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Role of Collective Intelligence (CI) in Urban Designs and Leading Smart Cities; Case Study: Niyavaran St.*

Sara Sadeghi[a]- Ali Safavi[b]- Mohammad Javad Mahdavinejad[c]**

[a] M.A. in Urban Design, Faculty of Art and Architecture, Tarbiat Modares University, Tehran, Iran.

[b] Assistant Professor of Urban Planning, Faculty of Art and Architecture, Tarbiat Modares University, Tehran, Iran (Corresponding Author).

[c] Professor of Architecture, Faculty of Art and Architecture, Tarbiat Modares University, Tehran, Iran.

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ABSTRACT

Today, smart tools, i.e., artificial intelligence-powered tools are the main drivers of smart cities, facilitating complex design processes and expediting modern urban traffic. The main problem, however, with using Artificial Intelligence (AI) in design processes would be the failure to use capacities of Collective Intelligence (CI), which remains one of the main shortfalls in urban design. Collective intelligence refers to the “shared capacities and potentials of a group or a team to perform a wide range of tasks and solve various problems” (Chikersal, 2017). The question is whether or not appropriate urban spaces could be designed without using the capacities of collective intelligence and appropriate citizen feedback. Meanwhile, citizens (collective intelligence) need to collaborate and engage in collective intelligence-based design processes because they are the main owners of urban spaces. The main objective of this study was to use collective intelligence and citizens’ actual experiences in designing Niyavaran Street in Tehran. Also, using other modern artificial intelligence-based techniques in collecting and analyzing data was another objective of this quantitative study. To this end, we invited 107 citizens to a real experiment on the street. Study data included the location data (geographical longitudes and latitudes) of the subjects’ presence and walking on the street, collected by a tracker application, called Geo-Tracker, designed by the researcher. The data were then coded into a JSON file. As the processed data were entered into the coding section of an artificial intelligence site, dubbed Geojason, the paths covered by people were drawn on the site’s map. As the paths were overlaid on each other, we could examine and identify the areas of the street where path nodes and their overlaps were most noticeable. It was concluded that these points finally attracted the attention of the study subjects the most.

Keywords: Collective Intelligence, Hybrid Intelligence, Digitalism, Niyavaran Street, Machine Learning.

* This article is derived from the first author’s M.A. thesis entitled "Urban Design of Niyavaran Axis, Tehran, by Investigating and Analyzing the Potentials of Digitalism of Connected Intelligence", supervised by the second author and read by the third author in 2022.

** E_mail: sasafavi@modares.ac.ir

1. INTRODUCTION

Around 66 percent of the world's population will have lived in urban areas by 2050 (Hashem et al. 2016), which will cause enormous challenges (Lu, Chen, and H. Yu 2019). Migrations, on the other hand, will cause air pollution, resource management problems, traffic congestion, and public health and infrastructure issues that will not be proportionate to the constantly evolving urban situations (Miguel et al. 2019; Correia et al. 2020; Castanho et al. 2021; Ortega-Momtequín et al. 2021; Nunes et al. 2021). Meanwhile, smart cities have emerged in response to these issues and made use of ICT to help improve people's quality of life and encourage social and environmental sustainability (Faria et al. 2018; Fernandes et al. 2018; Kumar et al. 2019; Nunes et al. 2021). In other words, these cities help facilitate information transfer and communications (Nunes et al. 2021). Early definitions of smart cities were mainly characterized by technologies (Effing and Groot 2016; Sivarajah et al. 2015). To give an example, Hall et al. defined a smart city as a "city that monitors and integrates the conditions of all its critical infrastructure" (Bowerman et al. 2000), as IBM defined it to be an "Instrumented, connected, and intelligent city" (Harrison et al. 2010; Effing and Groot 2016).

Karmaker et al. argued that the transition from a traditional city to a smart one requires an effective management plan to help ensure the proper functioning of intelligent technologies and infrastructure (Karmaker et al. 2023). The notion of a smart city is increasingly becoming a global phenomenon with the advancements in ICT (Zhu et al. 2022). It is widely seen that many cities are expanding smart city development strategies to utilize the opportunities provided by these technologies. A smart city is expected to provide better solutions to meet social, economic, and environmental challenges emanating from unprecedented urbanism. A smart city helps provide solutions to tackle such challenges as climate change, energy crisis, and social inequality through developing and applying advanced technologies (Manville et al. 2014; Michalec et al. 2019; United Nations, D.o.E.a.S.A. 2019; Yigitcanlar et al. 2019; Zhu et al. 2022).

Meanwhile, an emerging challenge in this connection is citizen collaboration (Caragliu et al. 2011; Mellouli et al. 2014). Living in cities tends to individualism and citizens are no longer interested in engaging in urban or local policy-making issues (Latour 2005), which will subsequently affect social solidarity and cause cities not to utilize their citizens' full capacities. To counter this, online tools can help tackle these challenges and find solutions (Townsend 2013; Effing and Groot 2016; Sivarajah et al. 2015).

The key subject in this study was the application of collective intelligence (CI) and citizens' actual experiences of presence in urban spaces in a real experiment. The study also aimed to examine how people's actual experiences in urban spaces can be collected in real experimental conditions, as cities would represent living laboratories (Sarkar 2017). The study also aimed to understand how capacities of collective intelligence can be employed to provide urban designs and how to incorporate both artificial intelligence and collective intelligence into urban design processes. This study, as mentioned earlier, aimed to use people's actual experiences in designing Niyavaran Street. By actual experiences, it is the same people's interactions with urban spaces in Niyavaran Street, which provided data for this study in an intangible manner. Actual experiences arise without the researcher's direct interference, questionnaires, and interviews. Interacting with the environment (e.g., by walking, pausing, etc.), the participating subject establishes communications with the environment without special questioning about a specific part of the street. The result of this interaction is converted into movement data in the tracking application of Geo-Tracker. Urban designers need to improve the functioning of urban spaces by replacing older data collection techniques with novel ones. It is increasingly becoming critical to apply modern techniques, especially artificial intelligence to collect and analyze information. Meanwhile, it is also essential to create an interaction between artificial intelligence and collective intelligence to use their maximum capacities in urban designs. It is widely realized that receiving information from artificial intelligence-based applications could be an appropriate alternative to common and old techniques. Smart phones-installed applications can also be used to collect urban data. This offers a more effective and efficient method of direct interaction between urban designers and citizens. As stated above, a smart city incorporates capacities of artificial intelligence, machines, data, and capacities of collective intelligence to offer a novel model of urban space designs.

