Amenity Mix of Innovation Districts

Abstract

Purpose — This paper identifies, compares and contrasts common and influential amenity mixes of innovation districts worldwide.

Design/methodology/approach — Urban amenity data were collected from Google Maps as 31,236 POIs in 24 innovation districts. The data were compared and categorised based on the density and diversity of amenity mixes using correspondence analysis. An overall amenity space of the 24 innovation districts was created using correlation and social network analyses.

Findings — This study found that innovation districts have broad ranges of diversity and intensity. Five groups were identified by correspondence analysis including retail, foodie, balanced, emerging and healthcare districts. The amenity space of innovation districts created using correlation analysis indicated the most influential amenities (highest Eigenvector centrality) as home goods store, florist, shopping mall, museum and lodging. Despite their high frequency, the presence of anchor institutions — universities and hospitals — did not correlate with other amenities.

Practical implications — Innovation districts and other kinds of places are encouraged to assess the density and diversity of amenities using the Big digital data available. Innovation districts can leverage their distinct amenity mixes and increase diversity by targeting highly influential amenities.

Originality/value — Despite some understanding, no previous research has thoroughly analysed the amenities available in innovation districts. This study is the first to comprehensively explore the amenities in innovation districts using data from Google Maps. Place managers can use the method introduced in this research to analyse innovation districts and other kinds of places.

1. Introduction

In the 21st century, cities have to adopt more systemic and holistic ways to generate knowledge and innovation because these assets help to improve competitive advantage (Yigitcanlar et al., 2020; Hsieh et al., 2014). As a result, innovation districts have emerged as a key approach for cities to harness technological innovations and rise to the economic, societal, spatial and environmental challenges (Yigitcanlar et al., 2020; Morisson and Bevilacqua, 2018). Innovation districts have become a new type of land use that boosts innovative productivity, revitalises urban areas and promotes mixed-use, diversity, density and compactness (Morisson, 2020). However, one overlooked attribute of innovation districts is urban *amenities*. Amenities play a role in creating vibrancy and lifestyle options that attract and retain talented knowledge workers — the "creative class" — to innovation districts (Leon, 2008; Esmaeilpoorarabi et al., 2018a; Wisuchat and Taecharungroj, 2021). Recent research also found that amenities are of the utmost importance to innovation districts (Esmaeilpoorarabi et al., 2018b; Esmaeilpoorarabi et al., 2020b; Adu-McVie et al., 2021). Nevertheless, no existing research has comprehensively studied the amenities of innovation districts as the research lacuna that this paper aims to fill.

This paper compares and contrasts amenity mixes of innovation districts worldwide and also identifies common and influential amenities in innovation districts. To achieve these objectives, amenity data were collected from Google Maps. POI data from Google Maps have been successfully used in recent research to identify urban amenities (Hidalgo et al., 2020; Taecharungroj, 2021). Twenty four innovation districts worldwide were selected from the

Global Network of Innovation Districts[1] and the existing literature. The innovation districts were compared and categorised based on the density and diversity of amenity mixes using correspondence analysis. An overall amenity space of the 24 innovation districts was created using correlation and social network analyses.

The findings of this research will help to shed light on the amenity mix of innovation districts. Results can show innovation district place managers a novel way to analyse their districts and plan for improvements. Success in facilitating and fostering diverse amenities in the district will increase vibrancy and buzz and attract knowledge workers and companies. Place managers can also use the methods introduced in this research to rapidly analyse other kinds of places including, but not limited to, business parks, industrial estates, town centres and high streets.

2. Innovation Districts

2.1 Innovation districts, common yet diverse

An innovation district is an urban model of innovation (Adu-McVie et al., 2021) that originated from the concept of innovation ecosystems (Lawrence et al., 2019) as a neighbourhood-scale geographic area within a city (Esmaeilpoorarabi et al., 2018b) that connects established institutions (such as a university or major tech hub) with entrepreneurial entities such as startups, business incubators and accelerators in a compact, transit-accessible and mixed-use physical environment (Katz and Wagner, 2014; Lawrence et al., 2019). An innovation district is a nucleus (Esmaeilpoorarabi et al., 2018b) or a nexus (Pancholi et al., 2017) of knowledge- and innovation-based activities underpinned by "an integrated culture of innovation, learning, commercialisation, governance, networking, lifestyle and environment" (Pancholi et al., 2017). Other terms such as high technology district, science and technology park, knowledge community precinct, innovation precincts and knowledge and innovation spaces are used interchangeably to describe innovation districts (Adu-McVie et al., 2021).

Innovation districts have become popular urban policy interventions worldwide because they offer several benefits to the city. They empower entrepreneurs to produce both higher quality and quantity of innovation outputs — with productivity rates per employee as much as four times higher compared with non-innovation counterparts (Drucker et al., 2019; Hegyi et al., 2021). They provide a broad variety of accessible jobs and educational opportunities for local communities and create denser residential and employment patterns, leading to reduced carbon emissions (Katz and Wagner, 2014). Innovation districts also foster diversified mixed-use development, dynamic ambiance, a variety of lifestyles and an 'authentic' identity in the city (Esmaeilpoorarabi et al., 2020c). These direct and indirect contributions enable cities to become more polycentric and help tackle underlying urban challenges including slow growth and fiscal challenges, social inequality and environmental degradation (Katz and Wagner, 2014; Esmaeilpoorarabi et al., 2020c).

Despite the aforementioned benefits, critics of innovation districts claim that mechanisms driving gentrification polarise the workforce and hollow out the middle class (Morisson and Bevilacqua, 2018). Kayanan (2022) posited that entrepreneurs with minimum real estate requirements were easy initial targets of innovation districts. However, once the economy improves, developers turn to secure higher rent thus displacing such entrepreneurs. This "corporate town" approach favours high-value technological sectors and induces the involuntary dislocation of disadvantaged residents (Morisson and Bevilacqua, 2019; Heaphy

[1] https://www.giid.org/global-network-of-innovation-districts/

and Wiig, 2020). In addition to escalated property prices and inequality, the natural environment was also perceived to be threatened by fast-paced development in innovation districts (Esmaeilpoorarabi et al., 2020b). To counter such negative externalities, leaders and actors within the innovation districts need to ensure that the benefits are distributed fairly; developments of urban facilities have to be balanced (Esmaeilpoorarabi et al., 2020b; Morisson and Bevilacqua, 2019). Achieving the right balance in innovation districts is no easy task because although they have many common characteristics, each district is diverse. This variety of innovation districts makes it difficult for place managers to select the right improvement and development plan (Adu-McVie et al., 2021).

