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Performance Indicators for the Evolution of Areas of Innovation: Porto Digital Case

Abstract

Areas of Innovation (AOIs) need urban, economic, social and governance development. Building upon the theories of Triple Helix, Knowledge-Based Urban Development, Clusters of Innovation, and the evolution phases of AOIs, this study presents in a novel way, key performance indicators (KPI) that can be used to track and monitor the progress of an innovation district in distinct phases of development towards the achievement of its goals. Using the Porto Digital Case in Recife, the most awarded project in Brazil underway for 20 years at a Triple Helix hybrid organization Núcleo Gestor do Porto Digital (NGPD), performance indicators are analysed and classified. This yields further understanding of which stage of development they have become operative (from inception to maturity), which dimensions affected (namely, urban, economic, social and governance), and who (Triple Helix agents) has been involved with the major action power over it.

Keywords: Porto Digital, Areas of Innovation, Evolution, Indicators, Triple Helix, Knowledge Based Urban Districts

Indicadors de rendiment per a l'evolució de les àrees d'innovació: el cas de Porto Digital

Resum

Les àrees d'innovació (AOI) necessiten un desenvolupament urbà, econòmic, social i de governança. Sobre la base de les teories de Triple Hèlix, Desenvolupament Urbà basat en el Coneixement, Clústers d'Innovació i les fases d'evolució de les AOI, aquest estudi presenta de manera nova, indicadors clau de rendiment (KPI) que es poden utilitzar per seguir i supervisar el progrés d'un districte d'innovació en fases diferents de desenvolupament cap a la consecució dels seus objectius. Utilitzant el cas de Porto Digital a Recife, el projecte més premiat al Brasil durant 20 anys, en una organització híbrida de Triple Hèlix, Núcleo Gestor do Porto Digital (NGPD), els indicadors de rendiment són analitzats i classificats. Això dona una major comprensió de quines fases de desenvolupament s'han convertit en operatives (des de la creació fins a la maduresa), quines dimensions han afectat (urbana, econòmica, social i governança), i qui (agents de la triple hèlix) ha estat involucrat amb el poder d'acció principal sobre ella.

Keywords: Porto Digital, Àrees d'Innovació, Evolució; Indicadors, Triple Hèlix, Districtes Urbans Basats en el Coneixement

Indicadores de rendimiento para la evolución de las áreas de innovación: el caso de Porto Digital

Resumen

Las áreas de innovación (AOI) necesitan un desarrollo urbano, económico, social, y de gobernanza. Sobre la base de las teorías de Triple Hélice, Desarrollo Urbano basado en el Conocimiento, Clústers de Innovación,y las fases de evolución de las AOI, este estudio presenta de manera original indicadores clave de rendimiento (KPI), que se pueden utilizar para seguir y supervisar el progreso de un distrito de innovación en fases diferentes de desarrollo hacia la consecución de sus objetivos. Utilizando el caso de Porto Digital en Recife, el proyecto más premiado en Brasil durante los últimos 20 años, en una organización híbrida de Triple Hélice, Núcleo Gestor de Porto Digital (NGPD), los indicadores de rendimiento se analizan y clasifican. Esto permite una mejor comprensión de cuáles son las fases de desarrollo que se han convertido en operativas (desde la creación a la madurez), qué dimensiones han influido (urbana, económica, social, de gobernanza), y quién (agentes de la triple hélice) ha estado involucrado con el mayor poder de acción sobre ella.

Palabras clave: Porto Digital, Áreas de Innovación, Evolución; Indicadores, Triple Hélice; Distritos Urbanos Basados en Conocimiento

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1. Introduction

Areas of Innovation (AOIs) are novelty ecosystems development initiatives deployed in urban contexts leading to major impacts in dimensions other than district economic development – through entrepreneurship, education, and innovation programmes – including the social and urban spheres. AOIs designed for converting degraded districts into dynamic hubs have attracted interest from policymakers and academics alike (Piqué, Miralles and Berbegal-Mirabent 2019a)

These knowledge-intensive areas (either cities or districts) provide environments and programmes to facilitate the concentration of creative industries integrated into a supportive social environment (Scott 2000) by offering specialised amenities (Yigitcanlar and Dur 2013) and infrastructures (Hutton 2004, Porter 1995, Utterback and Afuah 1998). Such an offering attracts knowledge-based companies, in substituting traditional businesses of old industrial districts of large urban clusters (Hutton 2004), stimulating the concentration of talented people (Florida 2008).

Each AOI is a complex network of components (citizens, business, transportation, communications, services, and other components of a cluster of innovation (Engel 2022) with their own unique strengths and weaknesses that face a constant change that generates the permanent challenge of developing new strategies under the development paradigm of the knowledge-based urban development (KBUD) (Yigitcanlar 2014). Understanding how an AOI can change and improve based on these elements is the starting point for it to achieve its vision and objectives and this can be achieved by refining its most complex link, but at the same time, essential: its strategy. Defining a strategy can help determine where and when to invest, define

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an integration and optimization schedule across all components and systems, and uncover new opportunities for growth and progress.

Evaluating the main systems and activities of an AOI is the first step in defining a strategy towards sustainable prosperity and developing a set of related indicators is the right activity to do so. Indicators show the changes and progress a program is making towards achieving a specific result. Hence, it becomes essential that the elements evaluated are directly linked to the main activities aimed at achieving specific goals. Even when indicators in innovation districts have been studied in order to define a framework that classify these areas of innovation (Yigitcanlar, Adu-McVie and Erol 2020), indicators evaluating performance (Lerro and Jacobone 2013) and their evolution through the lifecycle of these spaces, still require further development.

Following the recent works of (Piqué, Miralles and Berbegal-Mirabent 2019a), we assume that AOI evolve over time, consequently they evolve, certain aspects of the dimensions stand out and consequently, their performance requires close management and monitoring, as they are essential for the development of the next phase and reflect the more active participation of a certain actor in the ecosystem.

In each of the different phases of an AOI lifecycle (Moore, 1996; Etzkowitz 2005) the triple helix actors assume a diverse configuration in terms of role and leadership of the initiative. Specific characteristics and activities related to the social, economic, and urban dimensions are also involved (Pique 2019b, Pique et al. 2021).

Aimed at shedding new light on how to assess the performance of AOIs along their lifecycle, this study proposes a set of KPI for each lifecycle phase of an AOI that considers the four main dimensions (a) urban and infrastructure, (b) economic (c) talent and social transformation, and

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(d) governance. To do so, different conceptual frameworks – triple helix, knowledge-based urban development, clusters of innovation, lifecycle of AOIs, and performance indicators – are used as the theoretical foundations that support our exploratory framework.

We believe this study contributes to the existing literature in two main ways. First, it takes a step forward in the use of indicators, specifying the precise timing in which each indicator is meaningful and therefore, worthy of consideration, offering a more nuanced approach that facilitates planning, execution, and decision-making. Second, this study shows how these indicators can be put into practice. Specifically, we validate their suitability with the analysis of the case of Porto Digital, a reference innovation district located in Brazil.

Section 2 below presents the theoretical underpinnings and section 3 the methodology employed to explore the subject. Section 4 provides an overview of Porto Digital and presents the findings obtained. Section 5 discusses the main indicators for each stage of an AOI development relating them to the case. Finally, section 6 describes the main contributions of this work followed by concluding remarks.

2. Theoretical underpinnings

The theoretical foundations that support the use of different indicators to assess AOIs at their different stages of development can be found in different models and conceptual foundations. Specifically, we build upon the previous works that focus on the evolution of AOIs (Pique, et al., 2021; Piqué, Miralles and Berbegal-Mirabent 2019a), Pique, Berbegal-Mirabent and Etzkowitz 2018), expanding and refining these models, and combining them with performance evaluation theories.

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The foundation for understanding the components and behaviours of AOI ecosystem lies in the TH model (Etzkowitz and Leydesdorff 2000), which focuses on the relationships between universities, government, and industry, and on the Global Cluster of Innovation framework (Engel 2022, Engel 2015, Engel and Del-Palacio 2009). Both provide a comprehensive description of different agents' roles in developing ecosystems of innovation. The latter also analyses the interactions of new ventures, investors, and large companies, and describes the behaviours that lead to international engagements. The knowledge-based urban development (KBUD) theory (Yigitcanlar, Velibeyoglu and Baum 2008a and 2008b) is employed to understand the various dimensions of an AOI and its framework is used as a basis for tracing the elements of each dimension throughout its evolution.

Key performance indicators are explored in order to understand the main categories that apply to each AOI dimension and its applicability and to each development stage.

In the subsections that follow we briefly describe each of these frameworks.

2.1. The Triple Helix Model

The triple helix (TH) model analyses the development of knowledge-based economies from the perspective of the mutually reinforced interactions of three institutional spheres: university, government, and industry. It has been employed as a framework to foster regional economic growth and to promote entrepreneurship, through the understanding of the dynamics of such interactions (Cai and Etzkowitz 2020). Such interactions provide reciprocal benefits for each agent that tends to improve their original performance and expand initial activities, supporting the generation of new business. This process often requires institutional reconfiguration to provide support to startups and technology transfer as well as the creation of new mechanisms (Etzkowitz and Zhou 2017). AOIs, technology parks, business incubators and accelerators are

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examples of (hybrid) mechanisms resulting from these interactions and joint innovation strategies and processes (Kim, Kim and Yang 2012).

