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Identifying Communities within the Smart-Cultural City of Singapore: A Network Analysis Approach

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Abstract: This article investigates the intersection and convergence of Smart Cities and Creative Cities that emerge with the availability of social media data, technology—smart technologies—and the shifting mode of cultural production—creative economies—forming a new nexus of Smart-Cultural Cities. It starts with a short review of literature surrounding Smart Cities and Creative Cities to establish domain criteria on Smart-Cultural Cities for Singapore. The article draws on a database of actors from authorities, industries, academia, and artists established by the research community in Singapore. Actors and domains are described using bipartite graphs and then analyzed by solving a deterministic optimization problem rather than computing a statistic. The result of this analysis reveals new clusters, nodes, and connections in the actor–domain network of the Singapore Smart-Cultural Cities discourse. The identified clusters are called "Urban Scenario Makers", "Digital Cultural Transformers" and "Public Engagers". The method gives significant insights on the number of clusters, the composition of each cluster, and the relationship between clusters that serve to locate and describe a next iteration of the Smart City that focusses on human interaction, culture, and technology.

Keywords: smart-cultural city; actor network; bipartite graph

1. Introduction

The shifting discourse on Smart Cities away from "smart" technology alone towards centering on humans on one hand, and the rise of the Creative Cities on the other, offers new perspectives on the development of cultural activities in the city. This article explores the convergence of Smart Cities and Creative Cities toward a new nexus of Smart-Cultural Cities. It frames the main actors on the governmental, industrial, academic and artist levels that currently contribute to the discourse on both Smart Cities and Creative Cities in Singapore and delineates areas of convergence of both concepts, positioning fields of current and future operations and possible entry points in this discourse.

The research questions of this paper are the following:

- Do smart technologies that drive Smart Cities and creative economies that occur in Creative Cities give rise to the new Smart-Cultural Cities nexus?
- Can network analysis help formalize the relationships among actors of Smart-Cultural Cities?
- Can we identify meaningful groups of actors within the Smart-Cultural City of Singapore?

The article is structured as follows: Section 1 discusses the evolution and evolving definitions of Smart Cities to determine what makes Singapore a Smart City. It then introduces Creative Cities as a planning paradigm. A table illustrates what makes Singapore a Creative City, Creative State, and Creative Nation. The section concludes by discussing the convergence of Smart Cities and Creative

Cities. Section 2 introduces the database of actors within this Smart Cities and Creative Cities nexus from authorities, industries, academia, and artists established by the research community in Singapore. It further describes the methodology of bipartite graphs used to solve a deterministic optimization problem as presented here. This method is widely used in mathematics and engineering but is a new contribution to the field of digital humanities. Section 3 presents the results of the optimization problem. It reveals three emergent clusters that we interpret as Urban Scenario Makers, Digital Cultural Transformers, and Public Engagers. The cluster interrelations further reveal underlying connections between these clusters. Section 4 discusses the results by returning to the research questions.

1.1. Evolving Definitions of Smart Cities

The concept of Smart Cities emerged out of a technologically driven discourse and gradually broadened in scope to embrace a human-centric discourse in the early 2000s across the globe [1]. In parallel, the scale of observation and complexity grew from smart devices to smart homes, smart districts, and smart nations. Recent literature reviews [2] on smart cities include topics of governance and smart cities [3], sustainable development and smart cities [4], the role of the Internet of things (IoT) and smart cities [5], and innovation and smart cities [6].

Technological Definition. The concept of Smart Cities can be traced back to cybernetic thinking of the 1950s that understood complex man-made systems such as cities as sets of elements that interact and that can be regulated [7]. The advent of computation and the Internet fueled these thoughts in the decades that followed. Practical applications emerged in the context of energy efficiency applied to the scale of cities around the end of the 20th century. Around 2000 so-called "smart grids" were proposed as distributed energy networks that could react to dynamic energy demands. The upgrade of conventional to smart grids promised enormous efficiency gains. These smart energy grids were also seen as the back-bone of information and communication technologies (ICTs) that could give rise to Smart Cities. As part of the European Strategic Energy Technology Plan (SET-PLAN) [8], the European Union envisioned the creation of a network of thirty Smart Cities by 2020; these cities, samples of high energy efficiency standards, set some common goals, among which the minimization of emissions employed in building technologies and transportation, and the better use of information technologies for the education of energy-related professional figures [9]. The term "smart" refers to the potential of systems to automate routines, react faster, process more information, and thus become more resilient to future changes. Rapidly, many aspects of urban infrastructure were identified to become smarter: energy, transport, water and waste management, etc. [10]. Cisco defines smart cities as those who adopt "scalable solutions that take advantage of information and communications technology (ICT) to increase efficiencies, reduce costs, and enhance quality of life" [11]. Smart cities and smart infrastructure are explored by Pollalis [12]. The initial understanding of "smart" also gave rise to its later critique: a technology-driven definition with mainly economic benefits cannot describe the complexity of urban phenomena alone [13].

