Number of businesses assisted to improve their performance Number of businesses assisted to engage with new collaborations with the UK knowledge base
Regeneration	Public and private regeneration infrastructure investment leveraged Hectares of brownfield land reclaimed or redeveloped
Skills	Number of people assisted in their skills development as a result of RDA programmes Number of adults gaining basic skills as part of the Skills for Life Strategy that count towards Skills PSA Target Number of adults in the workforce lacking a full level 2 or equivalent qualification who are supported in achieving at least a full Level 2 equivalent or qualification

Having provided a summary of the changing industrial and policy context for innovation in the UK during the period of our analysis, we now provide a description of each open innovation infrastructure project.

Case descriptions

Case 1: The Manufacturing Technology Centre

The Manufacturing Technology Centre (MTC) is a collaborative manufacturing technology development facility located 10 miles from the city of Coventry, UK. It is a 12,000m^2 facility opened in 2011 with UK£40m funding provided by two RDAs (Advantage West Midlands and the East Midlands Development Agency) in partnership with the University of Birmingham, Loughborough University; University of Nottingham and TWI[1]. The MTC's

[1] https://www.twi-global.com/

first industrial members were Rolls-Royce, Aero Engine Controls (now part of Rolls-Royce) and Airbus. The MTC "*[..] develops and proves innovative manufacturing processes and technologies in an agile, low risk environment, in partnership with industry, academia and other institutions*."

The planning for the MTC took place during the era when the RDAs had responsibility for implantation of innovation activities at a regional level. As such, Advantage West Midlands and the East Midlands Development Agency were dominant in steering the location, design and operations of the nascent MTC. With the abolishment of the RDAs in 2012, the future of this major investment in regional innovation became very unclear. However, a parallel innovation policy initiative provided a solution. In 2010 the coalition government announced funding for the establishment of 'Catapult Centres' (loosely based upon the Fraunhofer Institutes[m] in Germany) funded by InnovateUK (a national government agency). One of these Catapult Centres was to be focused on High Value Manufacturing (HVM). Given the level of prior HVM-related investments made in a range of facilities across the UK by multiple RDAs, the decision was made to connect seven of these existing facilities together as the High Value Manufacturing Catapult (HVMC)[n], with one of those seven facilities being the MTC. Catapult Centres all share a broadly common business model (designed loosely on that implemented by the Fraunhofer Institutes) with income needing be balanced equally across government grants, industry sponsorship, and the provision of commercial services. Thus, in becoming one of the seven regional facilities that make up the HVMC, the MTC had its business model prescribed.

[m] https://www.fraunhofer.de/en.html

[n] https://hvm.catapult.org.uk/

The MTC's founding corporate members were also using their engagement with the MTC as one component in their evolving approach to managing R&D and innovation. Rolls-Royce and Airbus have been explicit in their intent to use various open approaches to innovation in order to strengthen their competitive position in the face of strong competition from their main US-based rivals and emerging threats from rapidly growing economies.

The MTC's core support for collaborative manufacturing technology development is now focused around assembly systems, component manufacturing systems (including additive manufacturing, high integrity fabrication, and non-conventional machining), and data systems.

The MTC's activities have expanded to encompass training for advanced manufacturing (via its Advanced Manufacturing Training Centre), and acting as a national hub for additive manufacturing innovation (via its status as the National Centre for Net Shape and Additive Manufacturing) and business incubation services (via its Business Launch Centre).

The need to balance its income across the three core streams (government grants, industry sponsorship, and commercial services) has presented some challenges, one of which has been the need to balance the delivery of large high value projects with multinationals with multiple lower value projects with smaller regional firms and university partners [48].

Case 2: The Exchange at Colworth Science Park

Colworth Science Park was set up as an open innovation campus in a rural location 9 miles outside the city of Bedford, UK. It is owned, developed and managed under a joint venture between Goodman (a property development company) and Unilever (a multinational corporation in the fast moving consumer goods sectors). The path dependency of the site is particularly significant. Historically, its origins lie in Unilever's global research centre network. Colworth was one of two UK research locations (from a global total of six) but had, as a result of shifts in the global markets, shed nearly two thirds of its peak-level workforce.