TH agents involved in these types of mechanisms assume complementary roles in supporting startups which benefit from the resources provided by TH agents in their path to growth, providing robustness to the ecosystem. TH agents also assume specific responsibilities in supporting the development of the mechanism itself: they evolve and remodel their role, accordingly, adopting new functions - at the different stages of the evolution of these mechanisms (Piqué, Etzkowitz and Solé 2007, Pique, et al. 2021). Individuals or organizations that initiate the interactions and have gained power and respect among TH agents, particularly at local and regional levels, and are key to bringing to fruition the full potential of the knowledge base (Cai and Etzkowitz 2020).

The inclusion of two further elements in the model is suggested: society (and its context), as a fourth helix, and the natural environment as a fifth helix. The quadruple helix model considers that knowledge should be democratized, therefore a knowledge society would evolve jointly with a knowledge economy. This expanded model endorses the role of society in using, applying, and generating knowledge, as well as encompassing the effect of culture and creativity. Building upon the quadruple helix, the Quintuple Helix elevates sustainable development as one of the main elements for collaboration, knowledge sharing and innovation that leads to a socio-ecological transition (Carayannis, Barth and Campbell 2012).

2.2. Clusters of Innovation

The Cluster of Innovation (COI) framework focuses on the main components of thriving business agglomerations in which the generation of fast-growing startups are strongly stimulated by the behaviours of those components (Engel and Del-Palacio 2009). In COIs, the

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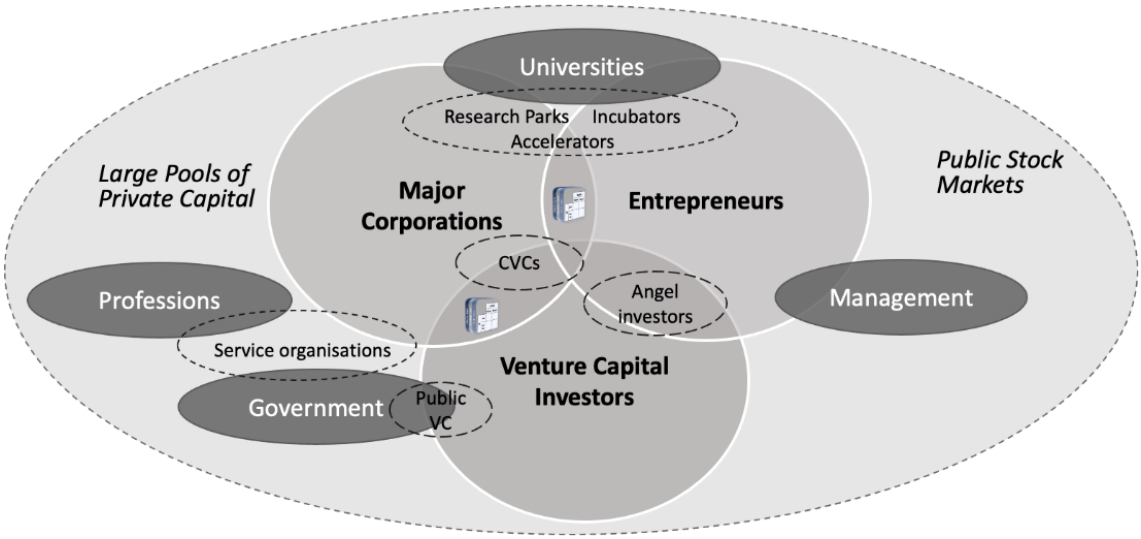
market potential disruption of innovative business models carried by dynamic entrepreneurs are resourced by venture capitalists and/or major corporations in a win-win game result. Relevant actors, as the government, universities, management (professional managers of startups) and professions (such as lawyers and accountants) play a highly enabling support role for the core components interaction (Engel and Del-Palacio 2009, Engel and del-Palacio 2011, Engel 2015). A set of hybrid components – such as corporate venture capital (CVC), research parks, incubators, accelerators, and service organizations – emerge from interaction between core and supporting actors, as new organizations or programmes, expanding the remits of the original component activities (Engel 2022).

FIGURE 1. Core, Supporting and Hybrid Components of a COI



Source: Engel (2022).

The emergence of COIs therefore depends on the interaction of the different components in the development of an innovation cluster. The interest alignment among components, joint definition and communication of a common agenda enables the interaction and facilitates the building of the COI identity (Bittencourt, et al. 2020). Thus, although the presence of the

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aforementioned components - or their functions provided by other components - are crucial, what actually bonds the relation and allows fast innovation in COIs are the shared behaviours: entrepreneurial process, high mobility of resources, alignment of interests, global perspective and global linkages (Engel 2015 and 2022).

The dynamic processes of COIs can evolve into a set of interactions with other physically remote COIs, enabling them to avail of shared ideas and information as well as people and resource mobility, leading to new opportunities. In this (Global) Network of COIs the interactions can vary from ephemeral contacts to more durable bonds embedded in contracts and formal partnerships, or, in a more radical form, two COIs essentially operate in a fully integrated manner (Engel and Del-Palacio 2009, Engel and del-Palacio 2011). Startups and other companies benefit from the international connections for finding customers, partners, and investors, and for exploring new disruptive opportunities. The brand of the AOI is endorsed by whoever creates a project locally and internationally (Pique et al. 2021).

2.3. Knowledge-based Urban Development

Talent is the raw material of the knowledge-based economy and society (Nikina and Pique 2016). Cities that want to be the platform of talent, need to develop strategies to create, develop, retain and attract talent (Bontje, Musterd and Pelzer 2011, Esmaeilpoorarabi, Yigitcanlar and Guaralda 2016, Nikina and Pique 2016) striking a balance with economic and social activities in the same place (Scott 2006). The role of the city is crucial in developing a strategy to cluster highly skilled people and to provide the platform for economic and social development (Pareja-Eastaway and Piqué 2010).

Innovative and creative talent is clustered in knowledge-intensive cities (Florida 2008). In the new economy the trend is to develop modern urban science parks that combine talent and

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technology in the innovation milieu of the cities (Pique et al. 2021). Urban planners replace old urban industrial districts into innovation districts, regenerating the old economy into a new knowledge-based economy in city centres (Knight 1995). Cities have been transformed into 'knowledge community precincts' (Carrillo 2006, Yigitcanlar, Velibeyoglu and Baum 2008b), that is, innovation districts hosting communities of talent that generate new knowledge (Yigitcanlar and Dur 2013).

City centres are the platforms of ecosystems of innovation taking advantage of the city amenities and the vibrant urban life. Innovation districts host significant concentrations of high technology sectors with creative and cultural industries which are integrated in the social context (Scott 2000) and provide socio-cultural amenities (Yigitcanlar and Dur 2013).

Knight (1995) provided an explanation about the knowledge-based development (KBUD) in cities, defining KBUD as the transformation of knowledge in local development. KBUD framework (Sarimin and Yigitcanlar 2012) includes social, economic, urban and governance development. (Piqué, Miralles and Berbegal-Mirabent 2019b), developed the framework in (1) Urban transformation: urban plan, infrastructure plan, legal framework and buildings, (2) Economic transformation: clusters and agenda of technologies, (3) Social transformation: creation, development, attraction and retention of talent, (4) Governance: government, universities and industry (the triple helix agents) playing a key role sharing the vision, and developing actions in all dimensions of the project.

Tangible (e.g., physical infrastructure or buildings) and intangible (e.g., knowledge or creativity) assets are necessary attributes of the innovation districts (Velibeyoglu and Yigitcanlar 2010) for living and working in the cities. TH agents play different roles building innovation districts in the urban, economic, and social dimensions (Pique et al. 2021).

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Innovation districts like Porto Digital, 22@Barcelona, or One-North in Singapore are illustrations of this transformation (Piqué, Miralles and Berbegal-Mirabent 2019b, Yigitcanlar 2011).

2.4. AOIs evolution phases

Based on the analogy of the lifecycle of a new venture of (Freeman & Engel 2007) (inception, launch, growth, and maturity), the ecosystems progress phases from (Moore 1996) (birth, expansion, leadership, and self-renewal or death), and (Etzkowitz 2005) stages of regional innovation ecosystems evolution (development of the idea of a new regional model; starting of new activities; consolidation, and adjustment; and self-sustaining growth), (Piqué, Berbegal-Mirabent and Etzkowitz 2018, Pique et al. 2021) propose four evolution phases for AOIs: inception, launching, growth and maturity.

For each of the phases, the model presents the evolving (re)configuration of the engagement and leadership of the TH agents, as well as the evolution of aspects of each dimension of the KBUD framework. Each phase depends on the contribution of the TH agents for governance, urban, economic, and social development, as it outlines the subsequent stage, strengthening or obstructing its evolution (Pique et al. 2021). In this context, the performance evaluation of the aspects of the dimensions involved in each phase becomes crucial for the orchestration or redesign of activities, programmes or processes.