Broad Definition. The research framework regarding the Smart Cities turned toward the "utilization of networked infrastructure to improve economic and political efficiency and enable socio, cultural and urban development" [14] and shifted in terms of its content and objectives in 2010 with Giffinger's study to define the "smartness" of medium-sized cities [15]. The study analyzes 70 European medium-sized cities, referring to six specific characteristics: economy, people, governance, mobility, environment, and liveability. What makes this research methodologically innovative is the involvement of additional variables outside of the energetic sphere, such as governance, participation, and quality of life. The White Paper, produced in 2011 by the Expert Working Group on Smart City Application and Requirements, clearly states the need to focus on broader aspects rather than only the technological ones: "The concept of Smart Cities is gaining increasingly high importance as a means of making available all the services and applications enabled by ICT to citizens, companies, and authorities that are part of a city's system. It aims to increase citizens' quality of life and improve the efficiency and quality of the services provided by governing entities and businesses. This perspective

requires an integrated vision of a city and of its infrastructures, in all its components, and extends beyond the mere 'digitalisation' of information and communication: it has to incorporate a number of dimensions that are not related to technology, e.g., the social and political ones" [16]. This broader definition is widely accepted today and understands Smart Cities as a processes rather than a static outcome, "in which increased citizen engagement, hard infrastructure, social capital and digital technologies make cities more liveable, resilient and better able to respond to challenges" [17]. Similar definitions have been issued by the Bundesverband Smart Cities [18] and the Centre for Cities [19]. Layne and Lee describe the development of e-government in four stages [20]. Mechant and Walravens analyzed the convergence of e-governance and smart cities enabled by new digital technologies leading to "better-informed decision making and high quality services, but assumes far more complex partnerships with very diverse stakeholders, such as large and small companies, civil society, academia, individual citizens and so on" [21].

Citizen-Focused Definition. It becomes apparent that this broad concept of a Smart City hinges on the inclusion of citizens [22]. A citizen-focused definition has as a foreground the human-centric aspects of cities sided by the ubiquity of mobile devices, the increased production of data, feedback, and response mechanisms. The Future Cities Laboratory at the Singapore-ETH Centre thus adopted the term Responsive City borrowed from Goldsmith and Crawford [23]. This concept places human-centered governance as its main objective, employing "the responsive, interactive and participatory possibilities of information technology" in the center of the discourse [24]. Responsive Cities are human-centered in two ways: (1) as a goal, which supports social justice and urban quality and is focused on people, rather than technology, and (2) with respect to governance, planning and design processes, which are knowledge- and data-based, transparent, open, and participatory [25]. This definition includes social media data produced by the citizens and gradually completing a picture of urban activities, interests, and intensities [26]. It further allows us to look at the inclusion of the Internet of things (IoT) from a citizen point of view [27]. This concept of the smart city aims to achieve the highest quality of urban life [28].

1.2. What Makes Singapore a Smart City?

Singapore is well positioned to be a smart city and has implemented many aspects of smart city technology and governance [29]. As a city-state, Singapore the smart city is at the same time a smart nation. The smart nation engages with all urban sectors and in particular mobility, health, safety, and productivity. Consequently, Singapore ranks high on international liveability rankings. Singapore's smart nation concept is [30]:

- Guided by "Liveability": "A Smart Nation is one where people are empowered by technology to lead meaningful and fulfilled lives."
- Technology-driven: "Through harnessing the power of networks, data and info-comm technologies, we seek to improve living, create economic opportunity and build a closer community."
- Embracing citizen-centric governance: "A Smart Nation is built not by Government, but by all of us—citizens, companies, agencies. This website chronicles some of our endeavours and future directions." [30]

1.3. Creative Cities as Planning Paradigm

The Creative City is a planning paradigm or urban agenda for cities, encouraging the inclusion of culture and creativity as solutions to urban problems. It is a term that summarizes different arguments, advocating that art and culture would eventually contribute in an urban environment to:

- Economic revenues
- Strong identity and cultural vibrancy
- Urban quality and liveability

These intangible assets are gradually included into the Smart Cities discourse as well [31]. Thite positions Smart Cities as central to human resource development [32], whereas Han and Hawken discusses innovation and identity triggered by them [33]. The implementation of cultural projects or activities will not only imply the creation of lateral local economic revenues [34], but also create incomes generated by tourism [35] and attract a creative class that will push urban economies into a post-industrial society [36,37]. In a period of knowledge economy [38], the production of ideas rather than the production of goods creates wealth. Knowledge production is dynamic, seeking innovation in order to remain competitive. The people, who are able to drive the innovation, are regarded as *creative people* and they constitute the creative class. Richard Florida positions the idea of the "creative class" that transforms cities undergoing the transition to a post-industrial economy. By creative class, he refers to a broad range of creative professionals that seek quality of life, tolerance, and creative vibes in cities (the three "Ts" are talent, tolerance and technology) [36,39]. In a global competition among cities, municipalities should back the arts and culture, precisely to feed the creative atmosphere to attract the creative class [40]. In this context, technology and human capital work together to advance society [41], implying that "'smart technology' advance(s) 'smart mobility', 'smart environment', 'smart people', 'smart economy', smart living' and 'smart governance'" [42].