2. LITERATURE REVIEW

2.1. Collective Intelligence

Collective Intelligence (CI) is understood to be the capacity of groups to make decisions, generate ideas, and solve problems more effectively than would be done by individual people (Galesic et al. 2023; Suran et al. 2020; Centola 2022). Collective intelligence has in recent years attracted much attention in different fields such as empirical studies (Wolf et al. 2015; Galesic et al. 2023), advanced computational modeling (Reia et al. 2019; Singh et al. 2009, 18; Singh et al. 2009; Galesic et al. 2023), social network analyses (Centola 2022; Ha and Tang 2022; Galesic et al. 2023), and artificial intelligence (Weld et all. 2015; Singh and Gupta 2009; Jung 2017; Galesic et al. 2023). This indicates that non-experts may even outperform experts (Hong and Page 2004; Galesic et al. 2023).

Thus, collective intelligence could be used to support participatory methods that go beyond voting or beyond consulting citizens for problem identification. Citizens can also offer solutions to problems. As demonstrated by the literature on collective intelligence, the quality of outcomes highly depends on the type of interaction between people. In essence, an intelligently designed system can be so structured to align individual efforts more constructively and to help produce high-quality outcomes, referred to as the Wisdom of the Crowd (Galton 1949; Watson and Levin 2023; Galesic et al. 2023). On the contrary, poorly designed systems are likely to easily generate chaotic processes with low-quality outcomes, usually referred to as the Madness of the Crowd" (Lorenz et al. 2011; Waddington 2008; Balietti et al. 2016; Galesic et al. 2023).

Table 1. Definitions of Collective Intelligence

Definitions of Collective Intelligence	Sources
Collective intelligence refers to the shared capacities and potentials of a group or team to perform a wide range of tasks and solve various problems.	(Chikersal 2017)
Collective intelligence refers to group knowledge and wisdom or wisdom of the crowd resulting from collaboration and competition between people.	(WLo and Zhang 2022)
Collective intelligence is an emerging interdisciplinary field of study involving a wide range of academic fields such as sociology, economics, biology, software engineering, and computer sciences.	(Berditchevskaia et al. 2022)
Collective intelligence refers to groups of people who work collectively and intelligently.	(Weld et al. 2014)
Collective intelligence refers to the capacity of a group for effective collaboration and cooperation; this process, meanwhile, is much more important for collective functioning than individual abilities. In other words, just having several smart people may be helpful, but not necessarily enough.	(Woolley et al. 2016)
Almost none of the tasks that we have performed so far have been done by individuals alone; rather they have been done by groups of people who work together.	(Malone 1959)
Collective intelligence provides a unified statistical coefficient that predicts how well a group will perform across a wide range of tasks.	(Malone and J. McGovern 1959)

2.2. Hybrid Intelligence (HI)

Human societies are struggling with numerous problems that require collaborative collective actions. Artificial intelligence has the potential to provide the necessary knowledge and action to explore and find solutions on a large scale. Meantime, to harness the potential of human systems and artificial intelligence, the main functions of collective intelligence must be perceived (Gupta and Woolley 2021). Peeters et al. (2021) did the study "Hybrid Collective Intelligence in a Human-AI Society" to define three approaches regarding collective intelligence and artificial intelligence:

1. Techno-centric: This approach states that real intelligence will ultimately be found only in developed and mature general artificial intelligence systems. Biologically, humans suffer from limited reasoning and information processing abilities, and for this, demonstrate various types of cognitive biases, whereas computers provide an endless amount of opportunities for expanding rational intelligence on human scales and beyond (Peeters et al. 2021).

2. Human-centric: This approach states that real intelligence will ultimately be found only in humans and (probably) in other living intelligent entities. Artificial intelligence enables humans to achieve their full potential; however, it will not be inherently capable of developing some fundamental traits found in humans, such as moral reasoning or empathy. This inability may make artificial intelligence harm human welfare (Peeters et al. 2021).

3. Collective Intelligence (CI)-centric: This approach states that real intelligence will ultimately be found only in an association of multiple interacting entities. In isolation, human individual intelligence and artificial intelligence are highly limited in a system. Real intelligence is generated when multiple entities collaborate over long periods (Peeters et al. 2021).

2.3. Collective Intelligence and Digitalism

In the digital age, we now have new models for learning and for co-designing and co-creating new services in collaboration with others. (Stenvall et al. 2022). The interaction between technology, society, and citizens is underpinning the core of the development of smart cities, and with the increasing penetration of Internet applications, digital governance is advancing constantly (Weibin et al. 2022). Digitalization is omnipresent in today's social and urban life. It emphasizes the 3C (connect, collect, comprehend) concept of Smart Nation, and design thinking empowers public service strategies, which will create important foundation support for digital collaborative governance in a diverse society (Ni 2022). Effing and Groot (2016), meanwhile, described 11 different e-participation ladders, generally discussing them as models or theoretical frameworks to define and classify various levels of citizen participation through electronic means. As noted, many authors have defined and measured electronic participation. These 11 ladders include e-information, e-consulting, e-involving, e-collaborating, e-empowerment, e-enabling, e-engaging, e-empowering, active participation, e-informing, and e-consultation (Anadiotis et al. 2010; Sommer and Cullen 2009). The ladders of e-participation include bottom-top levels of collaboration (Effing and Groot 2016).

3. SIMILAR LITERATURE

This section investigates a few similar studies conducted in this regard. These studies have provided online platforms for receiving information from citizens and using them to design and plan an urban space. Like the present study, these studies have provided an online interactive platform for citizens' better participation. By eliminating commonly found techniques such as questionnaires, interviews, etc. these studies demonstrated that in the digital age working with online tools could bring about better outcomes. The goal of this study was also to generate a platform for engaging citizens in designing an urban space via a smart application and an AI-powered interactive platform to apply the study's data.

Table 2. Similar Studies

Project and Year of Administration	Goals and Procedures of Interactive Platforms
Urban design of a Pollards Hill Residential Complex in London's Merton District (2024)	In this study, Stephen Marshall et al. (2024) designed an interactive digital participation platform in urban design for the Pollards Hill Residential Complex in London's Merton District. Goal: Measuring the efficacy of public participation based on the opportunities brought about by advancements in digital technologies (Marshall et al. 2024). Platform characteristics: Simple text inputs that enable users to describe their ideas for courtyards; image uploading that allows users to, let's say, enter photos of the features desired or a sample place; an online "design board" that allows users to use design tools to create a proprietary personal image: this can, for example, enable users to produce a solution, which could not be repeated by using available photos; a 3D model that allows users to add design interventions from a pre-determined set and arrange them as they wish; sharing this in the platform allows other users to propose new suggestions to edit those designs (Marshall et al. 2024).
Creating an AI-powered online support system for resolving problems of five Afghan cities (2024)	Shahab et al. (2024) conducted a comprehensive study over 30 days and engaged people from five cities across Afghanistan. The subjects were engaged in interacting in D-Agree, an AI-powered online discussion forum (Shahab et al. 2024). Goal: Using artificial intelligence to facilitate and improve collaboration and problem-solving in online discussions (Shahab et al. 2024). Platform: This study used D-Agree as a discussion tool which is an online text-based discussion support system and involves an artificial agent and a web platform, allowing users to share messages with the conversational artificial intelligence. This autonomous facilitating agent performs multiple tasks, including viewing the content of the text posted by users, extracting argumentative statements from the content based on the issue-based information system (IBIS), generating facilitative messages based on pre-defined rules, and posting the messages to a discussion board in response to other posts (Shahab et al. 2024).
Designing neighborhoods of Ang Sila City (2020)	Helena Rong (Rong et al. 2020) proposed generating an interactive design platform to design neighborhoods of Ang Sila City. Goal: Generating a platform that collects information about people's preferences and values in urban spaces to set out neighborhood-based visions. This will enable experts to better understand users' needs. Dubbed CoDAS by Rong et al. (2020), this tool serves as an interface linking developers, planners, designers, and citizens, engaging a large number of users. As a process, CoDAS serves as an ongoing dialogue between various stakeholders, starting from pre-design and pre-planning processes and continuing to post-operation processes. Providing the digital coverage of personal narratives and perceptions of the city, this platform helps generate a sentimental consensus over Ang Sila's neighborhoods (Rong et al. 2020).