A variety of innovation districts has stemmed from the socioeconomic heterogeneity of cities (Yigitcanlar et al., 2020). There is no one "cookie cutter" approach to develop an innovation district because of the distinct economic strengths and spatial uniqueness leveraged in each area (Katz and Wagner, 2014). Nevertheless, many scholars have attempted to categorise innovation districts. Katz and Wagner (2014) identified three types including the anchor plus, the re-imagined urban area and the urbanised science park. The anchor plus model refers to innovation districts that co-locate with anchor institutions (e.g., a university), while re-imagined urban areas involve the transformation of historic obsolete industrial areas into innovation districts and the urbanised science parks are rejuvenated low-density business/research parks with mixed-use developments. Forsyth (2014) posited six district types based on their urban forms as corridors, clumps, cores, campuses, technology subdivisions and scattered sites. Recently, Yigitcanlar et al. (2020) systematically investigated several bases for the typology of innovation districts including types of industry, investment, management model, economic scale, setting and social activities, and space-use.

Notwithstanding their variety, innovation districts also share many common characteristics that differentiate them from other types of urban land uses (Adu-McVie et al., 2021). Many innovation districts worldwide have adopted the quadruple helix model of governance — a partnership between public, private, academia and the community (Pancholi et al., 2020). In addition to the main entities, innovation districts contain various complex spatial and socioeconomic elements (Esmaeilpoorarabi et al., 2018a), summarised by Katz and Wagner (2014) as the three interlocking economic, physical and networking assets. Physical assets are firms and organisations, public and privately-owned spaces and infrastructure, while networking assets are the relationships between individuals and organisations in the district. Esmaeilpoorarabi et al. (2020a) conceptualised the characteristics of innovation districts using a framework that contained five elements as *context* (city systems and quality), *form* (physical patterns, structures and layouts), *function* (functions of buildings and open spaces), *ambience* (urban, cultural, creative and digital scenes) and *image* (unique perceptions in the minds of stakeholders). These existing frameworks help place managers to invest, plan and develop innovation districts to accelerate growth in the city. The connections of the key institutions and other elements — an example of the whole being greater than the sum of its parts — led to the development of an innovation district that is dense, mixed-use, flexible, decentralised, open, public, technologically advanced, communal and distinct (Drucker et al., 2019; Lawrence et al., 2019).

2.2 Amenity mix: a driver of vibrancy and buzz

Despite some understanding of the components of innovation districts, there remains an important research gap. No current research has thoroughly analysed one key component of innovation districts — *urban amenities*. Examples of amenities are restaurants, bars,

nightclubs, coffee shops, retail, grocery stores, pharmacies, hotels, entertainment venues and public transport (Adu-McVie et al., 2021; Esmaeilpoorarabi et al., 2020c; Katz and Wagner, 2014; Lawrence et al., 2019). The agglomeration of such amenities provides *necessity* and creates a *vibrancy* that attracts talent to the district and encourages engagement, sharing and creating (Read and Sanderford, 2017; Drucker et al., 2019). A comprehensive understanding of the amenity mix or "amenity space" (Hidalgo et al., 2020) of innovation districts could help place managers to better assess amenities in the district and plan for future developments.

Amenities are of the utmost importance to innovation districts because they constitute "quality of life" that appeals to knowledgeable workers (Katz and Wagner, 2014; Esmaeilpoorarabi et al., 2020c). They are the enablers of the "live-work-play" environment, the *raison d'être*, of the innovation districts (Drucker et al., 2019; Yigitcanlar et al., 2020). Amenities create *buzz* or active energy and *vibrancy* or the soul of the innovation districts (Drucker et al., 2019; Esmaeilpoorarabi et al., 2018b; Lawrence et al., 2019; Esmaeilpoorarabi et al., 2020a).

Recent research confirmed the importance of amenities. According to Esmaeilpoorarabi et al. (2018b), cultural amenities such as meeting places, cinemas, libraries and theatres are an integral part of the *ambience* of innovation districts as the most important place quality theme based on expert interviews. Social amenities including restaurants, cafes and bars are also regarded by residents of innovation districts as important factors that can encourage community engagement (Esmaeilpoorarabi et al., 2020b). Social amenities are also an important factor when considering the various types of innovation districts (Adu-McVie et al., 2021).

Several studies suggested that innovation districts accelerate sustainable growth by fostering balanced diverse amenities (Leon, 2008; Esmaeilpoorarabi et al., 2018a). However, the existing literature has not comprehensively studied amenities. This study aimed to fill this research lacuna by answering the underlying research question "What are the amenity mixes of innovation districts worldwide?" The objectives were to (1) compare and contrast amenity mixes of innovation districts and (2) identify the common and interdependent amenities in innovation districts.

The availability of digital technologies has helped to answer this research question. Adu-McVie et al. (2021) recommended the use of Google Maps to evaluate amenities. Recent research also demonstrated the suitability of points of interest (POI) data on digital maps as inputs to assess urban amenities (Hidalgo et al., 2020; Taecharungroj, 2021). The next section elaborates on the research process.

3. Methodology

3.1 Samples

There is no comprehensive list of innovation districts worldwide. Therefore, this list of innovation districts was based on the Global Institute on Innovation Districts.[2] They have actors — district leaders, facilitators or practitioners — who are actively improving their districts. Fourteen out of the twenty two districts that participated in the Steering Committee and interim network were included in this study comprising Buffalo Niagara Medical Campus (Buffalo, US), Cleveland Health-Tech Corridor (Cleveland, US), Cortex Innovation Community (St. Louis, US), Innovation Quarter (Winston-Salem, US), Pittsburgh Innovation District (Pittsburgh, US), Technology Square (Atlanta, US), uCity Square (Philadelphia, US),

[2] https://www.giid.org/global-network-of-innovation-districts/

DistritoTech (Monterrey, Mexico), Medellín Innovation District (Medellín, Colombia), Be'er Sheva Innovation District (Be'er Sheva, Israel), Knowledge District Zuidas (Amsterdam, the Netherlands), Liverpool Innovation Precinct (Liverpool, Australia), Melbourne Innovation District (Melbourne, Australia) and Tonsley Innovation District (Adelaide, Australia). Seven were excluded because their maps were not publicly available or the district had no clearly defined boundary. One district, MIND Milan, was not included because the area was undergoing development.

Other notable innovation districts that were mentioned in the existing literature were also included in this study, with a focus on districts in Europe and Asia to increase representation in those regions. Additional districts included Boston Innovation District (Boston, US) (Yigitcanlar et al., 2020), 22@ (Barcelona, Spain), Silicon Sentier (Paris, France) (Morisson, 2020), Strijp-S (Eindhoven, the Netherlands) (Pancholi et al., 2018), Oxford Road Corridor (Manchester, UK), Seoul Innovation Park (Seoul, South Korea) (Katz and Wagner, 2014), Smart Docklands District (Dublin, Ireland) (Kayanan, 2022), Macquarie Park Innovation District (Sydney, Australia) (Pancholi et al., 2020), One-North (Singapore) (Adu-McVie et al., 2021) and Yothi Medical Innovation District (Bangkok, Thailand) (Pujinda and Sanit, 2022). This research covers 24 innovation districts; 10 in the Americas, 6 in Europe, 4 in Asia and the Middle East and 4 in Oceania.