Both the art tourism, the local induct, and the creative class consider art and culture as a commodity, carrying contradictions and limits. For example, the creative occupations explored by Florida include lawyers, scientists, managerial and business professionals as well as creative people. These professional groups can be attracted by consumption strategies of art and culture, regarded mainly as entertainment, unlikely to benefit artists per se [43].

Culture and art are also part of an urban agenda, as they are able to impact people's identity and quality of life. Cultural approaches haven been seen as tools for urban regeneration [44]. Through the implementation of flagship cultural projects, public spaces, and urban landscaping, it is possible to develop a shared urban vision or national image. These projects can contribute to building a shared character and a distinct identity for the place. In the case of Singapore's city-state, they can be mobilized to the level of nation-building. In the context of Singapore, Calder provides an overview of Singapore's socio-economic solutions as a state, exploring national policies relative to smart states. According to Calder, Singapore is providing "social protection, facilitating economic development, conduction of foreign relations through a minimalist and enabling governance". Singapore's ongoing urban transformation is fueled by revolutionary ICT developments and supported by a holistic planning process [45]. Singapore makes a particular case. Precisely because of its small territory, city, state, and nation coincide. Due to its lean government organization, the deployment of smart city technologies and policies is achieved at a fast pace. Distinct places not only develop the potential to draw people and serve as a driver to develop tourism industry and attraction of inward investment [46], but the presence of distinct places also most likely increases the interaction intensity between people and the urban environment, improving people's quality of life and urban quality.

From a planning perspective, the Creative City argues for new modes of governance. Starting from the assumption that contemporary governance arrangements inhabit innovative initiatives, new modes of governance should have a double creativity, in terms of its potential to both foster creativity in social and economic dynamics and creatively transform its own capacities [47]. Flexibility and the ability to transform and to adapt to multiples needs are key aspects necessary to respond in multiple ways to the city creative dynamism [47].

1.4. Art, Cultural, and Creative Industries

There are different cultural models that define and describe the relation between art, cultural, and creative industries. According to KEA's model referring to Europe, they are as follows [48]:

The *cultural sector*, including:

1. In the non-industrial sectors producing non-reproducible goods and services aimed at being consumed on the spot (a concert, an art fair, an exhibition). These are the arts field (visual arts

including paintings, sculpture, craft, photography; the arts and antique markets; performing arts including opera, orchestra, theatre, dance, circus; and heritage including museums, heritage sites, archaeological sites, libraries, and archives).

2. In the industrial sectors producing cultural products aimed at mass reproduction, mass dissemination and exports (e.g., a book, a film, a sound recording). These are cultural industries including film and video, video games, broadcasting, music, book and press publishing. The creative sector:
3. In the creative sectors, culture becomes a creative input in the production of non-cultural goods. It includes activities such as design (fashion design, interior design, and product design), architecture, and advertising. Cultural resources are often considered intermediate consumption goods for production processes in non-cultural sectors, and thereby seen as a source of innovation. In this sense, the non-industrial cultural sectors and the cultural industries support the development of other fields such as cultural tourism and, perhaps more importantly, information and communication technology (ICT) industries, revealing the links between culture, creativity, and innovation.

1.5. What Makes Singapore a Creative City?

Singapore adopted a framework to support art production in urban settings. Singapore's first contribution in cultural planning was the Report of the Advisory Council on Culture and the Arts (ACCA) [49]. Supporting art was seen as necessary to develop national identity, societal bond, individual benefit, quality of life, and mass tourism. The Report of the Advisory Council on Culture and the Arts mainly lamented the lack of physical infrastructure to support the arts in Singapore. The reaction was the development of the National Museum and more space given to the National Library, but also programs such as the Art Housing Scheme.

The Renaissance City 2.0 plan was announced in 2001 [50]. This plan shifts the attention from the development of the hardware (facilities) to the software (capacity building, audience development). It also claims the need to merge art with entertainment, mixing the agencies related to commercial and non-commercial art and adopting a creative industries perspective, with creative industries benefitting from the presence of core art. The following planning frameworks by the Urban Redevelopment Authority thus included tangible urban planning measures. The Centre for Liveable Cities in Singapore retraced the path toward Singapore as a "City of Culture" [51].