The emergence of open innovation changed Unilever's approach to value creation and capture (as documented in [49]) and enabled the Colworth site to be re-positioned as a key component in the implementation of Unilever's new open innovation strategy. In parallel, the East of England Development Agency (EEDA, the local RDA), was seeking opportunities for stimulating economic development in specific locations in the East of England through targeted capital investment. Unilever sold some of its land at the Colworth site to a joint venture that it established with Goodman (a property development company) to convert the single company R&D facility into an open innovation campus. The joint venture was then able to bid for funding from EEDA (UK£4.4m) to cover part of the costs of developing new collaboration focused facilities on the science park that would attract new companies and existing small and medium sized enterprises (SMEs) to re-locate to the site.

The core of open innovation infrastructure enabled by the EEDA funding was the construction of 'The Exchange' building. Officially opened in May 2011, The Exchange building is a combination of office space, lab space, meeting and conference rooms, and a cafeteria.

The funding from EEDA was explicitly aimed at stimulating open innovation to support regional economic development (and this was highlighted in the 2008 East of England Regional Innovation Strategy which talked of the ambition to: "*Develop a major open innovation park at Colworth, anchored by Unilever*" [39]). The plan was to provide a venue that brought together and made connections between the anchor tenant (Unilever), other multinationals, the academic partner organisations, start-ups, SMEs, service providers, *et al*. through networking, events and the delivery of support services.

The joint venture management team explored the possibility of becoming an InnovateUK Catapult Centre, though this was not implemented. Since opening, Unilever's open innovation strategy has continued to evolve in response to changing competitive pressures.

Many of the key individuals involved in the transformation of the Colworth facility have moved on to other roles within the company or left the company. Colworth Park is now positioned as a commercial facility for R&D, with Unilever's Scientific Research listed as one of its tenants, and the Exchange as commercial facility for office and lab space.

Case 3: ideaSpace

The ideaSpace Enterprise Accelerator (iEA) (now just named 'ideaSpace') was launched in 2009 with the aim of supporting the generation of economic, strategic and social value across the East of England through stimulating entrepreneurial and innovative activity. Its primary facility is located on the West Cambridge campus of the University of Cambridge. The West Cambridge campus sits on the outskirts of the city, and combines facilities for several of the University's science and technology departments as well as space for commercial organisations linked to the University (e.g. at the time of launch, Microsoft, Nokia *et al*.). The iEA occupied one floor (3,000 sq ft) of a University-owned building in the Hauser Forum, a complex of buildings that includes commercially rentable office and lab space, the University's technology transfer company, a café, and seminar rooms.

The physical infrastructure provided by the iEA was desk-space for start-ups, meeting rooms, office space for support staff, and a common room. iEA programmes were split into the activities to support individual entrepreneurs and start-up teams within the iEA facilities, and externally focused activities to stimulate the regional innovation network (such as the awarding of small grants for new innovative collaborative projects). iEA established five types of fee-paying membership aimed at individuals through to large corporations.

Open innovation was a key theme of the iEA programme from the outset. The original funding proposal submitted to EEDA presented a vision for the delivery of "*a regional infrastructure for open innovation*" [50]. The business model of iEA was designed to address

a major challenge facing start-ups (the lack of resources to address the targeted opportunity) through enabling connections to a wide of possible resource providers, locally and regionally. It also aimed to support larger firms seeking to identify new opportunity areas from within Cambridge and the wider region.

A UK£2m grant from EEDA (through a capital-revenue swap with a donation from the Hauser-Raspe Foundation) provided sufficient funding to resource the iEA for 4 years. This represented a change in strategy for EEDA who previously had been reluctant to support projects within Cambridge, as Cambridge was perceived as a part of the region where there as no market failure as innovation was flourishing within the 'Cambridge Phenomenon' [51].

Within that period, the iEA had to develop alternative funding streams to cover its operational costs. In 2016, the EEDA-originated funding ended, and iEA (now branded simply as ideaSpace) has focused its activities within the wider Cambridge area with the opening of facilities in the centre for Cambridge, and at the Cambridge Biomedical Campus located to the south of the city. It is currently exploring how to develop large-scale open innovation initiatives with several of the University's academic departments to address global challenges.