3.2 Data collection

Maps of the 24 innovation districts were collected from public/official sources, with QGIS version 3.12 used to draw the polygons. Hexagon grids were created on top of each innovation district. Centroids of hexagons were located as coordinates for data collection on Google Maps. Polygon and centroid shapefiles were imported to RStudio for data collection. Centroid radius values were set to ensure full coverage of each district area with minimum overlap. Figure 1 displays an example of the shapefile creation in QGIS and data collection areas in RStudio.

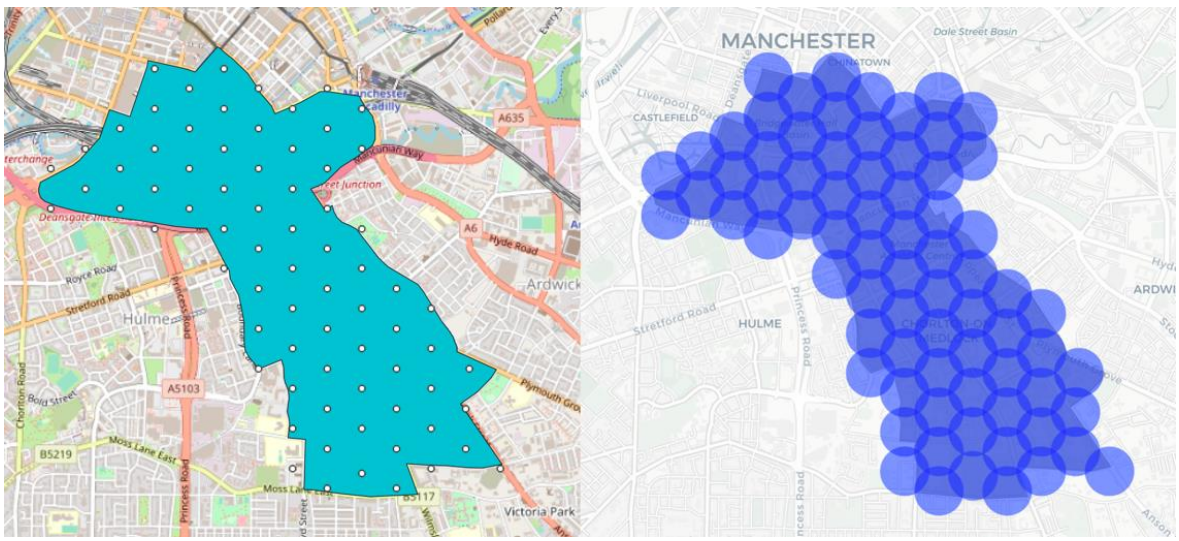

Figure 1 Data collection in QGIS (left) and RStudio (right)

Ninety-six *types* of POI[3] within each innovation district area were collected in March 2022 using the "googleway" package in R. Amenities outside the district boundary and duplicated POIs were removed. A total of 31,236 POIs were collected to represent the urban amenities in the 24 innovation districts. All but four types of amenities — zoo, aquarium, RV park and campground — were present in the innovation districts. Figure 2 displays the boundaries of the 24 innovation districts and amenity locations. The 96 types of amenities were grouped into 12 categories based primarily on the study by Hidalgo et al. (2020) (Table 1).

Table 1 Categories and types of amenities

Category of amenities	**Types of amenities (Google Maps)**
Accommodation	Lodging
Education	Library, primary school, school, secondary school, university
Finance	Insurance agency, accounting, ATM, bank
Food and drinks	Bakery, bar, café, meal delivery, meal takeaway, restaurant, nightclub
Government	City hall, courthouse, embassy, fire station, local government office, police
Health	Dentist, doctor, gym, hospital, physiotherapist
Leisure	Art gallery, museum, amusement park, aquarium, casino, movie theatre, tourist attraction, zoo, bowling alley, stadium
Nature	Campground, park
Religion	Cemetery, church, Hindu temple, mosque, synagogue
Retail	Bicycle store, book store, car dealer, clothing store, convenience store, department store, drugstore, electronics store, florist, furniture store, hardware store, home goods store, jewellery store, liquor store, pet store, pharmacy, shoe store, shopping mall, store, supermarket
Services	Beauty salon, car rental, car repair, car wash, electrician, funeral home, hair care, laundry, lawyer, locksmith, movie rental, moving company, painter, plumber, post office, real estate agency, roofing contractor, spa, storage, travel agency, veterinary care
Transport	Airport, bus station, gas station, light rail station, parking, RV park, subway station, taxi stand, train station, transit station

[3] https://developers.google.com/maps/documentation/places/web-service/supported_types

Figure 2 Maps of the 24 innovation districts and amenity locations

3.3 Analyses

Density and diversity: These two key measures of amenities were calculated in the innovation districts. Density was calculated using the total number of POIs in the district divided by the size of the district (sqkm). Diversity in urban areas is an important measure because it indicates the quality of mixed use. In this research, two popular diversity indices were used as Shannon entropy and Simpson diversity (Yue et al., 2017). Shannon entropy determines the uncertainty/surprise of the event, whereas Simpson diversity indicates the probability that two amenities (POIs) taken at random represent different categories. Values of the two indices were calculated using the "vegan" package in R.

Correspondence analysis: To visualise the differences among innovation districts and their associations with amenities, correspondence analysis was performed and visualised using the "FactoMineR" and "factoextra" packages in R. Correspondence analysis helps to display innovation districts and the categories of amenities on a two-dimensional map to evaluate associations (Greenacre, 1992). The results were used to categorise innovation districts.

Collocation of amenities: This research assessed how each type of amenity collocated with the other amenities in the innovation districts. The technique, first proposed by Hidalgo et al. (2020), calculates collocation using correlation analysis between each pair of amenities across all districts and visualises the results by constructing a social network — an amenity space. Instead of Spearman's correlation, this research used Kendall's Tau to measure the monotonic relationships between ranked variables because it is more robust and interpretable (Newson, 2002). This research used the density of each type of amenity instead of the number of POIs to account for varying district sizes. All significant correlations over 0.3 Kendall's Tau were visualised using the "igraph" and "ggraph" packages in R.

4. Findings

4.1 Size, diversity and density of innovation districts

Table 2 displays the profiles of the innovation districts, with sizes ranging from the smallest innovation park in Seoul (0.08 sqkm) to the largest Health-Tech Corridor in Cleveland (6.77 sqkm). The median size of districts in the dataset was 1.87 sqkm. Silicon Sentier in Paris had the highest number of POIs and density (9191 POIs; 4571.78 POIs per sqkm), while Tonsley Innovation District in Adelaide recorded the lowest POIs and density (33 POIs; 86.55 POIs per sqkm). Median values of POIs and density were 1006.5 POIs and 503.78 POIs per sqkm.

Diversity was measured by the Simpson Index and Shannon Entropy. The district with the lowest diversity was Cortex Innovation Community in St. Louis (0.51 Simpson Index and 1.16 Shannon Entropy), while Innovation Quarter in Winston-Salem and Smart Docklands Districts had the highest diversity measures; Innovation Quarter had the highest Simpson Index at 0.87, while Smart Docklands had the highest Shannon Entropy at 2.18.