Singapore joined the UNESCO Creative Cities Network and focused on "design" in 2015. The focus on design indicated that creative industries were understood in the wider sense of Florida (2002) and KEA (2006) and were meant to support the rise of industry 4.0 and economic diversification. According to the DesignSingapore Council: "Design remains the key driver of the local creative economy by contributing annually about $2.13 million to the citystate's GDP, with an estimated 5,500 active design enterprises employing up to 29,000 people" [52]. Singapore as a Creative City is presented in Table 1.

Table 1. Singapore as a Creative City, State, and Nation.

Goal	Scientific Concept	Evidence of Implementation in Singapore
Creation of lateral economic revenues generated by the implementation of cultural projects or activities	Myerscough, Liu and Chiu, Negruşa et al., Heilbrun and Gray [34,53–55]	Singapore cultural statistics 2015–2017 [56]
Income generated by tourism	Landry, Degen and García, Franklin, Heilbrun and Gray [35,55,57,58]	Singapore cultural statistics 2015–2017 [56]
Attract a *creative class* that will push urban economies into a post-industrial society	Florida, Liu and Chiu, Rao and Dai, You and Bie, Buettner and Janeba [36,37,53,59,60]	Singapore cultural statistics 2015–2017 [56]

Table 1. *Cont.*

Goal	Scientific Concept	Evidence of Implementation in Singapore
Cluster of cultural activities to produce economic benefits and other benefits, like pools of common knowledge and skills, flexible human resources, relations of trust, and a sense of common goals	Roodhouse, Tavano Blessi et al., Keane, Fung, and Moran [61–63]	Singapore Art Belts in Art Housing Scheme (1985), Masterplan of the Civic and Cultural District (1988), Framework for the Arts Spaces (2010) [64,65]
Social inclusion and cohesion	Landry, Yarker, Bailey, Miles, and Stark [35,66,67]	Community/Sports Facilities Scheme (CSFS) (2003), Art Reach (2012) [68,69]
Shared urban vision or image	Landry, Yarker, Degen and García, Bailey, Miles, and Stark [35,57,66,67]	Implementation of national infrastructures like the National Gallery (2015), etc.
Interaction intensity between people and the urban	Landry 2006 [35]	Singapore cultural statistics 2015–2017 [70]
Creation of a framework for culture	Landry 2006 [35]	The Renaissance City Plan I-II-III (2001-2011), Report on Art and Culture Strategic Review (2012–2018) [49,71]

1.6. Convergence of Smart Cities and Creative Cities

The white paper by the Expert Working Group on Smart City Application and Requirements describing the Smart City included "Smart People", referring to people with a high level of qualification, affinity to life-long learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism and open-mindedness, and inclined to participate in public life [16]. Participation and the Smart City are central to van Waart [72]. The Smart People have much affinity, already in the definition, with the creative class supported by Florida [36]. According to the white paper, these people appreciate Smart Living that includes cultural facilities and tourism attractions. Both planning paradigms, in the evolution of their concepts, point in a similar direction. We argue that these two positions—of Smart Cities and Creative Cities—converge as they both consider the quality of life of people, or more specifically, the "urban quality", "open governance processes", and "cultural life and participation" as central components. We could actually consider these three points as the intersection of the two planning paradigms, designing a common path of actions.

As discussed, the Smart City moved away from a technologically oriented goal, but it is still technologically intensive in its methods, meaning that it supports processes which are enhanced by technology. The most innovative technologies that can support planning and decision-making, or revolutionize the way we live and refer to cities are "big data", "model and simulation", "artificial intelligence", "blockchains", "automation or robotics", and "Internet of things or information technologies". We thus see a clear overlap of smart technologies on the one hand and creative economies on the other [73]. The intersection gives space for an emergent Smart-Cultural City with Smart-Cultural Clusters and Smart-Cultural Actors in Singapore.

2. Materials and Methods

2.1. Domain Definition

This article identifies actors in the Smart-Cultural Cities discourse in Singapore. The actors are selected from a database collected by the Singapore-ETH Centre (SEC) drawing upon shared contacts of the institutional partners of the Campus for Research Excellence and Technological Enterprise (CREATE) endorsed by the National Research Foundation (NRF) of Singapore. Given the tight network of governmental, academic, entrepreneurial, and artistic actors in Singapore, this database is considered the most representative available. All actors are anonymized. The field of actors on the topic of smart cities has been divided into the following four sectors deemed significant as they overlap and potentially converge on the topic of Smart-Cultural Cities discourse in Singapore:

- Authorities
- Academia
- Industry
- Artist

The actors are selected according to their position toward the field of Smart-Cultural Cities. To do so, we transform the domain of the problem into a network and analyze the network using a clustering optimization algorithm. The advantages of this methodology can be summarized as follows:

1. Unlike other clustering methodologies, the number of clusters is not required as input. Rather, it is found automatically when solving the problem.
2. The problem can be solved exactly. Many other popular clustering problems are often solved heuristically (e.g., K-means [74]).
3. This methodology allows a better visualization and interpretation of the results. As a matter of fact, regardless of the number of actors and domains, visualization is always possible, whereas methods like K-means allows for visualization only up to dimension 3. Other methods that reduce dimension (e.g., principal component analysis (PCA)) may allow visualization but, due to the change of domain, the interpretation could prove to be difficult.