Project and Year of Administration	Goals and Procedures of Interactive Platforms
Creating a public urban space in the Palestinian city of Nablus using a smart platform for citizen participation (2023)	Itair et al. (2023) conducted a study on citizen participation using a smart application to monitor and provide information and real-time services in the Palestinian city of Nablus in 2023. Goal: Using smart technologies to create an inclusive public urban space (Itair et al. 2023). Itair et al. (2023) used the open-source application of the Kobo Toolbox to collect data from ten field surveys. The Kobo Toolbox tool was used to simplify the process of data collection by effectively and accurately facilitating data entry. This tool allows for collecting various types of data, including images and videos. To gain an overview of public space inclusion, some interviews were conducted with various groups of people day and night. This approach also helps provide diverse citizens' perspectives, including those with different age groups, genders, and people with disability (Itair et al. 2023).

4. METHODOLOGY

This study employed a smart, updated technique to collect and analyze data, primarily aiming to apply the subjects' actual experiences of presence in urban spaces. The design of the representative urban space (Niyavaran Street) was based on using the subjects' actual experiences of the study. Any interaction, including questionnaires, observations, interviews, etc. between the researcher and citizens involved in the study was eliminated, as the subjects were invited to be present in the urban space to interact and engage with the space. In so doing, a routing application was installed on the subjects' smartphones to record their movement path information, which would be later analyzed to help design the urban space intended. When the subjects were present in the space, no questions as to which part of the urban space would be attractive to them were asked, as this was understood by examining their movement paths. The existing paths were overlaid using artificial intelligence to examine points of space that would exhibit greater overlaps of the paths. The outcome indicated the use of collective intelligence in the design process, which was the main goal of the study.

4.1. Study Data Collection

Data were collected using a tracking application, which received subjects' locations and exhibited them in geographical longitudes and latitudes. Relevant longitudinal and latitudinal numbers varied by the movement of the subjects on the street, resulting in a list of locations in the application.

Study data included the subjects' date of presence in the study, their duration of presence on the street, and their geographical coordinates. Geographical coordinates included the geographical longitudes and latitudes that varied by the subjects' changing geographical locations and movement on the street. Below is sample data collected by one of the subjects.

2022-05-23 19:32 Long: 51.4384769 Lat: 35.8057259
2022-05-23 19:33 Long: 51.4384258 Lat: 35.8057941
2022-05-23 19:34 Long: 51.4384279 Lat: 35.8057746

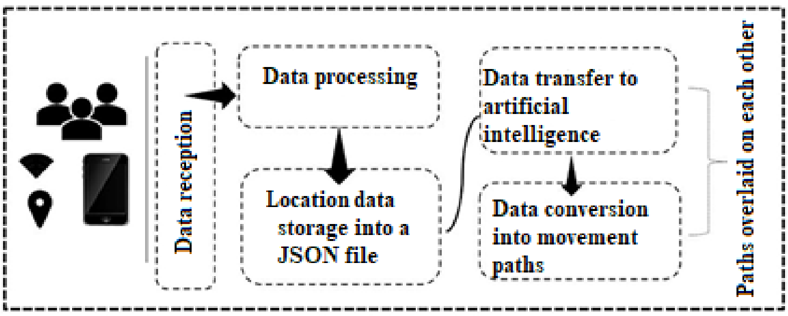

Fig. 1. Model of Study Procedure Process

4.2. Application Architecture

This program has been coded under the trademark "Geo-Tracker" for the Android operating system using Python and Kotlin programming languages. To work with this app, users activate their Internet and GPS and start their movements after the command "start" is executed. The task having been completed, the command "Export" is executed to store the received data into a Word file in mobile phones' memory.

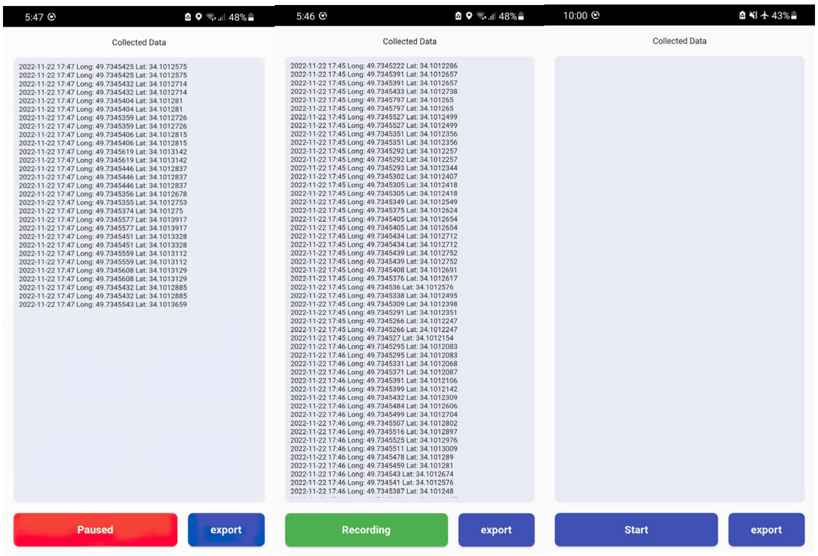

Fig. 2. Tracker Application Workspace (Geo-Tracker)

4.3. Type of Data

As mentioned earlier, the study data included the time, location numbers, and date falling under quantitative data categories.

4.3.1. Statistical Population and Sample

As many as 107 citizens of Tehran voluntarily participated in the study. Some of them were residing in the area of the study (Niyavaran Street). They were in different age groups and genders.