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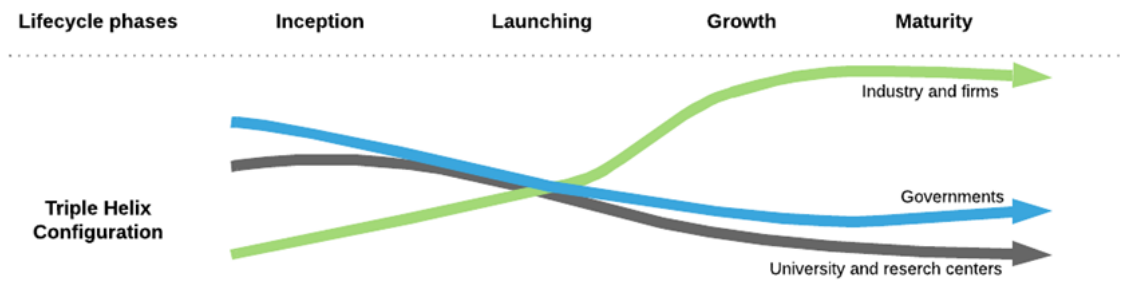
FIGURE 2. Stages of the AOIs development and its dimensions



Key role	Government and Universities	Adding tractor companies	Assignment of leadership in business associations and clusters	Explicit leadership from companies, talent and related networks
Talent and social transformation	Promoters	Managers of AoI	Communities and networks	International networks Local social networks
Companies and economic transformation	Involvement of key Institutions:Universities, Government, and Associations of Companies	Tractor Companies. Location of research and technology centres. Incubation and landing services.	Attraction of companies. Creation of companies Clusterisation.Open innovation Management.	Growth models. Decentralisation and internationalisation. Superclusters. Megaregions. Network of networks of research and innovation.
Infrastructures and urban transformation	Planning	Utilities. Consulting. Real estate. Developers.	Investors. Real estate. Developers.	Territorial growth. Exporting the model.

Source: Pique et al. (2021, 153).

2.5. Performance Indicators of AOIs

Strategic management literature has analysed mission statements as a tool to understand and evaluate how organizations perform (Alegre et al. 2018). Every organization has its own mission, and the way it is articulated can reveal crucial information about the strategy an organization is following. In the specific domain of science and technology we can find the recent works of (Wang, Wan and Zhao 2014) and (Berbegal-Mirabent, et al., 2020) in which mission statements of science parks are scrutinized in order to find potential links between the strategy and the real performance. In these studies, organizational performance is

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operationalized in a variety of ways, ranging from indicators of a number of startups to the indicators of funding.

Performance indicators are metrics used by organizations to measure and evaluate their behaviour and ensure that their efforts are directed towards achieving their objectives. Effective assessment is significant to prove the value of projects and initiatives and the benefits delivered to city authorities and all city stakeholders (Caird, Hudson and Kortuem 2016). To support the monitoring of relevant projects and initiatives, KPIs can be a universal instrument to evaluate the progress of strategies (Dameri 2017). With regard to the lifecycle of a product or innovation environment, managing the lifecycle generates maximum value and profitability at each stage. The selection of correct strategies and KPIs is important to drive the value maximization process.

KPIs are the answers, therefore, it is important to think about the question that needs to be answered and since some indicators will be more time-consuming and costly than others to collect and analyse, simplicity is paramount for a measure to be taken and reproduced periodically. For this reason, an existing and known indicator that answers exactly the required question may be better than proposing a perfect new but unknown measure. Strong indicators are simple, precise, and measurable.

Within the different categories in which the indicators can be grouped, there is one that is related to the different parts of a program or project, which also allows a temporal analogy. Within this, there are three main and most common categories of indicators.

- Input indicators. Measure the resources required to allow the program to be implemented. (e.g., funding, staff, key partners, infrastructure).

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- Process indicators. Measure the program's activities and outputs assessing whether the program is implemented as planned. (e.g., direct products/deliverables of the activities).

- Outcome indicators (or Impact indicators). Measure if the program is achieving its expected effect in the short, intermediate, and long term.

3. Method and Data

AOIs require urban, economic, social and governance transformation over its lifecycle. Although some evidence can be found concerning the elements that trigger and favour these transformations (Piqué et al. 2019), (Piqué, Miralles and Berbegal-Mirabent 2019b**)**, it is not clear how to measure this evolution. This situation calls for the development of performance indicators able to capture the different phases of development of an AOI, when these indicators are activated, and the agents involved in this process. Aimed at tackling this problem, we present a framework of key performance indicators that is expected to become a useful tool for controlling and monitoring how AOIs evolve.

This paper adopts the form of a case study (Yin 2018), since it analyses (1) "how" and "why" is the process of urban revitalisation, (2) there is no control over the AOI analysed, and (3) it is a contemporary phenomenon with real-life context. More precisely, a single-case study approach was adopted to explore and pilot the validity of a set of key performance indicators. Porto Digital in Brazil was chosen as a unique case, as it presents three unique characteristics that make it worth being examined: (a) it allows for a longitudinal study, since it has been in operation since 2000, (b) the initiative is recognized as one of the most comprehensive AOIs in terms of dimensions developed — social, economic, and urban — (Pique et al. 2021), and (c) there is strong engagement of the triple helix actors (university, industry, and government) that is also extended to the fourth helix (society).

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The indicators presented in this study, as well as overall data were collected from multiple sources, including official reports and webpages, as well as scholarly articles describing the case of Porto Digital, compiled and fed during 20 years of the district's evolution, from its inception to its maturity (see Table 1). Also, primary data was considered by means of two interviews carried out in December 2021 with the past president of Porto Digital (Francisco Saboya) and the current innovation director (Heraldo Ourem).

TABLE 1. Source of Data of Porto Digital

Year	Source of the Data – Official reports and webpage
2001	• DECRETO Nº 23.212, DE 20 DE ABRIL DE 2001 Qualifica a Associação Núcleo de Gestão do Porto Digital como Organização Social - OS, e dá outras Providências • Plano Bi-anual 2001-2002
2002	• Relatório de Metas e Atividades para 2002 • Anexo J – Prestação de contas 2002
2003	• Plano de Atividades e metas financeiras de Março 2003 a Março 2004 • Anexo B - Prestação de contas 2003
2004	• Metas Físicas do Contrato de Gestão Mar 2004-Mar2005 • Resultados Metas Físicas Contrato de Gestão Mar2004 - Mar2005
2005	• Relatório de Desempenho de Atividades do Plano de Trabalho de Março a Dezembro de 2005
2006	• Monitoramento do Planejamento Estratégico Período 2006 – 2008 Balanço do Cumprimento das Metas do período 2006
2007	• Relatório de Prestação de Contas – 2007
2008	• Prestação de Contas 2008 - Relatório Gerencial 2008
2009	• Prestação de Contas 2009 - Relatório Gerencial 2009
2010	• 5º Relatório Semestral de Progresso. Contrato de Gestão SEE e NGPD • 4º Relatório Semestral de Progresso. Contrato de Gestão SEE e NGPD
2011	• Relatórios de Prestação de Contas dos Contratos de Gestão 2011
2012	• Relatórios de Prestação de Contas dos Contratos de Gestão 2012
2013	• Relatórios de Prestação de Contas dos Contratos de Gestão 2013
2014	• Relatório de Prestação de Contas dos Contratos de Gestão 2014
2015	• Relatório de Prestação de Contas do Contrato de Gestão nº 4 – 2015
2016	• Relatório de Prestação de Contas do Contrato de Gestão SECTI/PE – 2016 • Relatório de Prestação de Contas do Contrato de Gestão 04/2014 PCR - 2016
2017	• Relatório de Prestação de Contas do Contrato de Gestão SECTI/PE – 2017 • Relatório de Prestação de Contas do Contrato de Gestão 04/2014 PCR - 2017
2018	• Relatório de Prestação de Contas do Contrato de Gestão 04/2014 PCR – 2018 • Décima_Reforma_do_Estatuto_Social – 2018
2019	• Relatório de Prestação de Contas do Contrato de Gestão 04/2014 PCR - 2019
2020	• Extrato de Relatório de Execução Contrato de Gestão No 001/2019 – 2020
WEB	• https://www.portodigital.org/parque/o-que-e-o-porto-digital/documentacao

Source: Own elaboration.

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To link the data to the proposition, the key categories in which the indicators were grouped were derived from the main domains proposed by the KBUD to model a knowledge-based development. From here, the indicators were analysed to arrange them within the urban, economic, social and governmental categories, to later locate them in the different stages of evolution of an innovation district (Inception, Launching, Growth and Maturity). It means the moment in which each indicator begins to be used or "activated" is indicated on a timeline that outlines the different phases of evolution of an innovation district. An active indicator is conceived, in this case, as the period of time in which the information provided by the indicator is necessary for an accurate decision-making process essential for the district to reach its goals in time and complete its evolution. Knowing which indicator comes into action in each phase could help the main decision makers to decide what type of data to generate and start measuring from the beginning of each phase to guarantee compliance with their actions and anticipate future decisions.

The activation period was identified through the information presented in the district's official reports and websites. That is, when the need to start measuring a parameter was mentioned or when it began to record its measurement according to different evolution needs of the district. That done, the analysis was complemented with contextual and validation information, which was obtained from the interviews carried out with the experts and from scientific articles prepared in advance.

Additionally, the TH agent that has the most influence on each indicator was also analysed. Here, the greatest influence is conceived as who has the greatest power of action to create measures that modify these observed data.

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Below the framework for allocation the aforementioned indicators are presented in order to link data to proposition.

TABLE 2. Framework for the Key Performance Indicators by Dimension and Phase

Phase / Dimension	Inception	Launch	Growth	Maturity	TH Agent
Infrastructures and urban transformation	Name of the indicators that are activated and remain active in each phase for each dimension				TH Agent with the biggest influence
Companies and economic transformation					
Talent and social transformation					

Source: Own elaboration.