These selected actors expand the conventional field of their operation toward a larger discourse on science, technology and policy in the city (e.g., Smart City). We included only those actors who directly address a wider definition of Smart City, which looks at the urban quality, governance, and cultural production, through the use of technology (information technology, artificial intelligence, data, etc.). The list of actors has undergone an optimization process as described below.

The Action describes the way of engagement of the actors within the Smart-Cultural Cities discourse. These forms of engagement are Discuss, Share, Criticize, Contribute, and Make. The Goals describe the larger topics that the actors want to contribute to within the Smart-Cultural discourse. These goals are Urban Quality of Life, Participation and Governance, support of Cultural Production. The Methods describe the technological tools, domain expertise, and approaches chosen by the actors relative to the Smart-Cultural discourse.

The selection of Actors prioritizes the Agency these actors exercise in their field in the light of the Smart-Cultural transition.

- Authorities: As the regulating and legislating bodies that govern the processes of urban transformation, this group engages with data, new media, and digital technology to cope with the changing duties of public service, to adjust to demands for data transparency and participation.
- Academia: As the scientific community that drives progress and innovation, this group uses data, new media, and technology to gain new insights and generate knowledge.
- Industry: As the applicators that transform economies, this group mobilizes data, new media, and technology to disrupt conventional business models and to innovate.
- Artist: As the critical inquirers and experimenters, this group explores data, new media, and technology to comment and to create.

2.2. Bipartite Networks

The problem under study is characterized by two groups of entities, namely, the actors and their corresponding domain. This scenario can be modeled by means of a bipartite network, that is, a graph which consists of two set of nodes, called red (R) and blue (B), such that edges can only link an element of R to one of B. In our case, red nodes represent actors, blue nodes represent domains, and edges connect each actor with their domains. This representation of the problem allows us to employ a network analysis technique which can, by exploiting the structure of the network, identify groups of actors and domains that are densely connected. Those groups are called clusters and are identified

by solving an optimization problem. More precisely, after the resolution, we get the values of the variables which tell us the cluster each node of the network belongs to.

Given a bipartite network, one way to identify clusters of nodes densely connected is to employ the bipartite modularity metric introduced by Barber [75]. The bipartite modularity value of a cluster represents the difference between the fraction of edges in the cluster and the expected number of such edges in a random network whose nodes have the same degree distribution. Hence, a large value of bipartite modularity for a cluster means that the relationship between its nodes is strong. As each cluster in the network can be characterized by its corresponding bipartite modularity value, the idea is to assign nodes to clusters in order to maximize the sum of bipartite modularity of all the clusters. This yield an optimization problem, whose model is presented here as Equation (1):

$$\begin{gathered} \tfrac{1}{m}\max \sum_{i\in R}\sum_{j\in B}\left(a_{ij}-\tfrac{k_i k_j}{m}\right)x_{ij} \\ \forall i<j<l\in N - x_{ij}+x_{il}+x_{jl}\leq 1 \\ \forall i<j<l\ \in N x_{ij}+x_{il}-x_{jl}\leq 1 \\ \forall i<j<l\ \in\ N\ x_{ij}-x_{il}+x_{jl}\leq 1 \\ \forall i<j\ \in N x_{ij}\in\{0,1\}, \end{gathered} \tag{1}$$

where N is the whole set of nodes (i.e., red followed by blue nodes), m is the total number of edges of the graph, a_{ij} is a value equal to 1 when nodes i and j are connected by an edge, 0 otherwise, and k_i is the degree of node i (i.e., the number of nodes connected to i). Concerning the variables of the problem, x_{ij} is a binary variable equal to 1 if nodes i and j are in the same cluster, 0 otherwise. The objective function to maximize is the bipartite modularity, and the constraints of the problem impose that if nodes i and j belong to the same cluster, and nodes j and l belong to the same cluster, then nodes i and l also belong to the same cluster.

Since Problem (1) can be considered an integer linear programming (ILP) one—an optimization problem where there are integer variables and linear constraints/objective function—it can be solved with a state-of-the-art software for ILP problems like CPLEX [76]. However, as the bipartite modularity maximization problem is NP-hard [77], when the size of the network is too large, finding the optimal solution may prove to be computationally challenging. Hence, heuristics should be used to find good quality solutions in a reasonable amount of time (see, for example, [78–80]). For the purpose of analyzing the Smart-Cultural City of Singapore, we do not need to employ heuristics because the size of the network under study is not too large. The solution of the ILP problem provides the optimal values of the variables x_{ij}, namely, the information indicating whether each pair of nodes belongs to the same cluster, and this information can be used to identify the clusters. Note that unlike other clustering methods such as K-means, the bipartite modularity maximization does not require as input the number of clusters.