4.3.2. Data Processing

The collected data about the subjects' location (i.e., geographical longitudes and latitudes) are considered raw and initial data and need to be processed to be used in later study stages. Values of geographical longitudes and latitudes must be stored in a JSON[1] file to be transferred into an artificial intelligence model. A sample JSON format-based processed data is given below, where each line starts with a feature and continues with a colon (:), followed by the geographical longitudes and latitudes.

```
{
"type": "Feature Collection",
"features": [
{
"type": "Feature",
"properties": {},
"geometry": {
"coordinates": [
[
51.44550026807451,
35.81045451446289
]
```

4.4. Artificial Intelligence Model

The artificial intelligence used in this study is based on the Website "Geojson.io", which is a quick and simple tool to create, view, and share location data. Geojson supports various coding formats, including KML, GPX, CSV, GTFS, and TopoJSON, among others. It also offers different formats from available maps, providing them in the form of Satellite Street View and OpenLayer maps.

4.4.1. Website Features

The features of this website are as follows:
- Calculating the geographical longitudes and latitudes of a point on the map using the Draw Point tool;
- Drawing lines with identified starting and ending geographical longitudes and latitudes using the Line String tool; changing the thickness and color of the lines and calculating the length of the lines in meter, kilometer, and other measurement units;
- Calculating the area of a point on the map using the Draw Polygon tool, Draw Rectangular Polygon, and Draw Circular Polygon
- Transferring coding files in various programming language formats and converting the codes into lines.

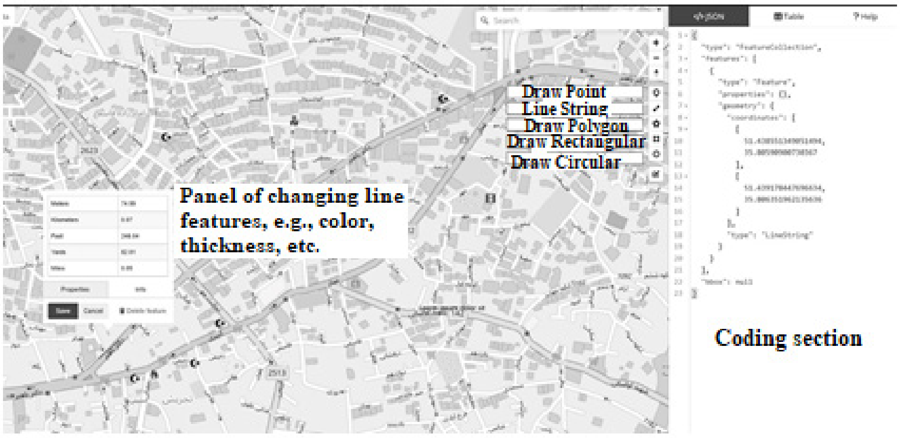

Fig. 3. The Website Workspace (www.geojson.com)
(www.geojson.io)

4.4.2. Mechanism of the Model

The procedure is as follows: the processed data, explained above, are first copied into the site's coding section, and this process continuous respectively for the data taken from each individual; for example, individual-specific location data are first entered (Fig. 4), which is followed by the entry of the next individual's data (Fig. 5). As demonstrated, the location data of the new path will be drawn on the previous path, after the transfer of location data.

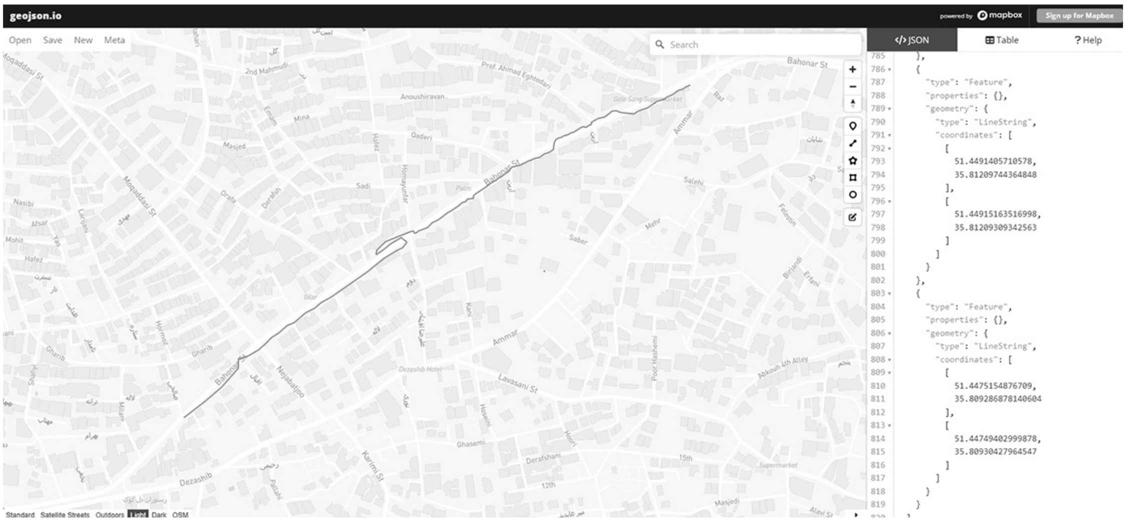

Fig. 4. Drawing Movement Path of a Citizen after Data Transfer

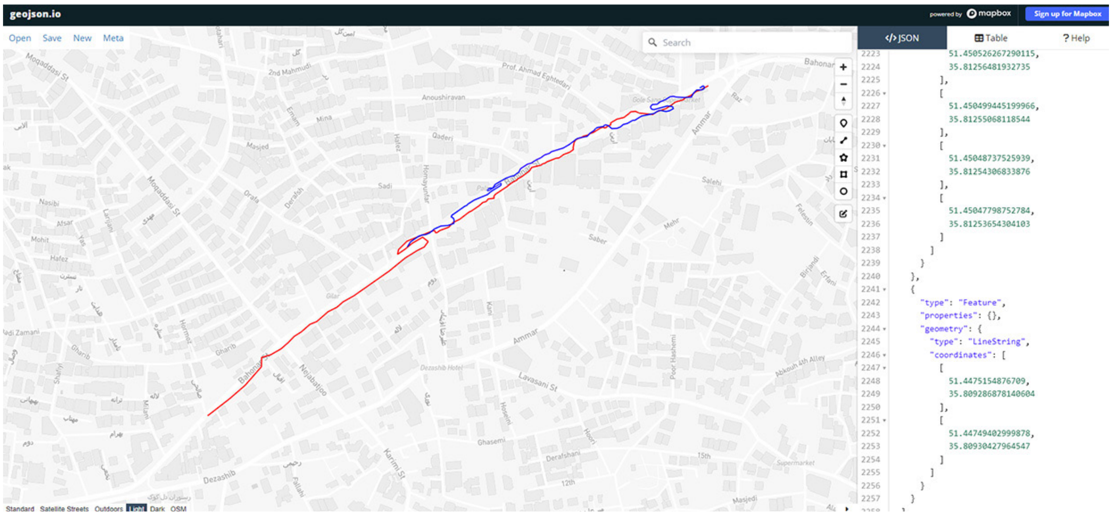

Fig. 5. Overlaying the Next Individual's Movement Path on the Previous Individual's Movement Path after Location Data Transfer

5. DATA ANALYSIS

5.1. The Model's Final Output

The final output is a model made of 107 recorded movement paths overlaid on each other (Fig. 10). Figure 6 demonstrates 10 representative paths the researcher selected from the paths taken by the subjects with different ages, each marked with a specific color to help the viewer correctly understand how the paths are overlaid and are identified.