Analysis

In Table 3, we map the phases of evolution of the three case study initiatives against the changing political and innovation policy context in the UK with the aim of highlighting some of the interplay between the changing political climate, national and regional innovation policies, and the open innovation related aspects of the strategies of key corporate partners.

Table 3: Mapping evolution of case study infrastructure projects against changing innovation policy context

National Government	**New Labour (1997-2010)**	**Conservative-Liberal Democrat (2010-2015)**	**Conservative (2016)**
Innovation policy approach	'Knowledge Economy' focus for innovation. RDAs lead on regional innovation activities, with funding allocated from UK HM Treasury via six separate government departments. Technology Strategy Board formed to provide firm-level support for innovation, including funding for Technology Innovation Centres (TICs).	RDAs abolished; Innovation re-centralised as responsibility of Department of Business Innovation and Skills (BIS). Technology Strategy Board continues as InnovateUK, providing funding for Catapult Centres (network of sector-specific TICs). Nascent role for Local Economic Partnerships.	Innovation policy under Department of Business, Energy and Industrial Strategy (BEIS) with firm-level support activities and Catapult Centres still funded via InnovateUK. University research and InnovateUK provide core innovation capability to brought together under ResearchUK.
Phases of case study projects	**t_0 Planning and launch**	**t_1 Response to policy transformation**	**t_2 Current state**
MTC	RDA-driven initiative to provide collaborative manufacturing development facility to support growth of regional manufacturing firms. Strong emphasis on public sector-funded initiative to support regional regeneration through collaborative manufacturing innovation. Emphasis on capital costs, not providing operational budget so needed to find appropriate business model.	MTC becomes part of HVMC and has 3-element business model prescribed. Core founder members are able to ensure design of MTC activities dovetails with their OI approach. Review of Catapults highlights need to balance commercially attractive company specific confidential projects with development of, and access to generic resources to support UK manufacturing innovation	MTC continues as key element within HVMC, with development of additional activities of National Centre for Net Shape and Additive Manufacturing and Advanced Manufacturing Training Centre. Has dual activities of commercially confidential services with open access skills and capability development.
Colworth Park	Unilever wishes to develop OI capability in face of competitive pressures and re-purpose existing corporate R&D facilities. RDA wants to ensure Unilever remains in region (struggling with low economic growth). Colworth project draws together partners to develop open innovation park to stimulate regional innovation and entrepreneurship.	Regional economic development targets remain in place, though light-touch management from central government. Goodman/Unilever explore possibility of becoming Catapult Centre. Attempts made to develop collaborative activities between park tenants and Unilever, but corporate /IP challenges hinder this. Faces challenges attracting innovation-based firms to move to remote location.	Colworth Park now positioned as a commercial facility for R&D, with Unilever's Scientific Research listed as one of its tenants, and the Exchange as commercial facility for office and lab space. Offering does not emphasise open innovation as strongly as before. Collaborations between Unilever and university partners continue.
ideaSpace	Change of strategy at RDA provides opportunity for University of Cambridge to develop its OI infrastructure. Private donation from alumnus provides additional funding to cover both capital building and operational costs. Plan positions ideaSpace as 'regional infrastructure for open innovation. Some operational challenges in finding organisational 'home' within university.	Programmes split to support individual entrepreneurs and start-up teams within the ideaSpace facilities, and externally focused activities to stimulate regional innovation network (such as the awarding of small grants for new innovative collaborative projects). Cambridge-focused activities prove successful, but harder to deliver regional activities.	ideaSpace builds on success of core business and scales to two additional locations within Cambridge. Business model is self sustaining De-emphasises regional outreach but seeks to develop OI programme to support university to address grand challenges through developing innovation capabilities of researchers.