Thirty actors from four professional groups or sectors have been evaluated for eleven domains of expertise. The graph network depends on the initial set-up and how we attributed the domains of expertise to the professional groups. Each actor from the four professional groups is linked to the domains applicable (see Table 2 below). It is important to note that this attribution is a qualitative judgement, identical to the selection of the actors. It is further noted that even though the sample size is small, the methodology is based on solving a deterministic optimization problem rather than computing a statistic which needs a large sample size to be significant. Clusters can be identified even when a network size is small; for example, a complete graph where each node is connected to the others is usually identified as a cluster by various community detection methodologies regardless of the dimension. The resulting graph strength (i.e., the optimal bipartite modularity value) gives an indication on the structure (or randomness) of the clusters. The graph strength value that is a measure of how far this graph network differs from a random graph was at 0.23, indicating a relatively structured graph. This underlines that the initialization was sensible and that the results yielded meaningful insights.

Table 2. The actor–attribution matrix creates the bipartite graph.

Actors		Discuss/Share/ Criticize	Contribute/ Make	Urban Quality of Life	Participation/ Governance	Cultural Production	Big Data/Social Media	Artificial Intelligence	Blockchain	Modelling/ Simulation	Internet of Things/ Technology	Robotics/ Automation
Authority	1		X	X	X		X	X		X		
Authority	2		X	X	X		X	X				
Authority	3	X	X	X							X	X
Authority	4		X	X	X		X	X				
Authority	5	X	X	X			X	X			X	X
Authority	6	X		X	X		X					
Academia	1	X	X	X		X	X	X				
Academia	2		X		X		X			X		
Academia	3	X		X	X		X					X
Academia	4	X		X	X		X	X				
Academia	5	X		X	X	X				X		
Academia	6	X	X			X	X			X	X	
Academia	7	X	X	X			X			X		
Academia	8	X		X	X		X	X	X		X	X
Academia	9	X		X							X	
Academia	10	X			X		X	X				
Industry	1		X	X							X	X
Industry	2	X	X		X		X	X		X		
Industry	3		X	X			X			X		
Industry	4	X		X	X		X	X				
Industry	5		X	X					X		X	
Artist	1	X		X	X		X					
Artist	2	X			X					X		
Artist	3	X		X	X							
Artist	4	X	X	X			X					
Artist	5	X			X						X	
Artist	6	X		X	X	X	X	X	X		X	
Artist	7	X		X	X	X	X	X	X	X	X	X
Artist	8	X	X			X					X	X
Artist	9	X		X		X					X	

3. Results

3.1. Emergent Clusters

The algorithmic optimization of the graph shows that three distinct emergent clusters appear (see Figure 1). These clusters mix the members of the four professional groups and are thus not a re-iteration of these groups. Note that the optimal number of clusters is not a parameter to be provided, rather it is found automatically by solving the optimization problem. The connections between the two sides of the graph from left to right relate actors to domains, that is, they analyze the primary connection and within clusters. The three clusters include ten actors each. The distribution of the different professional groups in the three clusters is quite balanced.