4. The case of Porto Digital

"Porto Digital is a public policy" (Ourem 2022)[1]

4.1. Overview

Launched in 2000 in the city of Recife, capital of Pernambuco State in the northeast of Brazil, Porto Digital (PD) is one of the most awarded AOIs in the country. In 2020, there were around 330 small and medium companies, knowledge institutions, research, and innovation centres (including from multinational companies), development organizations and governmental

[1] Ourem Heraldo (Innovation Director of Porto Digital). Notes of interview, December 2021.

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agencies in the area, with approximately 11 thousand professionals in total, generating an annual revenue of around BRL 2.3 billion in 2019 (Porto Digital 2021).

PD is an open well-defined urban AOI[2] that covers an area of 171 hectares of the Recife old historic neighbourhood and part of three adjacent neighbourhoods, with one unit in the countryside (Caruaru). Most of the area is listed by public heritage and, therefore, follows strict rules regarding its modification. The city law 17244/2006 and its further modifications provide the basis for its operation, that aims at urban revitalization and economic and cultural development with focus on information and communication technology (ICT), creative economy (games, videos, digital media, animation, design, photography, and music), urban and future of technologies applied to cities (Albuquerque Neto, Calheiros and Targino 2012, Porto-Digital 2021).

Established as a non-profit private association, the management organization of PD (NGPD) has deliberately pulverized governance. Its steering committee includes representatives of the government, academia (universities and research centres), industry (business associations) and the civil society (people of notorious knowledge), but without any group reaching the majority of representation[3] .

PD is a product resulting from the formation of human capital and capacity to generate research at the Federal University of Pernambuco (UFPE), in its three fronts: teaching, research and extension activities. In the beginning, PD was positioned around the UFPE competencies but with its consolidation, other institutions were attracted to the area or for joint projects.

[2] Best Technological Park/Innovation Habitat in Brazil in 2007, 2011, and 2015 (ANPROTEC 2021)

[3] Porto Digital Statute. https://www.portodigital.org/arqSite/Decima_Reforma_do_Estatuto_Social.pdf

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Currently, more than 15 institutions integrate the human capital formation ecosystem, offering research and extension activities as well: UFPE, Rural University, Catholic University of Pernambuco, and private ones, such as Cesar School (which started in 2010 and offers undergraduate, master and doctorate programs). Most institutions do not have a physical presence in the PD area but offer co-branded courses. These involve the co-creation of a curriculum, adapted to the needs of the ecosystem, and a mandatory module of professional technological residency (analogous to medical residencies, but in this case carried out in PD companies), in which students have the opportunity to experience the AOI. Co-branded courses facilitate the development of hard and soft skills required by the companies in the selection process, as well as the development of joint projects between companies and the universities.

When it comes to economic development, since its inception, a threefold strategy was in place:

- Creation of new companies (through incubation, acceleration programs, etc.).
- Strengthening of established businesses (internationalization, obtaining certification, support for financing).
- Attracting large companies.

The 3-element strategy allowed for more formal action on a given element depending on the context. For instance, currently the trade-off in undertaking entrepreneurship through startups is considerable due to the high salaries paid to IT professionals (there is a high demand for this type of professional). Thus, the focus shifted to strengthening existing companies and attracting large companies to PD. It is important to mention that the PD has already reached a considerable level of maturity through endogenous generation of strong business: from the 10 most important companies in the area, 7 were created in Porto itself.

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PD is in one of the more prestigious areas of the city, where Recife was founded, and which has a series of cultural facilities (bars, restaurants, museums, a shopping mall, handcraft market, and areas for cyclists). In the area there are several political and cultural manifestations (such as Carnival) on a city landmark, the "Ground Zero" square. As the creative economy is one of the PD's areas of interest, the NGPD carries out a series of monitored activities to engage with the cultural movements that take place in the area. One of the cinemas is linked to Porto Media, a laboratory for experimentation of the creative economy that offers post-production services, which has already participated in Brazilian and foreign productions.

4.2. PD Performance Indicators and TH agent roles at each stage of the lifecycle

As described in section 3, 67 indicators were found. Their breakdown, by stage and dimension, is shown in Table 3. By closely examining which indicators are more relevant through the different stages, it is possible to obtain a better grasp of how an AOI has evolved and where was the focus at each stage of its lifecycle.

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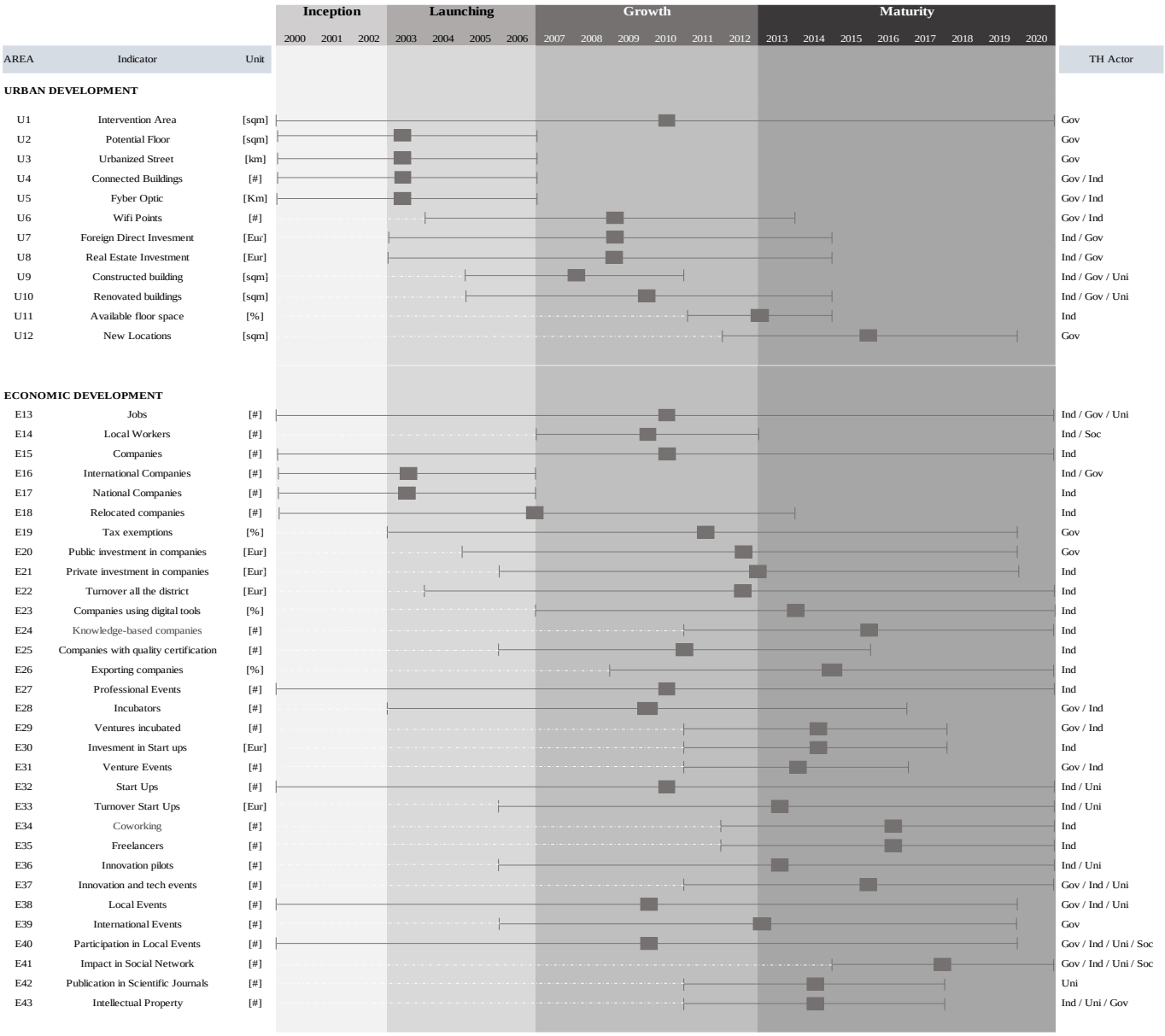
TABLE 3. Indicators activated in each stage of the AOI lifecycle



AREA	Indicator	Unit	TH Actor
URBAN DEVELOPMENT			
U1	Intervention Area	[sqm]	Gov
U2	Potential Floor	[sqm]	Gov
U3	Urbanized Street	[km]	Gov
U4	Connected Buildings	[#]	Gov / Ind
U5	Fyber Optic	[Km]	Gov / Ind
U6	Wifi Points	[#]	Gov / Ind
U7	Foreign Direct Invesment	[Eur]	Ind / Gov
U8	Real Estate Investment	[Eur]	Ind / Gov
U9	Constructed building	[sqm]	Ind / Gov / Uni
U10	Renovated buildings	[sqm]	Ind / Gov / Uni
U11	Available floor space	[%]	Ind
U12	New Locations	[sqm]	Gov
ECONOMIC DEVELOPMENT			
E13	Jobs	[#]	Ind / Gov / Uni
E14	Local Workers	[#]	Ind / Soc
E15	Companies	[#]	Ind
E16	International Companies	[#]	Ind / Gov
E17	National Companies	[#]	Ind
E18	Relocated companies	[#]	Ind
E19	Tax exemptions	[%]	Gov
E20	Public investment in companies	[Eur]	Gov
E21	Private investment in companies	[Eur]	Ind
E22	Turnover all the district	[Eur]	Ind
E23	Companies using digital tools	[%]	Ind
E24	Knowledge-based companies	[#]	Ind
E25	Companies with quality certification	[#]	Ind
E26	Exporting companies	[%]	Ind
E27	Professional Events	[#]	Ind
E28	Incubators	[#]	Gov / Ind
E29	Ventures incubated	[#]	Gov / Ind
E30	Invesment in Start ups	[Eur]	Ind
E31	Venture Events	[#]	Gov / Ind
E32	Start Ups	[#]	Ind / Uni
E33	Turnover Start Ups	[Eur]	Ind / Uni
E34	Coworking	[#]	Ind
E35	Freelancers	[#]	Ind
E36	Innovation pilots	[#]	Ind / Uni
E37	Innovation and tech events	[#]	Gov / Ind / Uni
E38	Local Events	[#]	Gov / Ind / Uni
E39	International Events	[#]	Gov
E40	Participation in Local Events	[#]	Gov / Ind / Uni / Soc
E41	Impact in Social Network	[#]	Gov / Ind / Uni / Soc
E42	Publication in Scientific Journals	[#]	Uni
E43	Intellectual Property	[#]	Ind / Uni / Gov