Table 2 Innovation district profiles

Innovation District	City	Country	Region	No. of POI	Size (sqkm)	Density	Diversity (Simpson Index)	Diversity (Shannon Entropy)
Medellín Innovation District	Medellín	Colombia	America	1445	1.56	924.78	0.80	1.87
DistritoTech	Monterrey	Mexico	America	2148	4.54	473.59	0.80	1.87
Technology Square	Atlanta	US	America	69	0.15	472.28	0.82	1.97
Boston's Innovation District	Boston	US	America	1098	3.13	350.26	0.77	1.84
Buffalo Niagara Medical Campus	Buffalo	US	America	435	0.65	671.14	0.58	1.35
Cleveland Health-Tech Corridor	Cleveland	US	America	2006	6.77	296.26	0.67	1.58
uCity Square	Philadelphia	US	America	321	0.18	1821.18	0.60	1.46
Pittsburgh Innovation District	Pittsburgh	US	America	1105	0.85	1292.51	0.58	1.30
Cortex Innovation Community	St. Louis	US	America	915	1.33	686.05	0.51	1.16
Innovation Quarter	Winston-Salem	US	America	142	1.37	103.67	0.87	2.15
Be'er Sheva Innovation District	Be'er Sheva	Israel	Asia	369	2.68	137.52	0.86	2.12
One-North Park	Singapore	Singapore	Asia	868	2.01	432.18	0.78	1.81
Seoul Innovation Park	Seoul	South Korea	Asia	34	0.08	430.82	0.80	1.84
Yothi Medical Innovation District	Bangkok	Thailand	Asia	2503	2.43	1032.00	0.80	1.89
Silicon Sentier	Paris	France	Europe	9191	2.01	4571.78	0.81	1.87
Knowledge District Zuidas	Amsterdam	Netherlands	Europe	795	2.58	308.41	0.85	2.10
Strijp-S	Eindhoven	Netherlands	Europe	299	0.30	983.30	0.79	1.90
22@	Barcelona	Spain	Europe	1614	2.03	793.46	0.80	1.93
Smart Docklands District	Dublin	UK	Europe	770	1.75	439.20	0.87	2.18
Oxford Road Corridor	Manchester	UK	Europe	1239	2.32	533.97	0.85	2.10
Tonsley Innovation District	Adelaide	Australia	Oceania	33	0.38	86.55	0.87	2.07
Liverpool Innovation Precinct	Liverpool	Australia	Oceania	1159	1.36	853.79	0.81	1.87
Melbourne Innovation District	Melbourne	Australia	Oceania	1522	1.98	767.11	0.86	2.14
Macquarie Park Innovation District	Sydney	Australia	Oceania	1156	3.76	307.40	0.83	1.95

Figure 3 illustrates the Simpson Index (Figure 3a), Shannon Entropy (Figure 3b) and a logarithmic scale of density. The size of the dots represents the size of the innovation districts. The figure shows the five groups of innovation districts as (1) the *low-diversity* districts on the left side of the graphs (Philadelphia, Pittsburgh, Buffalo and St. Louis), (2) the *low-density* districts at the bottom right corner (Be'er Sheva, Winston-Salem and Adelaide), (3) the *high-diversity/density* districts as the majority on the right side of the graphs, (4) the *extremely high-density* Silicon Sentier in Paris and (5) the *large moderate-density* Health-Tech Corridor in Cleveland.

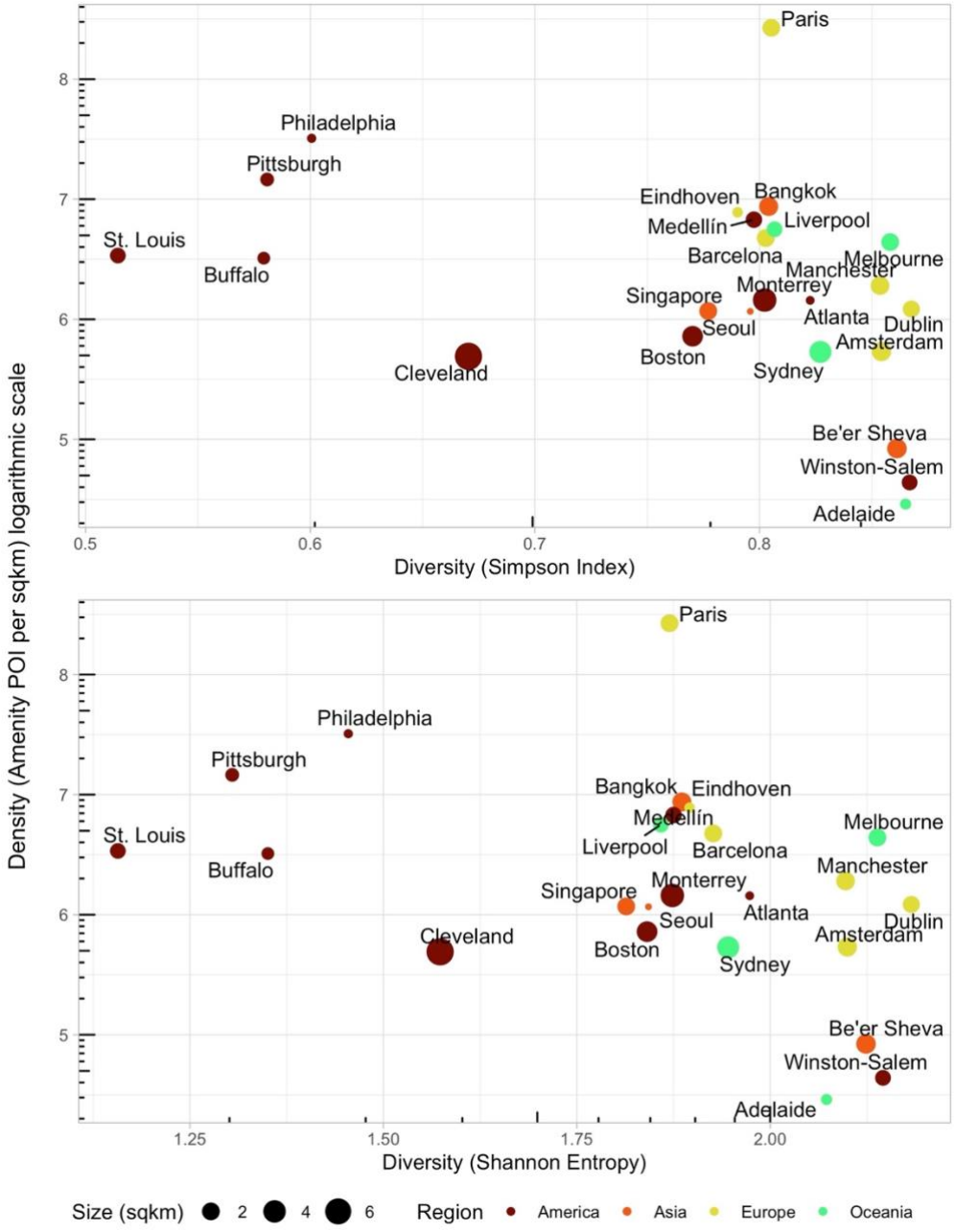

Figure 3 Density, diversity and size of the innovation districts

4.2 Associations between innovation districts and categories of amenities

Table 3 displays the density of amenities by the 12 categories. The three densest amenity categories were food and drinks, retail and services with median values 108.5, 92 and 70.5.