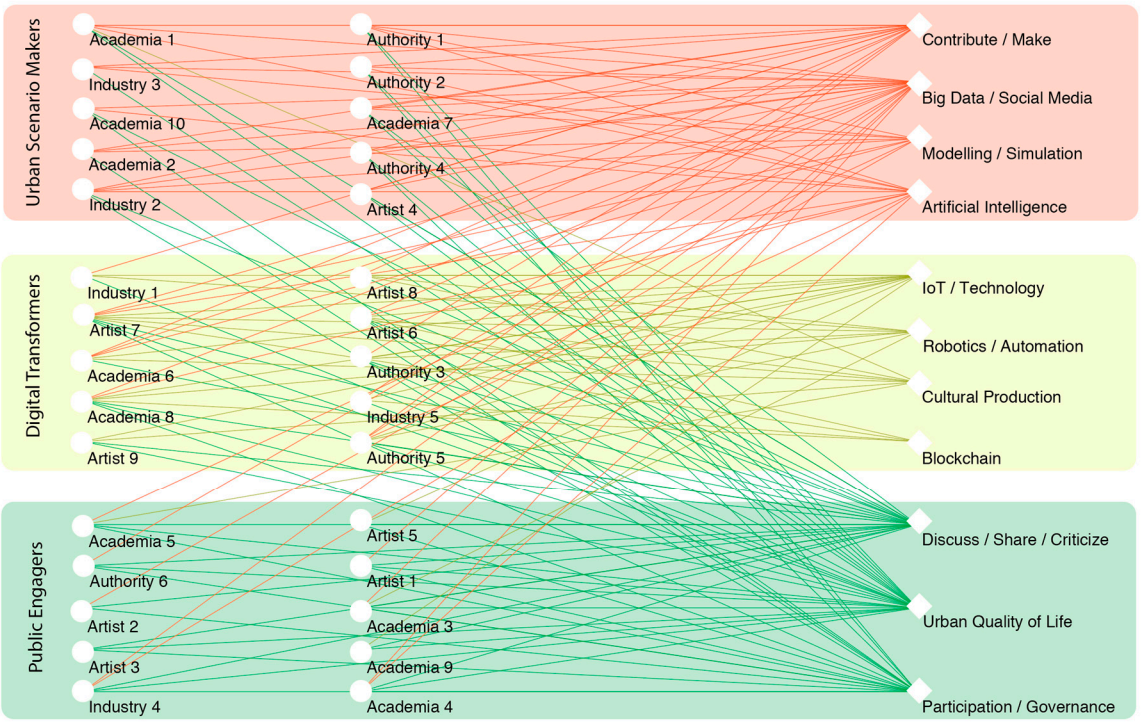

Figure 1. Bipartite graph and clusters of selected Smart-Cultural Cities discourse actors and domains in Singapore.

The first cluster is mainly defined by the use of technology (Fields/Methods) and the Action, as it includes 50% of the actors dealing with Big Data, Artificial Intelligence (AI), and Modelling and Simulation and 90% produce tools and services, rather than studying them. The combination of the four domains describe a clear method to automatically generate and assess urban scenarios. The first cluster will be called Urban Scenario Makers.

The second cluster is defined by a common goal as it includes 70% of the actors directly addressing the need to enrich cultural production in cities, using mixed technologies (100% of blockchains, 85% of robotics, 83% of IoT). The second cluster will be called Digital Cultural Transformers.

The third cluster is also mainly defined by a common goal and the type of Action, as it includes 50% of the actors dealing with participation or advocating for a different type of governance. Even in this case there is a clear methodology: these actors mainly discuss to raise awareness and produce more participation with respect to the smart-cultural city. The third cluster will be called Public Engagers.

3.2. Cluster Interrelations

Further engagement areas open in close examination of the graph structure. The graph secondary connections from right to left relate domains to actors, that is, they analyze the supportive links across

clusters (see Figure 2). These "weak" links indicate potential areas for fruitful engagement discussed in the conclusion section. Finally, we describe the three emergent clusters in detail by examining the commonalities of the actors that make up the cluster. The three clusters are interdependent and their links and interdependencies deserve closer attention.

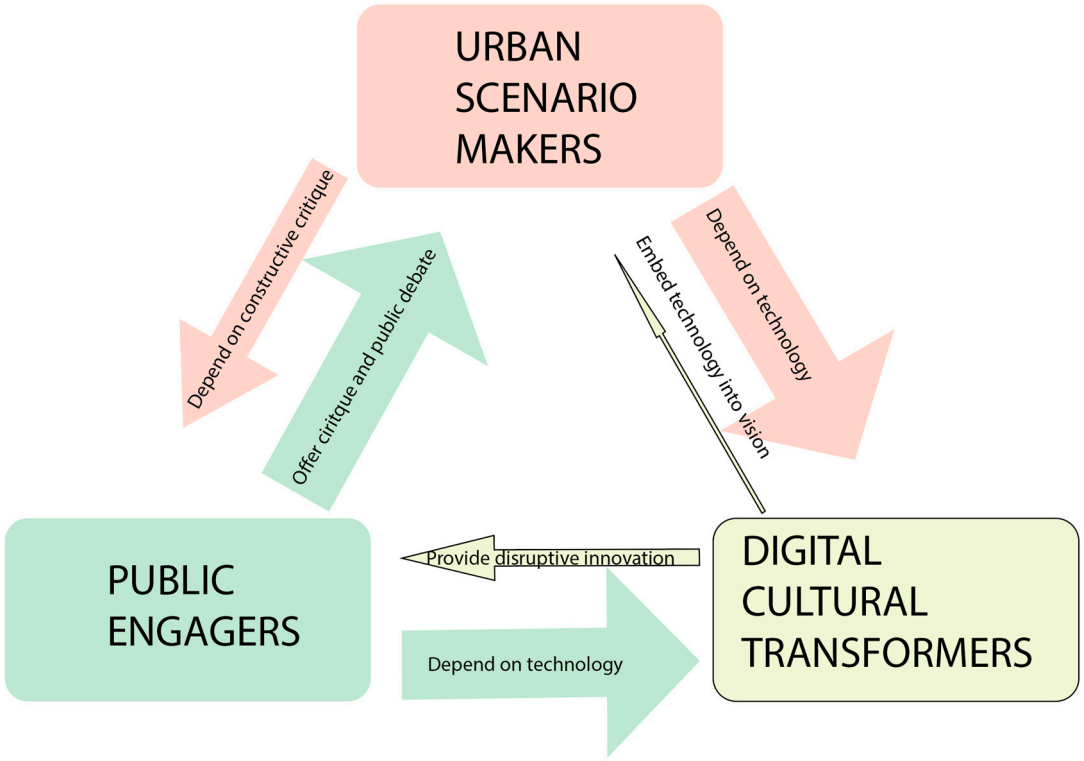

Figure 2. Framework of Smart-Cultural Actor clusters in Singapore and their interdependencies according to the number of connections.