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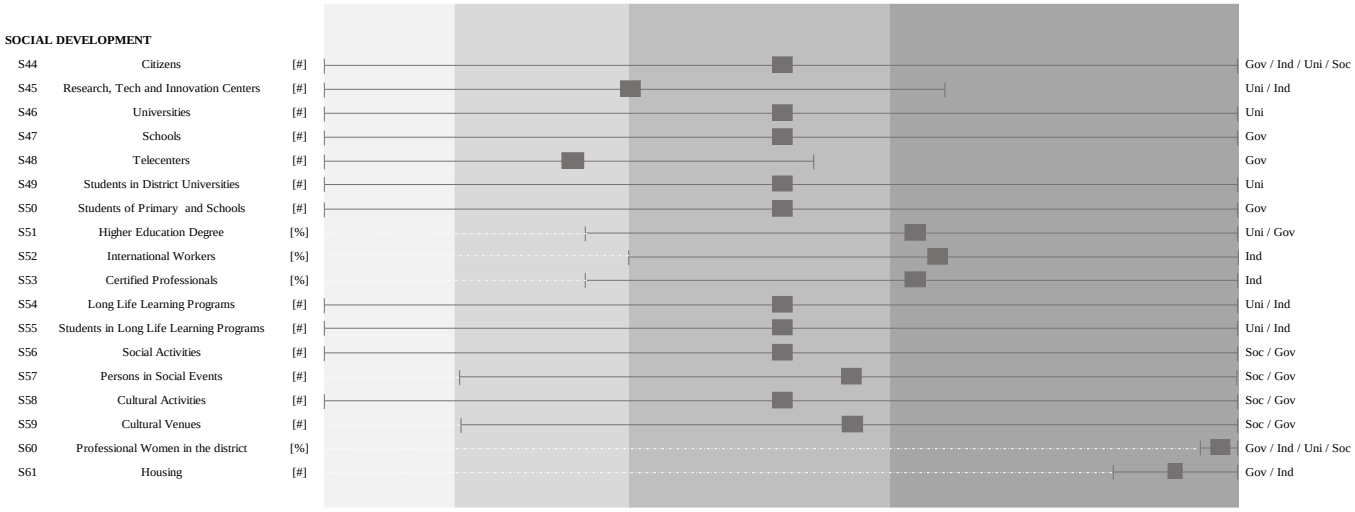

Source: Own elaboration.

Below we elaborate on each stage of the lifecycle of PD and discuss the rationale behind the relevance of the indicators taking into account the strategy adopted by the AOI.

4.2.1 Inception

In terms of infrastructure and urban transformation, a new planning regulation[4] was created at this stage in order delimit the area of PD, the type of uses intended for the land – streets, business and commerce, cultural equipment, etc – and to provide incentives for attracting investors to the innovation district. At that time, social housing was not available in the area. Accordingly, KPIs refer to the intervened area (measured as the total surface in which a modification of the urban space can been carried out), the potential floor available (proxied as the square meters that can be built), the urbanized streets (in kilometres), connected buildings (number of buildings with internet coverage) and high connectivity (kilometres of optical fibre cable). All measures here are linked and belonged to the Master Plan of the PD's project definition. Apart from the first indicator (Intervention Area) that was used over the 20 years of evolution of the

[4] City Law 17.244/2006 and further modifications

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district, the remaining indicators that pertain to this dimension were measured during the first 7 years, that is, during the Inception and Launching phases.

Moving on to the economic dimension, the participation of universities, government and industry was prioritized to articulate the collaboration that stimulated the strategic development of the knowledge-based economy in a formerly deprived area. At this stage, the State Government of Pernambuco, in partnership with Informatics Centre (Centro de Informatica – CI), involved the Association of Software Companies (Softex Recife) to explore the potential companies and jobs to be attracted/generated in the area through the regeneration of the port warehouses and historic real estate in the case of Recife.

KPIs that capture the interventions in the economic sphere where measures such as the number of current companies and jobs, could be used as a starting point to establish future development objectives. These two measures remained operative throughout the district's lifecycle. During the first two stages (inception and Launch), it was also important to differentiate between national and international companies, for this reason two different indicators were defined (National Companies and International Companies). Another parameter that was activated during this stage was an indicator that measured the number of companies attracted to the area (relocated company indicator), and they kept active up to the beginning of the Maturity phase. The number of professional events (professional events indicator), local events and the quantity of people that participate in them, were also analysed from the origin and their values, were recorded throughout development of the district. Finally, the number of startups was also activated at the inception stage and is still in use. Note that even when economic viability of the project is analysed, the focus here is not that much on measuring profit.

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As for the social dimension, the State of Pernambuco was the main stakeholder for converting the old quarter of the city into a new innovation district, thus the knowledge about the demographics of the area and the involvement of the residents, business owners and real estate owners were of utmost importance. The University of Pernambuco (UFPE), through its Informatics Centre (Centro de Informatica – CIn/) and the Recife's Advanced Studies and Systems Centre (CESAR) were also involved at the time of inception. In this sphere, the role of citizens acquires prominence, as can be seen in the suggested KPI as knowing the number of citizens is used to forecast the future number of inhabitants, and thus, the number of houses and other infrastructures that will need building. The number of research, technology and innovation centres, universities, schools and telecentres also began to be registered at this stage, as well as the number of students attending university or primary school. Accounting for the number of students was an activity maintained throughout the four stages, while measurement of numbers of research, technology and innovation centres stopped when the district reached maturity. The measurement of number of telecentres was discontinued in the growth stage.

Additionally, continuous training was also analysed and maintained from the beginning to the end of the development (indicators Long Life Learning Programs and Students, which seek to record the number of programs offered and the students enrolled, respectively).

Finally, the number of social and cultural activities was recorded as a measurement parameter of how lively the AOI was. Recording of this indicator started during the inception stage and has been maintained as of today.

Finally, looking at the governance dimension, main KPIs refer to quantify the monetary value made available for district activities and projects (district budget), and the number of

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professionals in the management team (district management team professionals' indicator). Both metrics have and are still being used since inception.

4.2.2. Launching

In order to coordinate the efforts of the main actors in terms of the talent and social transformation, it was established the management organisation of the AOI, the Núcleo Gestor do Porto Digital (NGPD), a private not-for-profit company that represents the Triple Helix actors and that has as its mission to the promotion of competitive conditions that create, attract and strengthen innovative information technology and creative economy ventures to the innovation district.

The implementation in the district of organisations, such as the State Secretariat of Science, Technology and Environment (SECTMA), research institutes as the CIn – UFPE and the Institute for Innovation in Informatics (I3) and the continuous involvement of incubators like CESAR and Cais do Porto, and the support of the Interamerican Development Bank, created the trust for attracting other institutions and companies to engage with the project. CESAR also oversaw the development of physical and logical conditions for the creation and growth of startups, matching startups with entrepreneurship programmes and connections with investors.

New indicators were created and identified in the Launch phase, indicators such as Foreign Direct Investment and Real Estate Investment, which measure the money invested both externally and internally. The Constructed building and Renovated buildings indicators, which measure square meters built and renovated respectively. Wi-Fi Points were also considered here, which counted the number of Wi-Fi connection points within the district. All these new indicators remain active until the beginning of the Maturity phase.

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Similarly, the economic dimension also begins to measure the investments amount in this Launching stage. Indicators such as Public Investment in companies and Private investment in companies are activated here and will continue to be measured until the end. The percentage of tax exemptions (Tax exemptions), the invoicing of the existing companies and the startups (indicators of Turnover all the district and Turnover Startups respectively). The number of companies with quality certification (Companies with quality certification indicator), the number of incubators (Incubator indicator), the number of innovation pilots (Innovation Pilot indicator) and international events (International Events indicator), begin to be measured in this phase, remaining operational throughout the development cycle.

In terms of the Social dimension, measurement of the following indicators began during Launch stage: Higher Education Degree: percentage of students with higher education; Certified Professionals: percentage of professionals who have participated in certification training; Persons in Social Events: number of people participating in social events and Cultural Venues: number of Cultural Venues.

The Governance dimension activated here the District Companies Associated indicator, that measures the number of associated companies and the number of professionals that belong to district company associations (Professionals in district companies associations indicator).

4.2.3 Growth

The management organisation of the area, NGDP, drove the building and integration of communities and networks. In terms of cultural activities, the tax incentives and local projects led to an enhancement of social facilities for the district workers, local citizens, and tourists. Several facilities were implemented in the area, such as bars, restaurants, museums, a shopping mall, a handcraft market, and Recife's most famous space for festivities, especially during

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Carnival. On Sundays and holidays, itinerant artistic presentations animate the district, and the streets are exclusively for pedestrians and cyclist use.