As noted, in sections of the paths, there are more nodes and overlaps, suggesting that more subjects have walked past these points. Next, the data taken from the website will be analyzed.

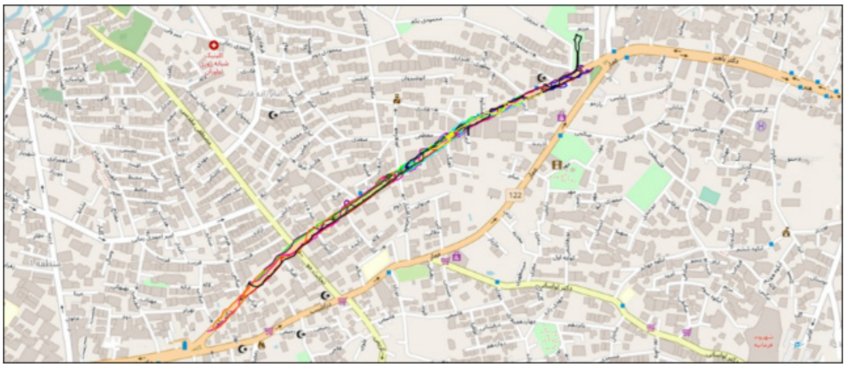

Fig. 6. Final Output of the Model (Ten Recorded Paths covered by Subjects)

5.2. Data Classification

As stated earlier, the study data included the number of participating subjects, their genders, distances covered, date, and duration of walking, and presence on the street. Data were classified using composite bar charts in the SPSS software. All charts incorporated two major factors of age and the number of subjects for better comparison and classification.

- Gender

As exhibited in Figure 7, the majority of the subjects were females. In total, 64 women and 43 men participated in the study, totaling 107 residents in Tehran.

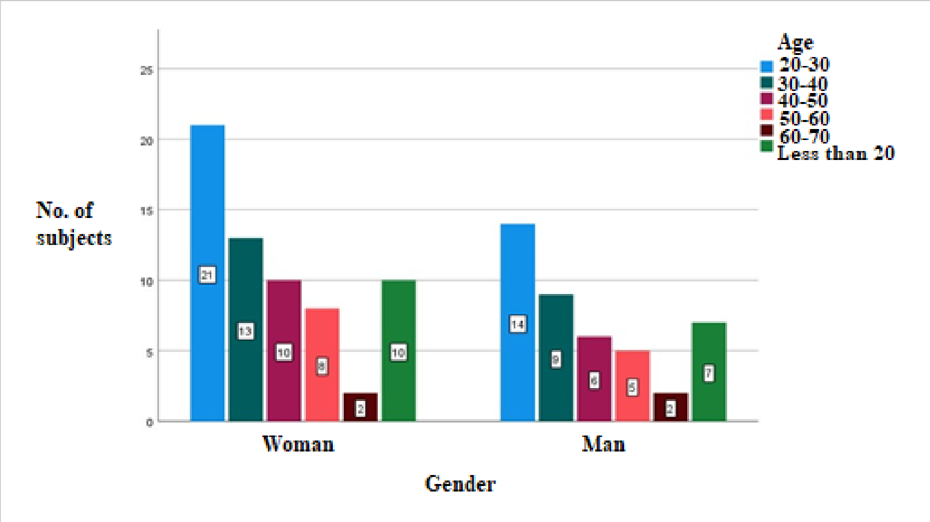

Fig. 7. Number of Participating Subjects, Their Ages, and Gender

- Age

As shown in Figure 7, 15.9% of the subjects were under 20, 32.7% from 20 to 30, 20.6% from 30 to 40, 15% from 40 to 50, 12.1% from 50 to 60, and 3.7% from 60 to 70 years.

- Distance Covered

The distance traveled by each individual is given in Figure 8. Around 20.6% of the subjects walked a distance of 1000 to 1500 m, 48.6% 1500 to 2000 m, around 24.3% 2000 to 2500 m, and 6.5% over 2500 m on Niyavaran Street. The number of people, as shown by the figure, who traversed a distance of 1000 to 1500 m fell under the middle-aged group. Meanwhile, the most distance traveled pertained to the subjects under 20 years.

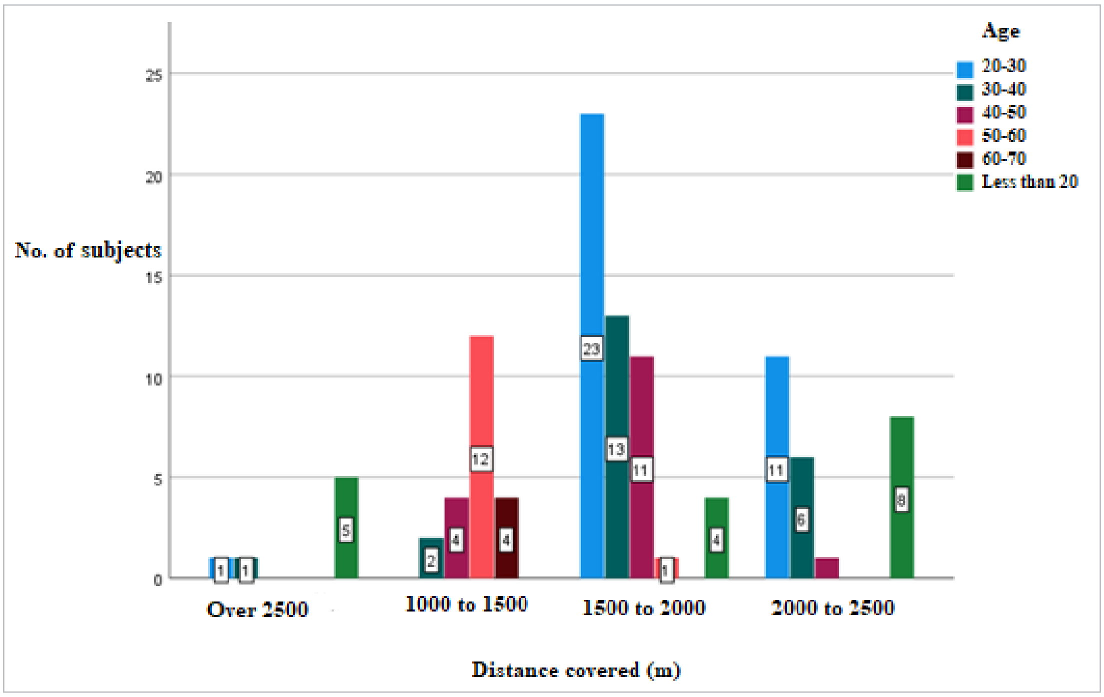

Fig. 8. Number of Participating Subjects, Their Ages, and Distances Covered

- Duration of Presence and Walking on the Street

As shown in Figure 9, 31.8% of the subjects walked for less than 20 minutes on the street, around 35.5% for 20 to 30 minutes, 19.6% for 30 to 40 minutes, and 13.1% for over 40 minutes. As noted, the number of subjects falling under the 20 and 20-40-year-old age category accounted for the highest time spent on the street.