The least dense amenities by median values were nature (3 POIs per sqkm), religion (3.5) and government (6). Correspondence analysis was performed to visualise the associations between innovation districts and amenities.

Table 3 Density of amenities by category

Innovation District	City	Density of Amenities by Category (POIs per sqkm)											
		ACC	EDU	FIN	FOO	GOV	HEA	LEI	NAT	REL	RET	SER	TRA
Medellín Innovation District	Medellín	26	51	47	221	4	31	16	9	10	286	184	38
DistritoTech	Monterrey	11	27	16	118	2	39	5	8	5	134	99	10
Technology Square	Atlanta	7	75	68	151	14	14	7	7	0	27	48	55
Boston's Innovation District	Boston	4	4	21	42	7	16	11	8	1	58	145	34
Buffalo Niagara Medical Campus	Buffalo	5	68	25	20	2	421	0	3	12	37	9	69
Cleveland Health-Tech Corridor	Cleveland	2	14	6	18	1	159	1	2	6	38	12	36
uCity Square	Philadelphia	6	170	68	74	28	1112	17	17	6	102	79	142
Pittsburgh Innovation District	Pittsburgh	6	221	29	33	5	797	7	2	8	95	15	75
Cortex Innovation Community	St. Louis	3	85	13	14	0	466	1	1	0	36	15	52
Innovation Quarter	Winston-Salem	1	12	8	8	7	20	1	1	2	10	15	19
Be'er Sheva Innovation District	Be'er Sheva	2	23	5	22	1	11	1	9	4	25	10	26
One-North Park	Singapore	12	34	15	157	2	21	5	4	0	111	44	27
Seoul Innovation Park	Seoul	0	25	13	114	25	25	13	0	0	139	51	25
Yothi Medical Innovation District	Bangkok	48	50	108	298	9	55	10	2	1	293	110	46
Silicon Sentier	Paris	258	121	266	980	30	327	135	12	11	1316	1039	76
Knowledge District Zuidas	Amsterdam	9	30	33	42	7	16	4	2	3	42	77	47
Strijp-S	Eindhoven	20	79	53	118	23	49	46	3	0	372	181	39
22@	Barcelona	28	44	21	146	11	28	20	8	8	265	158	56
Smart Docklands District	Dublin	31	23	47	103	6	30	19	5	3	59	64	48
Oxford Road Corridor	Manchester	27	62	25	126	5	26	10	3	8	67	90	86
Tonsley Innovation District	Adelaide	0	8	10	10	3	16	0	3	0	16	10	10
Liverpool Innovation Precinct	Liverpool	5	23	53	119	11	178	3	3	12	257	152	39
Melbourne Innovation District	Melbourne	40	98	37	178	6	83	24	12	10	147	88	44
Macquarie Park Innovation District	Sydney	4	17	15	56	2	41	2	3	1	89	43	34

Notes: Accommodation (ACC), education (EDU), finance (FIN), food and drinks (FOO), government (GOV), health (HEA), leisure (LEI), nature (NAT), religion (REL), retail (RET), services (SER), transport (TRA)

The correspondence analysis results in Figure 4 show that the innovation districts were associated with amenities in diverse patterns. On the left side of the chart, the five American districts Buffalo, Pittsburgh, St. Louis, Philadelphia and Cleveland were highly associated with health-related amenities, representing the typical “anchor plus” model of innovation districts (Katz and Wagner, 2014), with an established educational or medical institution as the anchor of the districts, such as the Washington University medical campus in St. Louis, Case Western Reserve University in Cleveland, University at Buffalo School of Medicine in Buffalo, UPMC Presbyterian in Pittsburgh and the University of Pennsylvania in Philadelphia.

The second cluster in the bottom right corner called “retail districts” contained high densities of *retail* and *service* amenities. Many of these were “re-imagined urban areas” (Katz and Wagner, 2014) that had gone through urban renewal programmes such as 22@ in Barcelona, Strijp-S in Eindhoven, Medellín Innovation District, Boston Innovation District and DistritoTech in Monterrey. The Liverpool Innovation Precinct presented an anchor plus model next to Liverpool Hospital, while Silicon Sentier in Paris displayed a form of market-driven high technology district (Yigitcanlar et al., 2020).

Another cluster of districts on the right side of the graph represented “foodie districts”. Although they also possessed high density of other amenities, the relatively strong

feature of this cluster was the high density of *food and drinks* amenities. These three foodie districts were located in the East Asian metropolitan areas of Seoul, Singapore and Bangkok. The Seoul Innovation Park and One-North Park in Singapore are examples of the "urbanised science park" model (Katz and Wagner, 2014), while Yothi Medical Innovation District is the anchor plus innovation district with Ramathibodi Hospital.

The fourth cluster of innovation districts was called "balanced districts". The retail, services and food and drinks amenities in this cluster were less dense than the former two clusters but their amenity mixes were diverse. Balanced districts were also located in the rightmost part of Figure 2a and Figure 2b demonstrating their great diversity. All but one — Smart Docklands District in Dublin — was located next to a major university as Technology Square and Georgia Tech in Atlanta, Oxford Road Corridor, the University of Manchester and Manchester Metropolitan University, Knowledge District Zuidas and Vrije Universiteit Amsterdam, Melbourne Innovation District and University of Melbourne, and Macquarie Park Innovation District in Macquarie University, Sydney.

The last cluster of innovation districts called "emerging districts" was also the least dense (Figure 3). This cluster did not specialise in particular categories of amenities; however, *nature* and *transport* were relatively evident. The three districts in this category were Be'er Sheva Innovation District anchored by Ben-Gurion University of the Negev, the Innovation Quarter anchored by Wake Forest Baptist Medical Center in Winston-Salem and the renewed Tonsley Innovation District in Adelaide.