Companies of two clusters — IT and the creative economy — were attracted to the area. Other companies, such as FIAT, Accenture, IBM, Uber were also attracted once the district became a reference for infrastructure, open innovation, and talent.

It also attracts the interest of real estate investors and developers, that see opportunity in the rising demand and tax incentives to regenerate the real estate.

Urban indicators were created in previous phases, here it was only registered indicators that measure the percentage of Available Floor Space and the New Locations, which is the expansion in square meters of the district.

In the economic field, indicators are developed to measure Knowledge-based companies: number of knowledge-based companies. Exporting companies: the percentage of companies that export. Ventures incubated: the number of ventures incubated. Investment in Startups, the monetary amount of investment in Startups. Venture Events: the number of venture Events. Coworking: the number of collaboration spaces. Freelancers: number of freelancers. Innovation and tech events: number of innovation and technology events.

In the social sphere, the indicators detected in the Growth stage were: International Workers: percentage of international workers in the district. Publication in Scientific Journals: the number of scientific publications made by works within the district. Intellectual Property: the number of patents registered within the district.

The governance dimension began to register at this stage, the number of clusters that the district had (indicator of Cluster).

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4.2.4 Maturity

The efforts made to consolidate Porto Digital attracted national and international events and visibility to the project, as well as enhanced competitiveness. It appeared in the *Financial Times* in 2014 as ”Recife: rebirth of the Brazilian Venice”, which entitles Porto Digital as a main driver in containing the region’s brain drains through the nurturing of a dynamic economic ecosystem based on culture, information, and knowledge.

NGPD consolidates its engagement with international networks (e.g., International Association of Science Parks and Areas of Innovation -IASP, American Chamber of Commerce, and Triple Helix Association), as well within Brazilian Networks (e.g., ANPROTEC, ASSESPRO, Softex Recife). In 2013, Porto Digital hosted the Annual Conference of IASP, strengthening its engagement with the international community. These engagements created a robust platform for the internationalisation of Porto Digital and to export the model to other regions/countries.

Porto Digital also expanded its operation to the countryside of Pernambuco State, through the innovation lab “Armazém da Criatividade” in Caruaru, and also expanded its companies cluster from IT and creative economy to include urban and future of cities technologies.

Apart from the indicators activated in previous phases that remain active in this phase, the following are created in this instance: Impact in Social Network: level of impact on social networks (High, medium or Low). Professional Women in the district: percentage of women working in the district. Housing: number of dwellings in the district. Regarding this last indicator, currently, Porto Digital does not have housing in the district and PD staff still commute to their homes in the satellite areas. However, there is in place a large-scale project to convert 35 thousand meters of idle areas into residential areas. This area, currently degraded, will be regenerated via private investment. Although priority will be given to housing for PD

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workers, the housing project is a mix of buildings of various categories, including social housing. The NGPD developed the concept and sought out the investor (they have a Memorandum of Understanding for the development of this project).

In the governmental sphere, measurement of the number of existing indicators that record the development of open data (Indicators in Open Data) began in the Maturity stage.

4.2.5 Triple Helix agents

The Triple Helix model allows the different actors (i.e., government, university and private sector) to engage at different speed and levels of commitment. When analysing the evolution of PD, one notices that indeed, Triple Helix agents show diverse strategies which differ not only in the type of activity but also in terms of when (timing along the lifecycle) and how (resources they put into play and level of influence). In the paragraphs that follow we briefly explain how each of the Triple Helix agents behaved.

Government had a dominant role in urban development (defining the area of intervention, the potential floor, and the streets that qualified for urbanization), although a joint collaboration with the industry was needed in order to develop the infrastructure and define new locations. In the economic dimension the government also stood out, holding in his hands the capacity to stimulate economic activity by means of tax exemptions, public investment, easing the creation of entrepreneurial ecosystems (e.g. incubator, ventures incubated) and promoting the district through events (e.g. venture events). In the social sphere, the government was responsible for defining the number of houses to be built and, consequently, setting an estimate for the number of citizens that will be able to live in the district, and therefore, the need for schools and social services (which will be in hands of the public administration). Finally, in the governance

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dimensions, the government plays a key role promoting the association of companies, the clusterization and the budget of the organization in charge of developing the district.

The Industry, in urban development, will deploy the infrastructures and buildings and will offer all the offices to the tenants and investors. In terms of economic development, the industry will also be in charge of generating and developing companies, with the job creation that this entails. This occupation could be analysed by local workers and freelancers among others. Also, as an expression of economic impact and development, industry will have indicators that follow the turnover of companies and the private investment in startups (Business angels in venture capital and corporate venturing). The competitiveness of the companies using digital tools and the quality certifications (organizational and personal) are also measures led by the industry. The number of knowledge-based companies and the number of pilots are expressions of the innovative industry in the district. The internationalization degree analysed by the number of the international companies and the participation in international events, are also measures managed by the industry. In Social development the industry contributes with the number of workers that live in the district being able to specify between international, women and others that will be neighbours in the district. In the governance development the number of the companies associated in the district and the number of clusters are indicators that have the industry as a relevant agent.

Universities, in urban development, can participate creating or renovating their own buildings. In terms of economic development, universities contribute with the development of new science, papers, and patents, the development of innovation pilots and new startups and finally with the participation in events. In Social development, Universities contribute with students and professors as citizens of the district and improving the education of workers. Also,

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providing education degrees and long-life learning programs. In Governance development, Universities are also involved in the cluster and the company's associations.

Society will be the user of the district, participating actively as workers in the economic development and as students in the social development. The dynamics of the district will be measured with social and cultural activities. In the case of Recife, the society was not deeply involved in the governance at the beginning.

4.2.6 Indicators' Categories

In terms of the part in the program that the indicator can be related to, three main categories can be observed (See Table 4)

- Input indicators, which measure the resources needed to implement the program (U1, U2, U7, U8, U12, E14(1), E19, E20, E21, S46, S47, S48, S49, S50, S61, G62, G63).
- Process indicators, which measure program activities and outputs (U3, U4, U5, U6, U9, U10, U11, E18, E23, E25, E27, E28, E29, E30, E31, E34, E36, E37, E38, E39, E40, E41, S51, S53, S54, S55, S56, S57, S58, S59, G64, G65, G66).
- Outcome indicators (2), which measure if the program reaches its expected effects (E13, E15, E16, E17, E22, E24, E19, E32, E33, E35, E42, E43, S44, S45, S52(3), S60, G67).

(1) Local workers, considered as a means of inclusion, it can be classified as an outcome, but at the same time if it is conceived as available resources, it could be classified as an input.

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(2) The indicators that measure outcome should be measured from the beginning in order to set the benchmark on which to improve.

(3) International workers are on one side, input for the internationalization of the company and could be the result of activities of attraction of talent. In our case, as an outcome because of the goal of the district of increasing the international diversity.

It could be observed here that some outputs became inputs of new activities and the addition of many outputs derived from the accomplishment of outcomes.

TABLE 4. Indicators' Categories

AREA		Indicator	Unit	Indicator Category
URBAN DEVELOPMENT				
	U1	Intervention Area	[sqm]	Input
	U2	Potential Floor	[sqm]	Input
	U3	Urbanized Street	[km]	Output
	U4	Connected Buildings	[#]	Output
	U5	Fyber Optic	[Km]	Output
	U6	Wifi Points	[#]	Output
	U7	Foreign Direct Invesment	[Eur]	Input
	U8	Real Estate Investment	[Eur]	Input
	U9	Constructed building	[sqm]	Output
	U10	Renovated buildings	[sqm]	Output
	U11	Available floor space	[%]	Output
	U12	New Locations	[sqm]	Input
ECONOMIC DEVELOPMENT				
	E13	Jobs	[#]	Outcome
	E14	Local Workers	[#]	Input
	E15	Companies	[#]	Outcome
	E16	International Companies	[#]	Outcome
	E17	National Companies	[#]	Outcome
	E18	Relocated companies	[#]	Output
	E19	Tax exemptions	[%]	Input
	E20	Public investment in companies	[Eur]	Input
	E21	Private investment in companies	[Eur]	Input

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AREA		Indicator	Unit	Indicator Category
	E22	Turnover all the district	[Eur]	Outcome
	E23	Companies using digital tools	[%]	Output
	E24	Knowledge-based companies	[#]	Outcome
	E25	Companies with quality certification	[#]	Output
	E26	Exporting companies	[%]	Outcome
	E27	Professional Events	[#]	Output
	E28	Incubators	[#]	Output
	E29	Ventures incubated	[#]	Output
	E30	Invesment in Start ups	[Eur]	Output
	E31	Venture Events	[#]	Output
	E32	Start Ups	[#]	Outcome
	E33	Turnover Start Ups	[Eur]	Outcome
	E34	Coworking	[#]	Output
	E35	Freelancers	[#]	Outcome
	E36	Innovation pilots	[#]	Output
	E37	Innovation and tech events	[#]	Output
	E38	Local Events	[#]	Output
	E39	International Events	[#]	Output
	E40	Participation in Local Events	[#]	Output
	E41	Impact in Social Network	[#]	Output
	E42	Publication in Scientific Journals	[#]	Outcome
	E43	Intellectual Property	[#]	Outcome
SOCIAL DEVELOPMENT				
	S44	Citizens	[#]	Outcome
	S45	Research, Tech and Innovation Centers	[#]	Outcome
	S46	Universities	[#]	Input
	S47	Schools	[#]	Input
	S48	Telecenters	[#]	Input
	S49	Students in District Universities	[#]	Input
	S50	Students of Primary and Schools	[#]	Input
	S51	Higher Education Degree	[%]	Output
	S52	International Workers	[%]	Outcome
	S53	Certified Professionals	[%]	Output
	S54	Long Life Learning Programs	[#]	Output
	S55	Students in Long Life Learning Programs	[#]	Output
	S56	Social Activities	[#]	Output
	S57	Persons in Social Events	[#]	Output
	S58	Cultural Activities	[#]	Output
	S59	Cultural Venues	[#]	Output
	S60	Professional Women in the district	[%]	Outcome

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AREA		Indicator	Unit	Indicator Category
	S61	Housing	[#]	Input
GOVERNANCE DEVELOPMENT				
	G62	District Budget	[€]	Input
	G63	District management team Professionals	[#]	Input
	G64	District Organizations associated	[#]	Output
	G65	Professionals in district companies assoc	[#]	Output
	G66	Indicators in Open Data	[#]	Output
	G67	Clusters	[#]	Outcome

Source: Own elaboration.