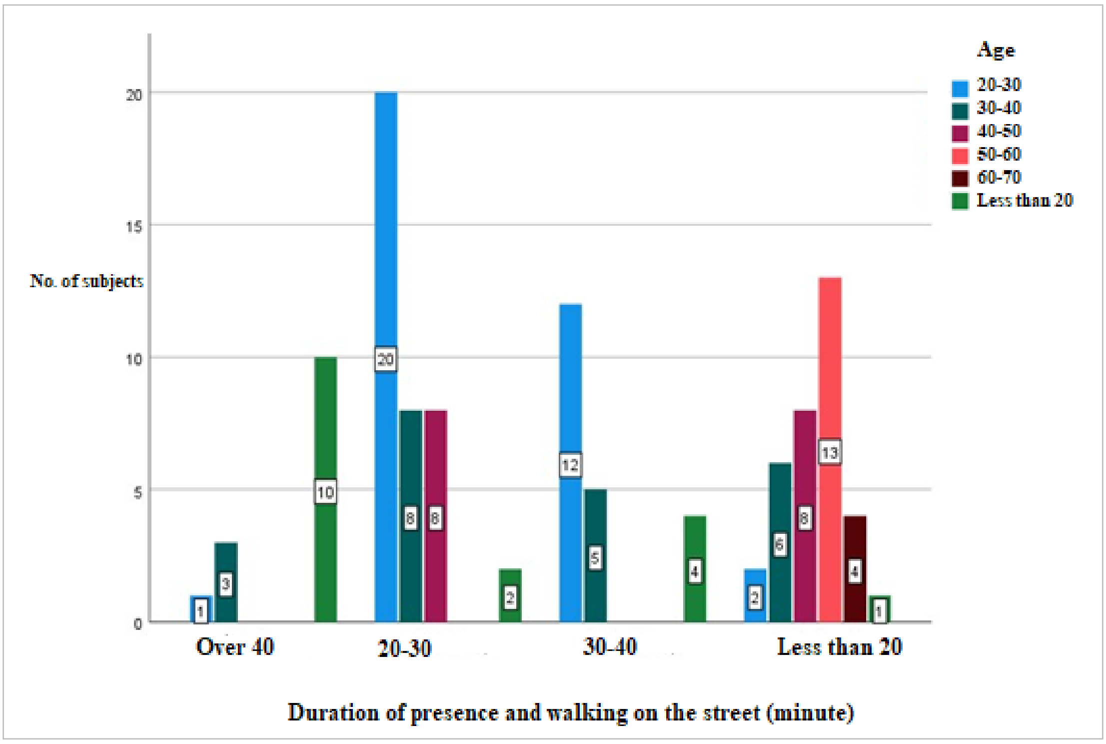

Fig. 9. Number of Subjects, Their Ages, Duration of Presence and Walking on the Street

6. FINDINGS

6.1. Paths Examined

As shown in Figure 10, in some sections of these 107 paths, there appear to be more nodes and greater overlaps, with the lines looking more visible and bolder due to the paths being overlaid. After completing the surveys, findings showed that the points, marked by red and black circles in the following figure, were the areas that captured the attention of the subjects, thus becoming the sections of the street under study that were selected by the citizens.

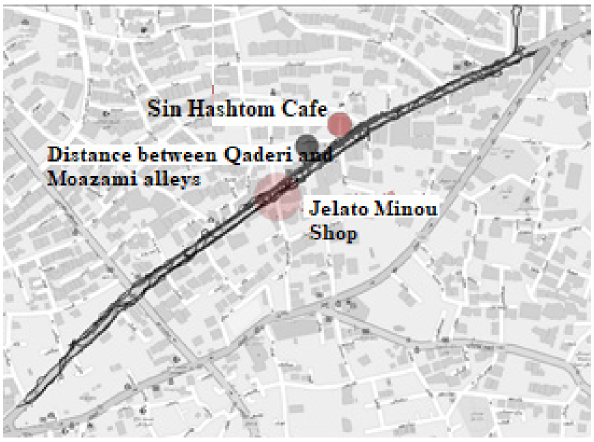

Fig. 10. Examining Nodes and Overlaps on the 107 Paths Overlaid

6.2. Introducing Points Selected by Subjects on the Street

Reviews and analyses of the paths and representative sections of Niyavaran Street indicated that three spaces of this street were more noticeable.

The first space was the Sin Hashtom Mansion, which is one of the famous café restaurants in Tehran, featuring a key element of the street due to its unique design.

Another space includes the zones at the beginning of Qaderi and Moazami Alleys, as well as Moazami Alley and Homayounfar St. These spaces were created due to buildings' setbacks at the beginning of the alley. These spaces span considerable areas.

The other space is the Jelato Minou Shop which, like the Sin Hashtom Mansion, is seen as a major land use on Niyavaran St. due to its famous site. Throughout these spaces, the pedestrian zone that lies in front of them is among the points selected by the subjects. These places are exhibited in Figure 10.

7. DISCUSSION AND CONCLUSION

It was concluded that capacities of collective intelligence can be used in urban design. To use the collective intelligence of the subjects, a tracking application, dubbed Geo-Tracker, was devised to record their movement paths. Then, the 107 paths were overlaid by an artificial intelligence tool (geojson.io) to identify the points where greater overlaps and nodes had been created by the paths interfering with those points. The collective intelligence of this study was made possible by investigating and analyzing the 107 overlaid movement paths recorded by the subjects. The surveys and analyses also showed how the subjects generally viewed the situation and which sections (spaces) of Niyavaran Street had attracted their attention. This could help select those spaces for implementing a better and more effective design process. As stated earlier, the 107 paths were the outcome of each individual's collaboration with designing Niyavaran Street, as each subject showed via their movement path which sections of the street attracted their attention and which sections they liked the most.