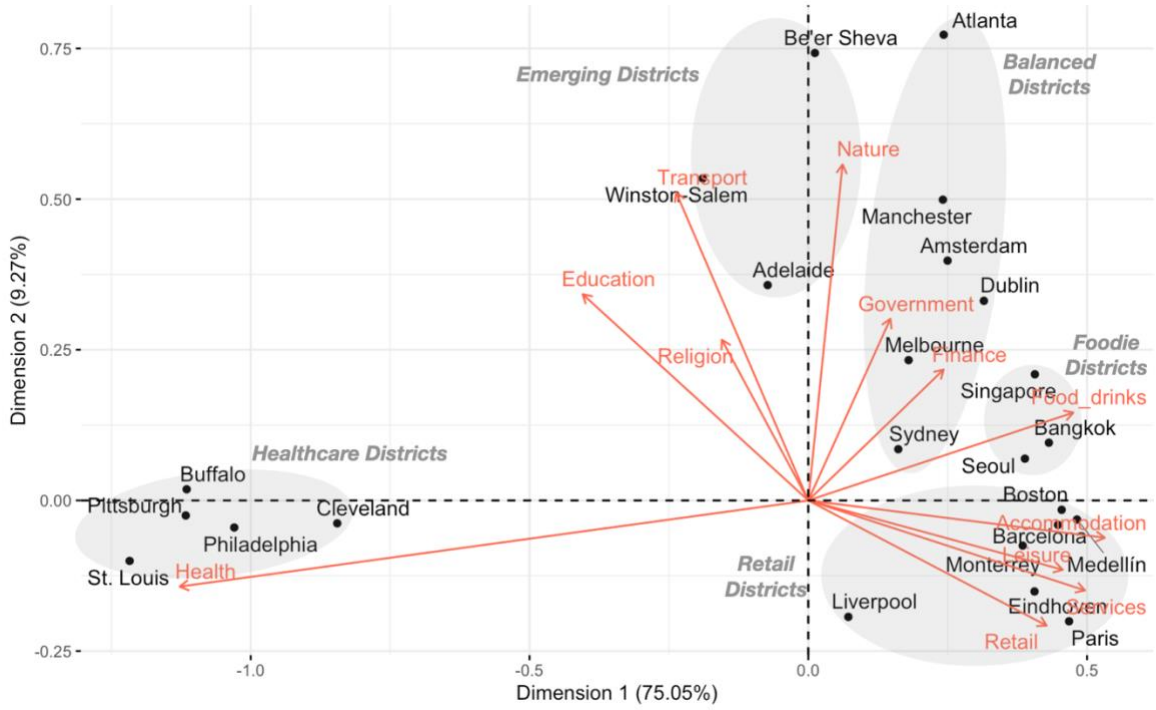

Figure 4 Correspondence analysis results between innovation districts and categories of amenities

4.3 Amenity mixes of innovation districts

Figure 5 illustrates the "amenity space" of innovation districts and visualises the network of correlations between each type of amenity. Only significant relationships higher than 0.3 Kendall's Tau were displayed. These correlations represent how amenities collocate. Higher

correlations, implying that a pair of amenities collocated strongly were represented by thicker network edges. For example, on the top left corner of the network, the correlation between airport and fire station was higher (the edge is thicker) than the correlation between airport and drugstore. Colours represent the different categories of amenities, while the sizes of the nodes imply the total number of POIs. Notable features displayed by this social network analysis are highlighted below.

First, *healthcare amenities* — doctor, dentist, pharmacy, hospital and physiotherapist — formed a tight network on the right side of the graph. Many of these were prominent parts of innovation districts that typically acted as an anchor institution; however, they were somewhat independent of the majority of amenities in the districts. Some types of amenities were significantly correlated with healthcare amenities such as light rail stations, ATMs, libraries, churches, primary schools and universities. Likewise, *universities* were eminent anchors of many innovation districts but they did not significantly correlate with other amenities, having only six connections (edges) including library (0.48 Kendall's Tau), hospital (0.46), pharmacy (0.35), parking (0.60), transit station (0.36) and light rail station (0.37). When Eigenvector centrality was used to calculate the centrality of nodes, university was ranked 87th of 92 nodes in the network implying little influence over the amenity space. This result demonstrated that a dense network of amenities in the innovation districts was not tightly associated with the anchor institutions.

Another notable characteristic of the amenity space of innovation districts was the dispersed *transport* nodes. Taxi stand, airport and gas station were located in the top-left corner of the graph, with bus station in the bottom-left corner, subway in the bottom-right corner and light rail station, transit station and parking on the right hand side of the graph. This result showed that modes of transport did not correlate with one another in the innovation districts. Districts tended to have particular modes of transport. For example, districts in Seoul and Liverpool had high density of bus stations at 12.67 and 5.89 per sqkm respectively. The district in Bangkok had the densest taxi stands (0.82 stands per sqkm), while Philadelphia and Paris had the most subway station POIs per sqkm (5.67 and 4.97 respectively) and Pittsburgh and Manchester had the most general transit station POIs per sqkm (47.96 and 46.98 respectively).

The most prominent feature of the amenity space in Figure 5 was the dense network of amenities in the middle of the graph. This showed that several *retail*, *services* and *food and drinks* amenities were collocated significantly in innovation districts. Within the dense network in the middle, the top portion tended to represent basic retail and necessary services or "*necessities*" such as hardware store, car dealer, convenience store, locksmith and car repair, while the bottom portion tended to represent "*luxuries*" such as beauty salon, bicycle store, gym, jewellery store, travel agency and art gallery. The central portion represented the most influential amenities that constituted the amenity space of the innovation districts.