Discussion

This paper seeks to provide some initial insight on the question of: *How have three examples of jointly public and privately funded open innovation physical infrastructure projects in the UK responded to a changing innovation policy context in the digital age?* To address this, we have analysed the evolution of the strategies and operations of these three open innovation initiatives through three phases: t_0 (planning and launch), t_1 (response to major transformation of national and regional innovation policy) and t_2 (current state). This structure has allowed us to identify the interplay between changes in national innovation policies, regional innovation policies, corporate innovation strategies, and the business models of specific open innovation infrastructure projects. From this, we can observe the following:

1. **Contingent aspects of location:** The geographic location of specific infrastructure facilities plays an important role in the implementation of open innovation, but this role is contingent on many other factors. For example, for ideaSpace, being located at the heart of an extant innovation ecosystem has allowed support to be developed, scaled and adapted rapidly. However, it found it difficult to deliver its open innovation support activities beyond Cambridge, as the value of its offerings were tightly bound to activities within the Cambridge innovation ecosystem. In contrast, Colworth Park, despite offering access to some of the significant R&D resources of Unilever, found it challenging to attract innovation partners to its somewhat remote location with a limited number of other innovation-related organisations. However, the MTC, despite also being 10 miles from the nearest major city was able to attract partners as it offered access to highly specialised equipment and associated expertise. However, these partners were typically large organisations with very specific innovation needs, and able to bring complementary assets required to support the innovation projects.

2. **Digital and physical:** All three of our examples have attempted to combine the provision of location-specific and on-line support. However, the provision of various on-line services did not seem to enable a break from the requirements of physical co-location to achieve the intended outcomes. ideaSpace has expanded its physical facilities and now has three separate locations (West Cambridge technology campus, Cambridge city centre, and Cambridge Biomedical Campus) but these are still relatively close ('within cycling distance'). Early attempts to deliver activities remotely across the region were not successful. The support that seems to be most valued by ideaSpace members (as reported in regular member surveys) are linked to physical co-location (i.e. interaction with support staff and other members). We did observe some examples of how on-line aspects of these organisations' business models were enabling the delivery of some of the emergent aspects of their business models. For example, the MTC provided collaborative on-line communities to support some elements of training activities for partners, but for their core manufacturing technology innovation-related activities the emphasis is still very much on physical co-location. Colworth Park and ideaSpace attempted to remotely deliver training, talks and support to other regional innovation hubs, but these were not continued beyond the piloting phase. ideaSpace has used digital infrastructure to support collaboration and exchange between its c. 150 members. It is interesting to report from consultation with members that a perceived success factor of these on-line tools is underpinned by the co-located (though often time-shifted) activities of the members.
3. **Policy discourse versus policy implementation:** Throughout the period of our research, our analysis revealed the impact of an emerging management theory on the innovation policy discourse. Open innovation had become pervasive in national and regional innovation policy documents. However, there seemed to be a gap between appreciation of the basic open innovation paradigm and the detailed understanding of how targeted public

spending on infrastructure projects could support the successful implementation of open innovation in different regional contexts, working with diverse corporate and academic partners. While the open innovation model at the high level resonated strongly with the post-2008 financial crisis need for austerity in public spending and the 'knowledge economy' model emphasised initially by the New Labour government of 1997-2010 but also taken forward by their successors, the scale of the jump between this general understanding and operational implementation did not seem to be well appreciated. One example problem was the need to attribute the impact of public spending to specific measureable outcomes within relatively short timescales. Given the known challenges of measuring open innovation effectiveness [52], attempts to do so within a complex multi-stakeholder, public-private, rapidly evolving context were particularly challenging. As such, our case studies support the views expressed by de Jong *et al*. [20] on the need for a broader view of public policy support for open innovation, beyond the commonly observed focus on support for collaborative R&D and technology transfer.

4. **Business model resilience:** Each of the case study organisations had to navigate through periods of significant changes in their sources of public funding. All three received a major proportion of their initial funding from the UK's Regional Development Agencies (RDAs). RDA funding was commonly provided only for capital expenditure (i.e. buildings and equipment) not for on-going operational costs. This resulted in the need for business models that allowed the organisations to be as open and accessible as possible but also sufficiently commercial to ensure operational sustainability. This became particularly challenging when the structure of innovation support was completely transformed with the disbandment of the RDAs in 2012. In navigating their way through such transformations, each organisation has had to develop business models that their management team believes gave them the resilience to cope with future changes. Each of