This study invited the subjects to a real experiment within an urban space because its methodology was completely different from those in which subjects had to respond to predefined questions posed by urban designers or those in which researchers selected methods such as observations or interviews to collect the data required. To use people's actual experiences in urban spaces, urban designers need to provide conditions to help citizens go through an actual experiment in urban spaces and gain an understanding of those spaces by being present there and interacting with them. This will be made possible by investigating people's movement paths in an urban space such as on a street, where designers will conclude which section of the street or space could be more attractive and critical for citizens, without having an interaction with them. Each movement path poses a real experience that results from the individual's presence in the space as the overlaying of paths could generate collective intelligence, one that is an outcome of citizens' real experiences in group work.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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PARTICIPATION PERCENTAGE

The authors state that they have directly participated in the stages of conducting research and writing the article.

ENDNOTE

1. JSON is an acronym for JavaScript Object Notation. JSON is a standard open format allowing for data exchange on the web using key-feature pairs. JSON represents a lightweight format for data storage and transfer. This format allows the user to transfer information in a text format and even out of the network. JSON files are both human- and computer-readable.

REFERENCES

- Anadiotis, George, Panos Alexopoulos, Konstantinos Mpaslis, Aristotelis Zosakis, Konstantinos Kafentzis, and Konstantinos Kotis. 2010. "Facilitating dialogue-using semantic web technology for eparticipation." In *Extended Semantic Web Conference*, pp. 258-272. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-13486-9_18
- Balietti, Stefano, Robert L. Goldstone, and Dirk Helbing. 2016. "Peer review and competition in the Art Exhibition Game." *Proceedings of the National Academy of Sciences* 113(30): 8414-8419. https://doi.org/10.1073/pnas.1603723113
- Berditchevskaia, Aleks, Eirini Maliaraki, and Konstantinos Stathoulopoulos. 2022. "A descriptive analysis of collective intelligence publications since 2000, and the emerging influence of artificial intelligence." *Collective Intelligence* 1(1): 26339137221107924. https://doi.org/10.1177/26339137221107924
- Bowerman, B., J. Braverman, J. Taylor, H. Todosow, and U. Von Wimmersperg. 2011. "The vision of a smart city." In *2nd international life extension technology workshop, Paris*.
- Caragliu, A., Del Bo, C., Nijkamp, P. 2011. "Smart cities in Europe." *J. Urban Technol.* 18: 65-82. https://research.vu.nl/files/2474218/20090048.pdf
- Carpentras, Dino, Regula Hänggli, and Dirk Helbing. 2024. "Collective Intelligence for Democracy: Empowering Minorities and Everyone in Participatory Budgeting." Available at SSRN 4832498. https://dx.doi.org/10.2139/ssrn.4832498
- Centola, Damon. 2022. "The network science of collective intelligence." *Trends in Cognitive Sciences* 26(11): 923-941. https://doi.org/10.1016/j.tics.2022.08.009
- Chikersal, Prerna, Maria Tomprou, Young Ji Kim, Anita Williams Woolley, and Laura Dabbish. "Deep structures of collaboration: Physiological correlates of collective intelligence and group satisfaction." In *Proceedings of the 2017 ACM conference on computer supported cooperative work and social*. https://dl.acm.org/doi/abs/10.1145/2998181.2998250
- Effing, Robin, and Bert P. Groot. 2016. "Social smart city: introducing digital and social strategies for participatory governance in smart cities." In *Electronic Government: 15th IFIP WG 8.5 International Conference, EGOV 2016*, Guimarães, Portugal, September 5-8, 2016, Proceedings 15, pp. 241-252. Springer International Publishing. https://doi.org/10.1007/978-3-319-44421-5_19
- Galesic, Mirta, Daniel Barkoczi, Andrew M. Berdahl, Dora Biro, Giuseppe Carbone, Ilaria Giannoccaro, Robert L. Goldstone et al. 2023. "Beyond collective intelligence: Collective adaptation." *Journal of the Royal Society interface* 20(200): 20220736. https://doi.org/10.1098/rsif.2022.0736
- Galton, Francis. 1949. "Vox Populi (1907). Translated by Romolo Giovanni Capuano." *Nature* 75: 450-451. https://www.romolocapuano.com/wp-content/uploads/2023/10/Francis-Galton_Vox_populi.pdf
- Gupta, Pranav, and Anita Williams Woolley. 2021. "Articulating the role of artificial intelligence in collective intelligence: A transactive systems framework." In *Proceedings of the human factors and ergonomics society annual meeting*, pp. 670-674. Sage CA: Los Angeles, CA: SAGE Publications. https://doi.org/10.1177/1071181321651354c
- Ha, David, and Yujin Tang. 2022. "Collective intelligence for deep learning: A survey of recent developments." *Collective Intelligence* 1(1): 26339137221114874. https://doi.org/10.1177/26339137221114874
- Harrison, Colin, Barbara Eckman, Rick Hamilton, Perry Hartswick, Jayant Kalagnanam, Jurij Paraszczak, and Peter Williams. 2010. "Foundations for smarter cities." *IBM Journal of research and development* 54(4): 1-16. https://doi.org/10.1147/JRD.2010.2048257
- Hashem, Ibrahim Abaker Targio, Victor Chang, Nor Badrul Anuar, Kayode Adewole, Ibrar Yaqoob, Abdullah Gani, Ejaz Ahmed, and Haruna Chiroma. 2016. "The role of big data in smart city." *International Journal of information management* 36(5): 748-758. https://doi.org/10.1016/j.ijinfomgt.2016.05.002
- Hong, Lu, and Scott E. Page. 2004. "Groups of diverse problem solvers can outperform groups of high-ability problem solvers." *Proceedings of the National Academy of Sciences* 101(46): 16385-16389. https://doi.org/10.1073/pnas.0403723101
- Itair, Mohammed, Isam Shahrour, and Ihab Hijazi. 2023. "The use of the smart technology for creating an inclusive urban public space." *Smart Cities* 6(5): 2484-2498. https://doi.org/10.3390/smartcities6050112 KoboToolbox. Available online: https://www.kobotoolbox.org/ (accessed on 23 June 2023).
- Jorna, Frans, and Mettina Veenstra. 2015. "Setting-up smart cities ecosystems–Essential building blocks." In *Proceedings of the International Conferences on ICT, Society and Human Being*, pp. 140-146. https://www.researchgate.net/profile/Piet-Kommers-2/publication/323278214_ICT_WBC_CSC_2015/links/5a8ba666458515b8af965b89/ICT-WBC-CSC-2015.pdf#page=161
- Jung, Jason J. 2017. "Computational collective intelligence with big data: Challenges and opportunities." *Future Generation Computer Systems* 66: 87-88. https://doi.org/10.1016/j.future.2016.08.021