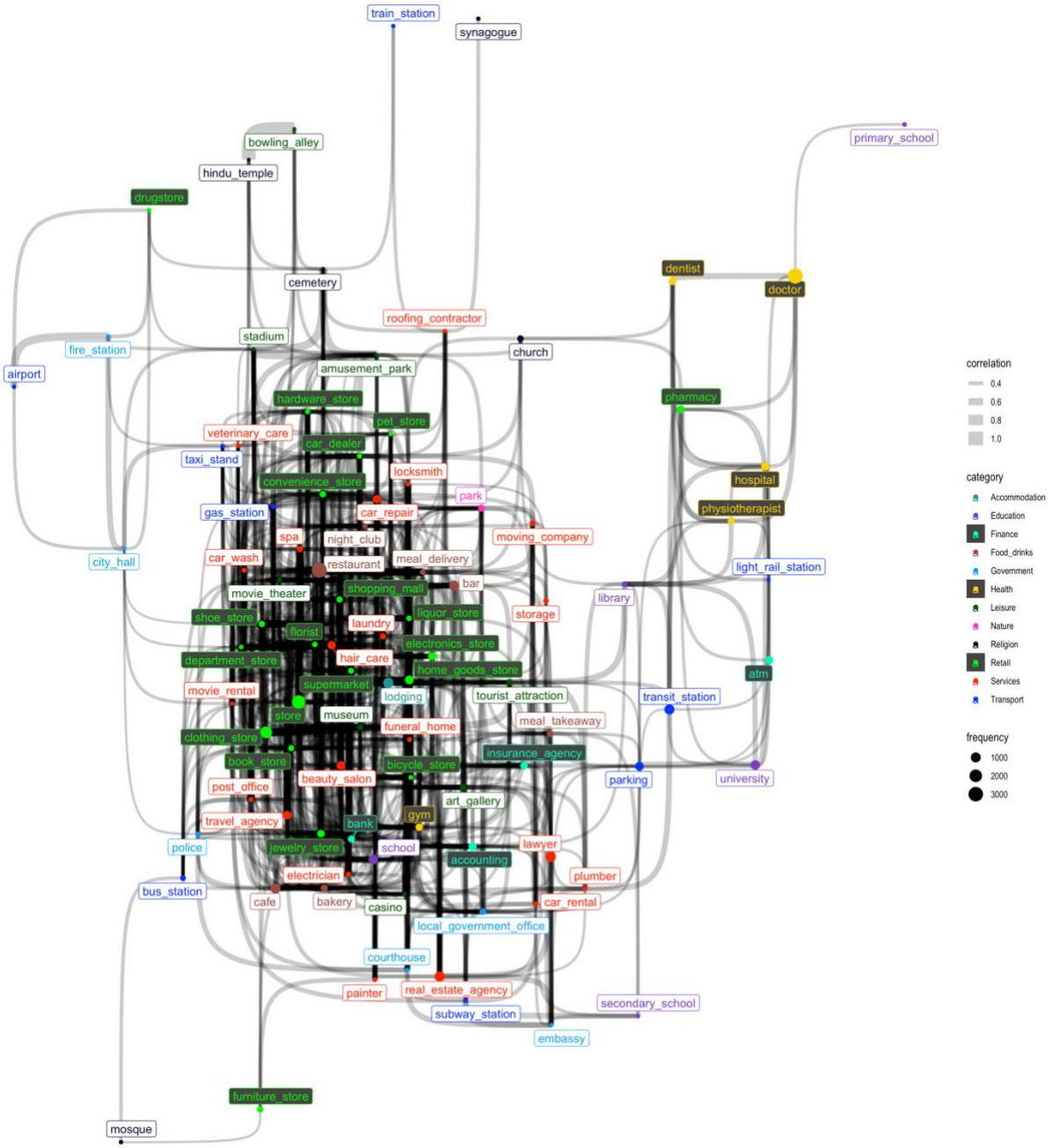

Figure 5 The amenity space of the innovation districts

Eigenvector centrality was computed for all 92 nodes to quantitatively analyse the centrality of amenities in the amenity space. Higher Eigenvector centrality implied that the amenity was connected to many other influential nodes in the network. In other words, highly central amenities often appeared with other amenities in the innovation districts. Measuring centrality does not imply causality but allows a better understanding of the pattern of amenity formation in innovation districts. The top ten central nodes were home goods store (1), florist (0.99), shopping mall (0.98), museum (0.98), lodging (0.97), store (0.96), supermarket (0.95), restaurant (0.94), beauty salon (0.92) and hair care (0.92).

Figure 6 displays the Eigenvector centrality, density (median POIs per sqkm) and frequency of amenities (represented by the size of the bubbles). The top ten amenities by density were restaurants (33.56 per sqkm), stores (25.09), transit stations (21.93), cafés

(19.55), schools (16.12), parking areas (13.90), universities (13.23), doctors (12.91), real estate agencies (9.58) and clothing stores (7.56). However, these amenities had varying centrality scores. Restaurants and stores had high density and centrality, implying their strong influence on the amenity space. Universities and doctors represented anchored institutions but did not correlate with the larger network of amenities in the innovation districts. Lower density amenities located in the top left corner of Figure 6 represented tight networks that constituted the vibrant core of the innovation districts.

Figure 6 Density and centrality of innovation district amenities

5. Discussions and conclusions

Amenities are important for the success of innovation districts (Esmaeilpoorarabi et al., 2018b). This research is the first to broadly analyse amenities and answer the question "What are the amenity mixes of innovation districts worldwide?". Amenity data of 24 innovation districts worldwide were collected from Google Maps. The authors compared and contrasted the mixes of innovation districts and identified the common and interdependent amenities. A vibrant and successful innovation district has to be dense with mixed-use (diverse) (Drucker et al., 2019; Lawrence et al., 2019). This research computed the density (POIs per sqkm) and diversity of amenities using the Simpson Index and Shannon Entropy (Yue et al., 2017). Correspondence analysis was performed and results concurred with Adu-McVie et al. (2021) who determined amenities as the most viable feature for categorisation of innovation districts. A network of amenities — amenity space — was created using correlation analysis to analyse the distinctive amenity mixes of innovation districts. The Eigenvector centrality of each node (amenity) was then computed to measure their influence on the amenity space.

5.1 Categorisation of innovation districts by amenity mix

The existing literature categorised innovation districts in various ways (Katz and Wagner, 2014; Forsyth, 2014; Yigitcanlar et al., 2020). Adu-McVie et al. (2021) conducted Delphi surveys with experts to identify the most important indicator that could classify innovation districts. Out of 16 indicators, "presence or availability of social amenities for public use" was ranked the highest. Thus, amenities were used as the basis of district categorisation in this study. The overall density and diversity of amenities were used to separate innovation districts into three main categories as *low-diversity*, *low-density* and *high-diversity/density* districts. The Health-Tech Corridor in Cleveland and Silicon Sentier in Paris did not conform to any of the three categories.

Correspondence analysis was employed to illustrate the associations between innovation districts and twelve categories of amenities. Five clusters of districts were identified based on their relatively strong amenities. This categorisation cut across traditional "anchor-plus", "re-imagined urban area" and "urbanised science park" models. For example, Liverpool Innovation Precinct (*retail*), Yothi Medical Innovation District (*foodie*), Technology Square (*balanced*), Cortex Innovation Community (*healthcare*) and Be'er Sheva Innovation District (*emerging*) were examples of anchor plus models in each category of amenity clusters, illustrating that innovation districts of a similar form can have distinct amenity mixes.

5.2 Identification of highly influential amenities of the innovation districts

Social network analysis as an amenity space of innovation districts was used to visualise how amenities collocated in innovation districts. Retail, food and drinks, and services formed a tight network of amenities as the core of innovation districts. These highly central amenity nodes brought *vibrancy* and *buzz* to the districts (Read and Sanderford, 2017; Drucker et al., 2019) because their presence correlated with several other amenities in the network. Such amenities were labeled "*influential amenities*" based on the remark by Machado and Diniz (2013) who posited that certain cultural/welfare amenities are capable of *influencing* choices to live and work and contributing to the formation of creative regions and agglomeration economies.

The restaurant node had both high density and centrality and was also found to be the most central node in amenity space analyses of urban neighbourhoods across the US (Hidalgo et al., 2020). This research found that amenities such as home goods store, florist,

shopping mall, museum, supermarket and lodging had high centrality in the amenity space of innovation districts, while Hidalgo et al. (2020) found these amenities to be much less central across normal urban neighbourhoods. Conversely, prominent anchors — universities and healthcare institutions — had very low centrality, implying that they did not correlate with other amenities. Anchor institutions provide knowledge and resource sharing in the district and facilitate networking, thereby creating a sense of pride (Pancholi et al., 2020); however, this research concluded that they had little network influence on other amenities in the districts.

5.3 Policy implications

The methods and results of this research can be used to inform cities, places and innovation districts on how best to improve the existing districts or to establish a new one.

Assess the density and diversity of amenities: Digital data from Google Maps allow place managers to assess the amenity mix of the district and also enable a broad collection of data from districts around the world. Innovation district managers can benchmark the amenity mix of their district to other innovation districts. City managers who are searching for innovation districts can rapidly and broadly compare the amenity mix of several districts or neighbourhoods to find the most promising location.