the projects we studied made significant changes to their business model compared to the one they presented in their submitted proposal for funding to their respective RDAs, and this resulted in some new challenges. A review of the MTC (as part of a wider review of all Catapult Centres [48]) highlighted concerns at the over-reliance on collaborative projects with large corporate partners at the expense of projects with smaller firms [48]. Colworth Park's shift from its original aims can be put down, in part, to Unilever's evolving strategy in managing its real estate assets. As Unilever sold real estate and then leased-back space for its labs, it also passed over the management of its open innovation Exchange facility to an external service provider. This put Unilever one degree removed from potential users of the open innovation infrastructure it had helped put in place. While ideaSpace attempted to implement support for regional innovation activities throughout the period of its RDA funding award (as this was a condition of the award) it proved to be particularly challenging to implement, and activities were re-focused within the Greater Cambridge area.

5. **Specialisation versus generalisation:** Our three cases reveal three different approaches to having a core technology focus for their open innovation support. ideaSpace has remained technology agnostic, though the bulk of its members are focused on ICT-related opportunities. Colworth Park initially aimed to be focused on food technologies, then 'health and wellness' but has now broadened its scope to science-based innovation. The MTC has, since its foundation, been focused upon advanced production processes. Its focus has mirrored the stage of maturity of different technologies (e.g. MTC's recent support activities have emphasised innovation relating to additive manufacturing, but it is now shifting to provide more support for the integration of cyber-physical systems under the banner of 'Industry 4.0). The different approaches to technology focal areas of these case studies highlight some of the relative benefits and risks of specialisation versus

generalisation with open innovation support. Generalisation offers flexibility but may limit attractiveness when attempting to draw in innovation-based firms seeking targeted help. Specialisation offers focus but may limit the number of potential partners and raises concerns at the risk of 'white elephant' assets that may be hard to re-purpose. This also ties in with the observation that public investments in open innovation infrastructure need to be considered in the context of balancing regional needs with national competitiveness, and the role of large multinational corporations in leveraging benefit from public support in different nations [53].

6. **Projects and people:** While the main activities of our case study organisations were targeted on the delivery of support for innovation *projects*, it was interesting to observe an emergent additional set of activities related to the development of the skills of *individuals*. ideaSpace developed its support activities with an emphasis on helping individual entrepreneurs discover the appropriate business and collaboration model for the current idea, but with an emphasis on engaging them with a community / ecosystem that could support them with future ventures. For MTC, they developed a programme explicitly for the development of skills for helping individuals innovate with emerging production technologies. These examples from practice reflect the observations by de Jong *et al*. [20] on the importance of skill and capability development for open innovation policy.

Conclusions

This paper has attempted to structure observations of the design and evolution of publicly funded physical infrastructure projects designed to support the implementation of open innovation. Our aim has been to develop understanding of how the strategies and operations of open innovation infrastructure projects have evolved over time in response to contextual factors. Our key observations can be summarised as follows. Unsurprisingly, attempting to

develop an innovation ecosystem around an open innovation infrastructure facility at a remote location without a strong and unique offering will be challenging. While there are many aspects of collaborative innovation that can be delivered on-line, for certain types of open innovation activity, the provision of physical infrastructure and the co-location of key actors seem essential. There seems to be a gap between the high level perceived promise of open innovation for national and regional economic development, and the implementation of activities required to deliver on this promise. Open innovation policy and implementation needs to consider a wide range of stakeholders and activities beyond a narrow focus on delivery of buildings to support collaborative R&D. Whatever activities are implemented, it is very likely that these will need to be adapted – perhaps quite frequently – in response to changes in technology, the regional and national economy, governments, and policies. Having activities that are very targeted on particular sectors, technologies, or type of innovation can help communicating with and attracting relevant stakeholders, but such focus can result in rigidities that may prevent adaptations to a changing context being implemented. Finally, while strong emphasis is given to the successful achievement of particular goals associated with innovation projects within particular open innovation facilities, the development of skills and capabilities that can be transferred to future innovation projects may be an under-recognised output.

Given the exploratory nature of this research, and the choice of case method drawing upon just three examples of open innovation infrastructure, our results need to be treated with caution. Replication of our approach to observe open innovation infrastructure projects in other contexts would reveal interesting comparative data and help develop our understanding of this important yet under-researched issue.

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