5. Discussion

The transformation of a district of innovation implies changes in the urban, economic, social and governance dimensions, with a holistic approach between all of them (Piqué, Miralles and Berbegal-Mirabent 2019a). The final result is the convergence of a common agenda in which government, universities, private companies and the society at large, collaborate and find synergies. The consolidation of an AOI implies going through a number of stages, and at each stage (from inception to maturity), the different agents will adopt different roles, get involved in different activities and interact with the other stakeholders differently. Within this context, we posit that identifying key performance indicators to monitor the progress of an AOI is of paramount importance in order to take more informative decisions at each stage and thus, allow policymakers to concentrate on those aspects that lead to successful implementation of the AOI. Using data that covers a 20-years period, in this study we have been able to analyse the case of Porto Digital and provide key insights at each phase of its development. To do so, we have defined a framework of indicators, established at which moment each indicator enters into play, and identified the role played by each of the Triple Helix agents.

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We believe this work will provide new knowledge for researchers and policymakers in order to prioritize actions that will impact the desired goals. In the subsections that follow we dive deeper in the implications that can be drawn from this study.

5.1. Triple Helix Agents

Under the lens of the Triple Helix model, the case examined evidence that triple helix actors play different roles and that the role each agent adopts evolves over time. According to the preponderance of the different actors in each stage of the lifecycle of an AOI, we observed that at the beginning, the government should take a leading role, particularly in urban planning and the development of infrastructures, not only making the location and the amenities surrounding them attractive, but also implementing financial incentives. This shows that the government power of action is preponderant in the urban dimension. The government is also the main driving agent for social development in the initial stages, therefore, actions undertaken should also be directed towards increasing and improving the number of citizens, schools, students and related areas. Concerning the role played by academic institutions (in the specific case under analysis, the University of Recife), the main contribution in the initial stages consisted of provision of the right talent and technology, to make the area attractive. As the AOI evolved, the industry came into play. First, being in charge of the construction of buildings and infrastructure, and later, settling national and international companies in the district and creating jobs. These companies formed clusters of innovation, which in turn, trigged the creation of startups, attracted venture investment, and contributed to corporate innovation and the establishment of a formalized innovative community. Last but not least, the society in PD, as a quadruple helix agent, was in charge of the cultural development and the organising of social events beyond professional life. Involving people was seen as critical to ensuring success,

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therefore, their participation began to be measured, particularly in the third and fourth stages, once opportunities were granted, and also as a strategy to monitor if the planning of housing and services was enough or required further investment to meet demand.

5.2. Evolution phases of the AOIs

At the *inception* stage, the AOI is conceptualized. A first decision is defining the location and what kind of transformation the area will require. According to the stages of AOI model, in the urban dimension the government should lead urban planning, infrastructure, and the foundation of the entity that will manage the district involving key institutions. In this phase, in tune with the theoretical model, the activated indicators reflect that in the case of study, evaluation of activities related to urban planning (indicators U1 and U2) and infrastructures (U3, U4, U5 and U6) commenced. It is important to mention here that the indicators U2 (Potential Floor) and U3 (Urbanized Streets) stopped being measured in the growth phase because the area was fully built, if there had been more space, this parameter would continue to be measured throughout all phases. On the other hand, the indicator that measured the kilometers of fiber optics (U5), was also discontinued in the growth stage, but for a different reason, related to the fact that it became a commodity, and every house was offered fiber optics. Also, the NGPD was created involving the Triple Helix Agents, applying the first budget (G62) and hiring the District Management Team (G63). Additionally, advancing the phase of launching of the AOI Model, PD activities related to the attraction of companies (E15), national (E17) and international (E16) were developed, but from the Growth stage, further census start to consider just companies, and make no differentiation with Multinational or National companies. Furthermore, in confrontation with the AOI model, PD activities linked to generation and development of talent (S46, S47, S49, S50, S51, S54 and S55) were developed. Also, in the case of PD, NGPD started

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promotion of the entrepreneurial ecosystem with creation of startups (E32) that in the AOI's evolution model was introduced in the growth phase. Overall, and after the analysis of this PD case, activities related to talent and startups, as well as social and professional activities could advance the inception stage of the AOI Model. This opens up or facilitates a debate about the importance of the relationship or dependence of the activities (conditions or resources previously required to carry out tasks or projects) over a fixed temporary disposition of each one of them in these promotional and social activities.

The *Launching* phase takes all the guidelines established at the Inception phase and puts them into practice. According to the stages of the AOI model, the district deploys the utilities and starts the activity of the Real Estate, the first tractor companies and research and technology centres are located, and the incubation and landing programs are developed. The PD case coincides in this aspect since the indicators that measure the investment in real estate (U7 and U8) and the construction and renovation of buildings (U9 and U10) are activated in this instance. Besides, anchor institutions (E15, E16, E17 and E18) were landing in the district and Incubators (E28) promoted the activities of startups (E33) and the innovation pilots (E36) that agrees with what the model proposes. In contrast, PD was continuing the talent development (S51 and S53), social and cultural activities (S57 and S59) that do not appear directly in the AOI Model. Also, the first associations of companies in the district started at the launch stage (G64), unlike what is established in the AOI Model, which proposes that these activities begin in the growth phase. It implies that as soon as the district has companies located, the networking could be activated, and the sense of belonging is necessary to be developed by tools as associations. This makes the relationship and dependence between indicators visible again, but not a temporary rigidity in terms of social activities.

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After the AOI has performed well on their KPIs in the Launching phase, the next step is the *Growth* stage. According to the Stages AOI Model, it's the moment of clustering and strengthening communities, while activities related to the urban and economic dimension (creation of startups, attraction of companies and open innovation) continue. In the case of PD, all the effort went into attracting new business and investment, and into boosting business clustering (G67) and networking, which made the indicators that measure the variations of these concepts operational at this stage. The Entrepreneurial ecosystem was growing with the ventures incubated (E29) investment in startupss (E30) and venture events (E31) building the clusters of innovation. A special mention should be made of these indicators (E28, E29, E30 and E31) during the maturity phase, since even when the reports do not continue to record their evolution in the traditional way, and during and after this stage, the data was and is collected through a tool, (now a prototype, that is self-declaratory). PD asks the ecosystem to register and disclosure information, which is then validated. Besides, the technology made possible the competitiveness of the firms and the knowledge-based companies (E23 and E24) and the tech base was boosted by tech events (E37) that are diffusing the research and the intellectual property (E42 and E43). PD started in this phase the involvement of the local residents as workers (E14) and international workers (E52), that the AOI Model is focusing on the maturity stage. A special mention must be made about the measurement of the number of local workers (E14), which began and ended during the growth stage; this situation arose because this measure was carried out through censuses, and these were solved with money from the projects, then, at the end of the associated project, the census was also stopped.

At the Maturity stage, according with the Stages AOI Model, this is the moment of territorial growth, internationalization and growth of companies, and social networks. In the case of PD, new locations (U12) started in the Growth Model. The Internationalization of the District started

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in the launch phase (E39). In the case of PD, in the urban dimension, the district deployed all the floor and infrastructure, and the indicators finalized depending on the fulfilment of the project. In economic development the jobs and companies are performance indicators of the success of the district and the community creation is fully activated (E41). In the social development, the talent of the district is provided by educational institutions and promoting the inclusion of gender in the case of PD (S60), incorporated as a strategic objective, gender equity was not emerging in Porto's strategy before. This conjunctural factor is evidence of the importance of the appropriate incorporation of the indicators over time, since an early measurement of female participation would have allowed for identification of its imbalance and for addressing it earlier on. Paradoxically, the debate of the housing started in the maturity phase (S61). Housing projects were not possible by PD authorities because the area is highly regulated. New projects with the city hall opened opportunities during this stage. Housing and social dimension measures should be included from first phases, as a way of attracting and retaining talent and in order to be a co-author of the unique identity that the district will have, generating commitment and a sense of belonging; measuring these parameters from the beginning would have made it possible to highlight this shortcoming and address it, through inclusion actions, at earlier stages.