Leverage distinct amenity mix: Innovation districts do not possess the same amenity mix. Innovation district managers should identify the prominent amenities in the district and use these as strengths to promote other "hard" factors such as knowledge and prestigious anchor institutions. Bustling retail and exciting food scenes are two examples that innovation districts can highlight to attract knowledge workers.

Expand the diversity of amenities: One of the goals of urban development is to enhance mixed-use or diversity of amenities that the public can access. The amenity space of innovation districts offers some guidelines on how to foster their diversity. Innovation district managers should facilitate the establishment of highly influential amenities such as restaurants, general and various types of stores, hotels, museums, gyms and various types of luxury and necessary services.

5.4 Study limitations and future research

Despite its contribution, this research also has some limitations. The 24 innovation districts examined in this study cover a broad geographical range but do not represent all innovation districts because the innovation district concept is still evolving. The inclusion of more innovation districts could impact the categorisation. The inclusion of more districts would also alter the amenity space. Future research on this topic should be conducted once a comprehensive list of worldwide innovation districts is available. Using POIs as amenities also requires caution when interpreting the results. For example, multiple university POIs in the same area do not imply several universities but could also represent several locations (e.g., buildings) as part of the same university. Finally, data from Google Maps do not possess the temporal dimension and a temporal/time-series analysis is, therefore, not applicable. Future studies could also apply this research process to examine places using different contexts.

6. References

Adu-McVie R, Yigitcanlar T, Erol I, et al. (2021) Classifying innovation districts: Delphi validation of a multidimensional framework. *Land Use Policy* 111: 105779.

Drucker JM, Kayanan CM and Renski HC (2019) Innovation Districts as a Strategy for Urban Economic Development: A Comparison of Four Cases. *Available at SSRN 3498319*.
Esmaeilpoorarabi N, Yigitcanlar T, Guaralda M, et al. (2018a) Does place quality matter for innovation districts? Determining the essential place characteristics from Brisbane's knowledge precincts. *Land Use Policy* 79: 734-747.
Esmaeilpoorarabi N, Yigitcanlar T, Guaralda M, et al. (2018b) Evaluating place quality in innovation districts: A Delphic hierarchy process approach. *Land Use Policy* 76: 471-486.
Esmaeilpoorarabi N, Yigitcanlar T, Kamruzzaman M, et al. (2020a) Conceptual frameworks of innovation district place quality: An opinion paper. *Land Use Policy* 90: 104166.
Esmaeilpoorarabi N, Yigitcanlar T, Kamruzzaman M, et al. (2020b) How can an enhanced community engagement with innovation districts be established? Evidence from Sydney, Melbourne and Brisbane. *Cities* 96: 102430.
Esmaeilpoorarabi N, Yigitcanlar T, Kamruzzaman M, et al. (2020c) How does the public engage with innovation districts? Societal impact assessment of Australian innovation districts. *Sustainable Cities and Society* 52: 101813.
Forsyth A (2014) Alternative forms of the high-technology district: corridors, clumps, cores, campuses, subdivisions, and sites. *Environment and Planning C: Government and Policy* 32(5): 809-823.
Greenacre M (1992) Correspondence analysis in medical research. *Statistical methods in medical research* 1(1): 97-117.
Heaphy L and Wiig A (2020) The 21st century corporate town: The politics of planning innovation districts. *Telematics and Informatics* 54: 101459.
Hegyi FB, Zhu M and Janosov M (2021) Measuring the impact of urban innovation districts. *Publications Office of the European Union*.
Hidalgo CA, Castañer E and Sevtsuk A (2020) The amenity mix of urban neighborhoods. *Habitat International* 106: 102205.
Hsieh H-N, Hu T-S, Chia P-C, et al. (2014) Knowledge patterns and spatial dynamics of industrial districts in knowledge cities: Hsinchu, Taiwan. *Expert Systems with Applications* 41(12): 5587-5596.
Katz B and Wagner J (2014) The rise of innovation districts: A new geography of innovation in America. The Brookings Institute.
Kayanan CM (2022) A critique of innovation districts: Entrepreneurial living and the burden of shouldering urban development. *Environment and Planning A: Economy and Space* 54(1): 50-66.
Lawrence S, Hogan M and Brown EG (2019) *Planning for an innovation district.* RTI Press.
Leon N (2008) Attract and connect: The 22@ Barcelona innovation district and the internationalisation of Barcelona business. *Innovation* 10(2-3): 235-246.
Machado AF and Diniz SC (2013) Urban amenities and the development of creative clusters: the case of Brazil. *Current Urban Studies* 1(04): 92.
Morisson A (2020) A framework for defining innovation districts: Case study from 22@ Barcelona. *Urban and Transit Planning*. Springer, pp.185-191.
Morisson A and Bevilacqua C (2018) Beyond innovation districts: The case of Medellinnovation District. *International Symposium on New Metropolitan Perspectives.* Springer, 3-11.
Morisson A and Bevilacqua C (2019) Balancing gentrification in the knowledge economy: the case of Chattanooga's innovation district. *Urban Research & Practice* 12(4): 472-492.

Newson R (2002) Parameters behind “nonparametric” statistics: Kendall's tau, Somers’ D and median differences. *The Stata Journal* 2(1): 45-64.

Pancholi S, Yigitcanlar T and Guaralda M (2017) Governance that matters: Identifying place-making challenges of Melbourne’s Monash Employment Cluster. *Journal of Place Management and Development*.

Pancholi S, Yigitcanlar T and Guaralda M (2018) Societal integration that matters: place making experience of Macquarie Park Innovation District, Sydney. *City, Culture and Society* 13: 13-21.

Pancholi S, Yigitcanlar T, Guaralda M, et al. (2020) University and innovation district symbiosis in the context of placemaking: Insights from Australian cities. *Land Use Policy* 99: 105109.

Pujinda P and Sanit P (2022) Concept of the Innovation District Development: A Case Study of Yothi Medical and Healthcare Innovation District. *Journal of Architectural/Planning Research and Studies (JARS)* 19(2): 81-92.

Read D and Sanderford D (2017) Innovation Districts at the Cross road of the Entrepreneurial City and the Sustainable City. *Journal of Sustainable Real Estate* 9(1): 131-152.

Taecharungroj V (2021) Google Maps amenities and condominium prices: Investigating the effects and relationships using machine learning. *Habitat International* 118: 102463.

Wisuchat W and Taecharungroj V (2021) A place to work: examining workplace location attributes that appeal to generation Y and Z talent. *Journal of Place Management and Development*.

Yigitcanlar T, Adu-McVie R and Erol I (2020) How can contemporary innovation districts be classified? A systematic review of the literature. *Land Use Policy* 95: 104595.

Yue Y, Zhuang Y, Yeh AG, et al. (2017) Measurements of POI-based mixed use and their relationships with neighbourhood vibrancy. *International Journal of Geographical Information Science* 31(4): 658-675.