- Karmaker, Ashish Kumar, S. M. Rezwanul Islam, Md. Kamruzzaman, Md. Mamun Ur Rashid, Md. Omer Faruque, and Md Alamgir Hossain. 2023. "Smart City Transformation: an analysis of Dhaka and its challenges and opportunities." *Smart Cities* 6(2): 1087-1108. https://doi.org/10.3390/smartcities6020052
- Latour, B. 2005. *Reassembling the Social*. Oxford University Press.
- Lorenz, Jan, Heiko Rauhut, Frank Schweitzer, and Dirk Helbing. 2011. "How social influence can undermine the wisdom of crowd effect." *Proceedings of the national academy of sciences* 108(22): 9020-9025. https://doi.org/10.1073/pnas.1008636108
- Lu, Hsi-Peng, Chiao-Shan Chen, and Hueiju Yu. 2019. "Technology roadmap for building a smart city: An exploring study on methodology." *Future Generation Computer Systems* 97: 727-742. https://doi.org/10.1016/j.future.2019.03.014
- Marshall, Stephen, David Farndon, Andrew Hudson-Smith, Athanasios Kourniotis, and Nikos Karadimitriou. 2024. "Urban design and planning participation in the digital age: Lessons from an experimental online platform." *Smart Cities* 7(1): 615-632. https://doi.org/10.3390/smartcities7010025
- Mellouli, S., L. F. Luna-Reyes, J. Zhang. 2014. "Smart government, citizen participation and open data." *Inf. Polity* 19: 1-4. https://www.academia.edu/download/91221903/download.pdf
- Ni, Minqing. 2022. "Digital Participation for Inclusive Growth: A Case Study of Singapore's Collaborative Digital Governance Model." In *Design for Vulnerable Communities*, pp. 323-337. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-96866-3_17
- Nunes, Simão A. S., Fernando A. F. Ferreira, Kannan Govindan, and Leandro F. Pereira. 2021. "Cities go smart! ": A system dynamics-based approach to smart city conceptualization." *Journal of Cleaner Production* 313: 127683. https://doi.org/10.1016/j.jclepro.2021.127683
- Peeters, Marieke M. M., Jurriaan van Diggelen, Karel Van Den Bosch, Adelbert Bronkhorst, Mark A. Neerincx, Jan Maarten Schraagen, and Stephan Raaijmakers. 2021. "Hybrid collective intelligence in a human–AI society." *AI & society* 36: 217-238. https://doi.org/10.1007/s00146-020-01005-y
- Reia, Sandro M., André C. Amado, and José F. Fontanari. 2019. "Agent-based models of collective intelligence." *Physics of life reviews* 31: 320-331.
- Rong, Helena H., Yang Juncheng, and William Jingwei Qian. 2020. "Enabling Participatory Actions in Community Design and Management: A Collective Intelligent Digital Platform in Ang Sila, Thailand." *Landscape Architecture Frontiers* 8(4): 126+. https://link.gale.com/apps/doc/A657581195/AONE?u=anon~c12df06b&sid=googleScholar&xid=4dae0e54.
- Sahab, Sofia, Jawad Haqbeen, and Takayuki Ito. 2024. "Conversational AI as a Facilitator Improves Participant Engagement and Problem-Solving in Online Discussion: Sharing Evidence from Five Cities in Afghanistan." *IEICE TRANSACTIONS on Information and Systems* 107(4): 434-442. https://www.jstage.jst.go.jp/article/transinf/E107.D/4/E107.D_2023IHP0014/_pdf
- Singh, Vivek Kumar, and Ashok K. Gupta. 2009. "From artificial to collective intelligence: Perspectives and implications." In *2009 5th International Symposium on Applied Computational Intelligence and Informatics*, pp. 545-550. https://doi.org/10.1109/SACI.2009.5136308
- Singh, Vivek Kumar, Divya Gautam, Rishi Raj Singh, and Ashok K. Gupta. 2009. "Agent-based computational modeling of emergent collective intelligence." In *Computational Collective Intelligence. Semantic Web, Social Networks and Multiagent Systems: First International Conference*, ICCCI 2009. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-04441-0_21
- Sivarajah, U., Z. Irani, V. Weerakkody. 2015. "Evaluating the use and impact of Web 2.0 technologies in local government." *Gov. Inf.* Q. 32: 473-487. https://doi.org/10.1016/j.giq.2015.06.004
- Stenvall, Jari, Ilpo Laitinen, Ruth Yeoman, Marc Thompson, Milena Mueller Santos, Jari Stenvall, Ilpo Laitinen, Ruth Yeoman, Marc Thompson, and Milena Mueller Santos. 2022. "Digitalisation and Public Values." *Public Values for Cities and City Policy*: 177-201. https://doi.org/10.1007/978-3-030-80799-3_9
- Suran, Shweta, Vishwajeet Pattanaik, and Dirk Draheim. 2020. "Frameworks for collective intelligence: A systematic literature review." *ACM Computing Surveys (CSUR)* 53(1): 1-36. https://doi.org/10.1145/3368986
- Townsend, A. M. 2013. Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia. W. W. New York: Norton and Company. https://www.dvrpc.org/plan/futuresgroup/pdf/futures_group_presentations_7_19_18.pdf
- Waddington, David. 2008. "The madness of the mob? Explaining the 'irrationality'and destructiveness of crowd violence." *Sociology Compass* 2(2): 675-687. https://doi.org/10.1111/j.1751-9020.2007.00079.x
- Watson, Richard, and Michael Levin. 2023. "The collective intelligence of evolution and development." *Collective Intelligence* 2(2): 26339137231168355. https://doi.org/10.1177/26339137231168355
- Weibin, Peng, Fang Liuqing, and Lin Xiaojing. 2022. "Digital governance for smart city and future community building: From concept to application." In *Smart Cities for Sustainable Development*, 41-67. Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-16-7410-5_4

- Weld, Daniel S., Christopher H. Lin, and Jonathan Bragg. 2015. "Artificial intelligence and collective intelligence." *Handbook of collective intelligence*: 89-114. https://homes.cs.washington.edu/~weld/papers/ci-chapter2014.pdf
- Wolf, Max, Jens Krause, Patricia A. Carney, Andy Bogart, and Ralf HJM Kurvers. 2015. "Collective intelligence meets medical decision-making: the collective outperforms the best radiologist." *PloS one* 10(8): e0134269. https://doi.org/10.1371/journal.pone.0134269
- Woolley, Anita Williams, Ishani Aggarwal, and Thomas W. Malone. 2015. "Collective intelligence and group performance." *Current Directions in Psychological Science* 24(6): 420-424. https://doi.org/10.1177/0963721415599543
- Zhang, Yong, Hao Wang, and Xuede Wang. 2023. "Research on the improvement of transportation efficiency of smart city by traffic visualization based on pattern recognition." *Neural Computing and Applications* 35(3): 2211-2224. https://doi.org/10.1007/s00521-022-07222-4
- Zhu, Huiying, Liyin Shen, and Yitian Ren. 2022. "How can smart city shape a happier life? The mechanism for developing a Happiness Driven Smart City." *Sustainable cities and society* 80: 103791. https://doi.org/10.1016/j.scs.2022.103791

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