4. Discussion

4.1. Answering the Research Questions

The findings show that smart technologies indeed contribute and increasingly drive Smart Cities and creative economies in Singapore. The proposed methodology also allows us to analyze the actor database and formalize the relationships among actors of Smart-Cultural Cities. We identified meaningful groups of actors within the Smart-Cultural City of Singapore as shown in the table. This article also demonstrates the presence of actors in Singapore who belong to, support, and discuss the creative fields and industries in Singapore and thereby contribute to the development of the Smart-Cultural City.

4.2. Interpretation of Clusters

Urban Scenario Makers navigate multiple urban scales and create scenarios in a pro-active way. The combination of technology including big data and AI as well as local and cultural insight allows Urban Scenario Makers to test decisions and the effects of decisions. For example: What is the effect of a new road on traffic, the neighborhood, and liveability? Real-time traffic information allows us to create realistic models, which can then react to the new element, highlighting limits and potentials of urban development. Urban Scenario Makers look at all aspects of urban life: the quality of public space, the diversity of artistic neighborhoods, gentrification processes. The Urban Scenario Makers test the city of the future before it happens. The Urban Scenario Makers depend on the Digital Cultural

Transformers for disruptive new technologies and applications and on the Public Engagers to critique and balance their work.

The Digital Cultural Transformers look at the transformation of our life introduced by new technologies, in particular the way we produce, consume, and broadcast art and culture or the way we experience public spaces, or the way we meet, consume, and overall judge the urban quality of our cities. The Digital Cultural Transformers not only discuss what is already happening and what most likely will happen, but they also propose and produce new technologies and new applications of existing technology to improve and have an impact on all those aspects of our life. Their innovations yield disruptive potential and needs to be discussed broadly by the Public Engagers. At the same time, they draw from the visions developed by the Urban Scenario Makers to frame their transformation projects.

The Public Engagers focus on public debate and discussion. They lift themselves above the Digital Cultural Transformers as they often lack the tools and technology to actually transform and instead engage the public. Being critical and reactive, the Public Engagers shy away from developing scenarios, yet depend on those proposed by the Urban Scenario Makers.

4.3. Activating the Smart-Cultural City of Singapore

This article investigates the emergent intersection and convergence of Smart Cities and Creative Cities that emerge with the availability of social media data, technology, and the shifting mode of cultural production forming a new nexus of Smart-Cultural Cities. The article identifies three emergent clusters in the Smart-Cultural Cities discourse for Singapore – Urban Scenario Makers, Digital Cultural Transformers, Public Engagers. These clusters present potential areas for meaningful and strategic engagement within the Smart-Cultural City of Singapore for future urban planning and cultural production as an expansion of the Smart City as well as the Creative City.

Each of these clusters has a balanced contribution of the different professional groups and actors. Yet, those groups and actors might not know of each other's work and rarely come together in real life. Even if they share similar goals, type of actions, and methods, they usually work in parallel addressing similar issues with different perspectives.

Very few artists are found in the "Urban Scenario Makers" cluster. As a result, there is little critical discussion about scenarios and visions (e.g., a strong prevailing techno-naïve attitude). The "Urban Scenario Makers" cluster have no links to "applied" technology in the digital transformation group. Their tools are data and simulation. In return, they do not engage with tangible technologies, yet.

The "'Public Engagers" cluster discusses primarily the consequences of shifting public engagement through technology and culture without actively developing technology or cultural production.

The "Digital Cultural Transformers" cluster is the most balanced of the three, as it includes actors who both discuss and make, they come from all the different professional groups, and they usually directly address the cultural production in cities with different and emerging technologies. This is the most "convergent" cluster in the sense of the Smart-Cultural Cities proposed here with a high potential of creative advancement of the discourse as they have many commonalities.

4.4. Outlook: Further Research and a New Tool forDdigital Humanities and Citizen-Centered Smart City Research

The bipartite graph method was tested as a new qualitative method for digital humanities. It allows us to reveal underlying structures in a network. Analysis and interpretation of the resulting partition of the network give insights into clusters and gaps. Being able to identify these clusters and their dynamic interrelation is essential to develop a citizen-centered Smart City research. This allows us to activate previously invisible linkages among actors and leverage synergies in civic participation. The findings hint at further research questions to be answered in the future, for example: Are data-rich environments necessarily supporting creative industries? How does research in disruptive technologies influence the number and impact of creative industries? Do e-governance processes influence cultural

production? If so, in what way? The geographic case study of Singapore and the particular thematic intersection of Smart-Cultural Cities can be translated to other cities, regions, and nations.

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