5.3. Clusters of Innovation

This study also serves to provide new evidence for the clusters of innovation (COI) theory. From the data collected, it can be concluded that PD is an innovation district that behaves as a COI. If we look at the core components of a COI, they are all covered, with specific indicators to capture their breadth and depth:

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- Major corporations and entrepreneurs are present and active throughout the entire lifecycle. Specifically, major corporations are embedded in a set of indicators in the economic dimension (E15, E16, E17, E18, E24, and E26). Entrepreneurs are measured in startupss related indicators (E24, E29, E32, and E33).

- Venture capital indicators appear since the beginning (launching phase) in the economic dimension. See for instance private investment in companies (E21) and investment in startupss (E30).

Regarding supporting components:

- Universities related indicators are reflected in the social dimension and are measured through a set of indicators which are relevant during the entire life cycle (see indicators S46, S45 and S51).

- Government: the impact of government related activities in the area can be drawn from indicators connected with the area development (urban dimension), such as intervention area (U1), potential floor (U2), urbanized street (U3) and fiber optics (U5), which were relevant in the inception and launching phases. Also, it is related to the economic dimension in terms of tax exemptions (E19), relevant from the launching phase on, and in the governance dimension, particularly in the district budget (G62);

- Supporting professionals, such as lawyers and accountants specialized in entrepreneurial issues, did not find any particular indicator in this particular case.

- Professional managers of startupss appear indirectly in Professionals in district companies associated (G65).

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COIs are also characterized by hybrid components. In the case of PD, these components have materialized as detailed below:

- Research Parks, Tech Parks, Incubators: there are specific indicators to measure the presence of such components, relevant from the launching phase on: Incubators (E28), Coworkings (E34).

- Corporate Venturing Capital (CVC) and Angel investment: the indicators found do not make distinction between private investment (E21) in terms of regular Venture Capital, CVC and Angel investment.

- Public VC: public investment in companies (E20) is measured from the launching phase on, but it includes grants as well, which precludes a more detail information on public VC.

- Service organizations and corporate foundations: there are no measures that capture information about this type of organizations (normally charities and a mix between governments and major corporations) in providing general support to the innovation process.

Finally, COIs embed a series of behaviours among the components. These behaviours are almost all present in PD, and can be captured by some of the indicators included in our framework:

- Entrepreneurial process: innovation pilots (E36), is the only indicator that provides some information on the topic. Although there are indicators related to infrastructures to support entrepreneurship (such as Incubators – E28), indicators to capture more detailed information for this category were not found, such as number of serial

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entrepreneurs, number of failed projects, number of grants approved (and from these the successful ones and the failed ones).

- High mobility of resources: there were no indicators found related to turnover of personnel or any other that disclosed or yielded information on the topic. Success rates of private investment (volume, number, series) and grants awarded could provide more information on the mobility of resources. As regards technology mobility, some indicators such as certified professional (S53), companies using digital tools (E23), companies with quality certifications (E25), and Innovation and Tech events (E37).

- Alignment of interests: although difficult to measure, and does not appear in specific indicator, PD has in its governance (PD Statute), the participation of the different actors in the ecosystem. One measure that would be helpful for the validation of interest, is the variation of the budget allotted by government, industry, and academy for activities to foster PD innovation ecosystem.

- Global perspective: some indicators which provide the interest of the AOI on global engagement were found, such as foreign direct investment (U7), international companies (E16), international events (E39), international workers (S52), all from the launching phase.

- Global linkages: no indicator was found that addresses more formal linkages, such as number of joint international projects, memorandums of understanding with international organizations, soft-landing programmes.

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5.4. Input, process and outcome indicators

When analysing the indicators according to the part of the program to which the indicator can be related and its three main categories (input, output and outcome indicators), the case analysed shows that the indicators that measure outcome, that is, that control that the district reaches its expected effect; they are concentrated in the economic and social dimensions, not registering outcome indicators in the urban and governance domains. Although, the strategic goals are specific to each project and this may vary from one particular case to another, it makes it possible to ask whether in the case of innovation districts, the data and measures related to infrastructures and governance are means to an end (input and output of intermediate projects), but not a goal in itself.

Additionally, also in the case of outcome indicators, measurement should begin before carrying out any activity that modifies the parameters they evaluate, so that it serves as a benchmark for improvement or growth. In the case of PD, there are certain outcome indicators that begin to be active after carrying out actions and projects that modify them (their respective output indicators are activated before), which prevents their growth from being accurately measured.

6. Conclusions

Areas of Innovation (AOIs) need urban, economic, social and governance development (Sarimin and Yigitcanlar 2012, Nikina and Piqué 2016). Building upon the frameworks of Triple Helix, Knowledge-Based Urban Development, Clusters of Innovation, AOIs evolution phases, and the knowledge in Performance Indicators, this study presents a new way of organizing performance indicators of the mission of the AOI activated in different phases of the development transformation. Using the Porto Digital Case in Recife, the most awarded project in Brazil, that has been ongoing for 20 years at a Triple Helix hybrid organization

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(NGPD), a set of performance indicators were defined, classified and analysed in order to understand when they have been activated at every stage of development in the urban economic, social and governance dimension, from inception to maturity, and what Triple Helix agents have been involved in every indicator with the major action power over it.

Four main conclusions emerge from the in-depth study of the case of Porto Digital district of innovation. First, to correctly monitor the progress and development of an AOI, indicators that capture the urban, economic, social and governance transformations that the territory will undergo are needed. Porto Digital is a brownfield transformation that has been developing for 20 years acting in (1) Urban revitalization renewing buildings and preserving historic patrimony, (2) Economic regeneration promoting entrepreneurship and Innovation, and developing Clusters in IT and Media, (3) Social activation with Amenities and activities beyond work, (4) Governance orchestration with an Administrative Council with members of Universities, Industry and Government.

Second, the indicators measure the result of the work in actions developed by Triple Helix Agents individually or collectively. (1) Likewise, Government defining the urban planning, infrastructure, and the new locations. Government also plays a key role providing investment, developing attractiveness of the district, and activating the ecosystem of innovation. Additionally, Government is the one that define the number of citizens that will live in the district and encouraging the location of main institutions. Overall, create the conditions for management and the orchestration of the AOI. (2) The industry acts through the Real Estate investment, through construction of building and the deployment infrastructures. It is also the main party responsible for the occupation, the number and size of companies, adoption of technology and turnover. (3) The University through talent creation and development, scientific

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productions, providing a tech base and research and technological centres, creates the foundations for innovation and scientific development that will also act as a means of attracting and retaining talent.

Third, Indicators are activated in different stages. In the (A) Inception phase, the number of Citizens, Jobs and Companies are important to establishing the boundary conditions on which development of the district will be planned. The Area of Intervention and potential floor are also included and relevant measures for this initial conceptual work definition, which seeks the enrichment of a specific area with the aim of creating an ecosystem of urban innovation, which requires identifying a local context that ensures that talent, technology and capital can flow freely (Etzkowitz and Leydesdorff, 2000). In the (B) Launching phase the number of anchor universities and centres and the tractor companies are essential to promote and drive innovation. Anchor institutions are key links to connect startups and business incubators aligning research interests with business needs (Pique et al. 2019b). Measuring the development of infrastructures makes it possible to guarantee the existence of the necessary structure for the settlement of the first tenants. Innovation pilots, district organizations, cultural activities, public and private investment and the economic impact starts to be measured here, granting a global perspective that fosters the innovative community, elevates its key competencies and allows for interaction with analogous communities. Housing and social dimension should begin to be measured at this stage as a way to guarantee and promote measures that retain talent and attract investment. In the (C) Growing phase, indicators related to the number of knowledge-based companies, number of exporting companies and the square meters of new locations begin to become operatives. The focus here is to attract business and investors promoting business clustering and networking. The indicators that measure the entrepreneurial ecosystem, the internationalization of the talent, and the Companies Clusterization are activated seeking to guarantee the actions

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that will be a source of attraction for innovative and international talent and business. In the (D) Maturity phase, the district deploys all the floor and infrastructure, and the indicators finalized depending on fulfilment of the project. The jobs and companies are performance indicators of the success of the district and the promotion and community creation is fully activated. The talent of the district is provided by educational institutions and promoting the inclusion of gender in the case of PD.

Fourth, being able to distinguish between input, output and outcome indicators allows us to glimpse the impact that the measures that are evaluated have on the general objectives and how they can affect other measurements of related indicators. In the case of PD, the indicators of the urban domain were identified as a means to an end, rather than a goal in itself, and this also conditioned the moments in which the measurements were carried out and generated boundary conditions for the other activities. Measurement of outcome indicators should begin before taking measures that modify the parameters, they assess so that there is a reliable benchmark against which to compare.

This study is not free of limitations, indicators are required for a comprehensive understanding of the dynamics of the PD ecosystem. Although the indicators found do provide a good overview of the AOI ecosystem components, more detailed indicators are needed in order to reveal the actual existence of supporting actors such as supporting professionals, professional managers, and a distinct approach to private investment (CVC, Angel, Public VC). It is also crucial that the AOI understands the behaviours, mainly the dynamics of the entrepreneurial process (for which just one indicator was identified), mobility of resources (personal and funds), the actual commitment of the main actors, and global linkages. Other limitations are that this research has been focused on one case study, in a brownfield transformation and that started 20

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years ago. Future research could analyse other projects in other countries with different starting points (green field and brownfield transformation) and might analyse different AOIs in a comparative base in order to find common indicators in the urban, economic, social and governance dimension and the relationship between them. Other future research could analysis the systemic relationship of the different indicators (input, output, outcomes) and how they impact or modify each other.

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