Situating Media Infrastructure:

Understand the Affordance of Public Space Characteristics in Influencing Public Interaction with Media Infrastructure

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Media Architecture scholars have outlined the importance of considering the urban design perspective in informing the deployment of digital media in public space. In this paper, we build on their work and provide a detailed account based on the knowledge from urban design theories coupled with literature from Human-computer Interaction research. Specifically, we address the role of location- its physical and spatial characteristics and situated human activities- in influencing public interaction with media infrastructure. We aim to provide a framework for understanding the complex relationship between media infrastructure and urban public spaces, and explore the impact of locations on how people interact with media infrastructure by: 1) developing an initial framework of public space characteristics based on urban design knowledge, 2) conducting a case study of InLinkUK network with detailed field study and analysis on 3 selected sites in London. We discuss the initial outcome of the case study analysis and report on the next stages of this research. This paper addresses the question: how media architecture can contribute to a sense of place and provide a detailed account based on a case study in London. It attempts to broaden and extend existing calls by media architecture scholars to consider urban design knowledge in informing the deployment of digital media infrastructure in public spaces.

CCS CONCEPTS • **Human-centered Computing • Human-computer interaction (HCI) • HCI design and evaluation methods**

Additional Keywords and Phrases: Media infrastructure, public space characteristics, physical and spatial characteristics, human activities, urban design knowledge

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1 INTRODUCTION

Originated from media studies, the notion of "media infrastructure" represents "a material resource network that is arranged to distribute audio-visual content in urban public spaces" (Parks, 2015). Accompanied by the technological evolution, the embodiment of media infrastructure has expanded from radio and outdoor billboards to urban screens and GPS satellites. Within this domain, since the fall in the cost of display technology, the digital screen has become a prevalent form of media infrastructure. Along with the increasing integration of network technology, it constituted an essential part of global cityscape.

In the course of development, urban screens have received a lot of attention on its relationship with surrounding environment and the public. Initially, in the late 19th Century, with the proliferation of billboards and screens in the city, the advertisers were urged to consider where to seat the displays in order to strengthen the power of message conveyed to surrounding people (David, 1997). The constant visual influence of displays on the cityscape eventually led to the planning control over the deployment of these mediums. Since the 2000s, the introduction of interaction technology to the outdoor display industry transformed the way the urban screens communicate with the public, and the role of human has changed from "message receiver" to "(potential) participant". Within this context, it requested a reconsideration of the relationship between the screens and the environment regarding public engagement. Among current planning regulations, however, the deployment of interactive screens is still assessed using the same criterion as non-interactive displays (Fatah gen. Schieck et al., 2009). The local authorities lay a major emphasis on the influence which the screens may bring to the surrounding environment, while the affordance of the environment on accommodating the public interaction with the screens has been neglected.

McCullough is one of the early scholars who highlighted the role of situation in designing for human interaction with digital interfaces and displays, from mobile devices to media facades (McCullough, 2004). In his book, he appealed for the cooperation between architecture and HCI research to pre-set user scenarios for a better experience. Subsequently, extensive HCI research attempted to define the relationship between the interaction and its situated environment. A range of public space characteristics that affect interactions with urban screens in the real-world setting have been studied, such as the visual order of surrounding objects (Huang et al., 2008), design of architectural features (Dalton et al., 2015), the salience of display and positional order of surrounding objects in space (S. Dalton et al., 2015), and social activities (Akpan, et al., 2013). However, seen from the perspective of urban design, most research focuses solely on specific characteristics and neglected the influence of other possible factors in the space. We suggest, to a certain extent, this leads to an incomplete evaluation of how environment impacts public interactions, and further limits its contribution to support the decision-making on the placement of media infrastructure.

In this research, we ask the question: To what extent do public space characteristics support the interactions with media infrastructure? Drawing from existing literature, this research aims to categorize and examine possible public space characteristics, including physical characteristics that embody the properties of physical segments in space (e.g. function, size of segments); spatial characteristics that express the layout and structure of space (e.g. enclosure, accessibility); and human activities that involve pedestrian behaviors in situ (e.g. walking, standing). This research conducts a case study of an emergent media infrastructure project- InLinkUK network in London. We will examine the influences of these three categories of characteristics on public interactions and explore the way they reinforce diverse interactions. "Public interaction" in this research will be investigated in the following aspects: 1) the form of interaction, such as reading screen content or exploring screen function; 2) spatial distribution of interaction, such as where onlookers stay to observe the screen.

In the next section, we first outlined the related work, followed by the development of a framework of public space characteristics identified from architecture and urban design literature. We suggest that these characteristics have strong prospects to support screen-mediated interactions. Through the case study of InLinkUK kiosks on

representative sites in London, we explore how suggested characteristics influence public interactions with kiosks, at the same time refine and validate the framework based on case study results. Our research is based on an interdisciplinary approach combining methods from urban design and HCI, with qualitative methods drawn from ethnography. To establish an inclusive framework of characteristics, this research will dissect public spaces from 3 key dimensions: physical, spatial characteristics, and human activities. Physical characteristics embody the properties of physical segments in space (e.g. function, assize of segments); spatial characteristics express the construction of space (e.g. enclosure, accessibility); and human activities focus on pedestrian behaviors in situ (e.g. walking to work, sitting on the bench). The case study contains the investigation of InLinkUK kiosks on three representative sites followed by an in-depth field study on one of them. The case study will uncover whether and how these characteristics support public interaction with kiosk screens. Following the analysis of field study results, we conclude by discussing the application of framework in future research, and the implications for the future deployment of media infrastructure.

2 BACKGROUND AND RELATED WORKS

Research in the domains of pervasive computing, digital cities, and the emergent development of smart cities has been evolving rapidly. Oja et al. outlined that unlike research in Urban Transformation, which is relatively mature, research in Smart Cities, and related areas is relatively new (Oja et al., 2016). Here, pervasive computing is defined by the fourth wave of computing in which many devices serve the customers in a personalized way on a global network; the notion of digital cities is framed through Information Communication Technologies (ICT) driven infrastructure and services; and the view of smart cities, which is, according to Oja et al., led by urban innovations that aim to harness the physical infrastructures, knowledge resources, ICT and social infrastructure for economic regeneration, social cohesion, and better city administration. In this respect, scholars emphasized the importance of 1) considering urban environments as an integral system that mediate both, digital systems and the built environment and 2) addressing digital systems as a key facet of urban design with its spatial, social and temporal relationships (Aurigi, 2013; Fatah gen Schieck et al., 2006). Aurigi, for instance, has suggested that in the example of UBI hot spot in Oulu, that more could be done to improve the role urban ICT plays in Oulu's places by relating to their specific characteristics as places of transactions (Ojala et al., 2010). Fatah gen Schieck et al. outlined that the integration demands an ensemble of the disciplines of urban design, computer science, human factors and interaction design. The key to this interdisciplinary integration is the concept of space, which requires a better understanding of the properties of the built environment in which people move and interact and the interaction spaces, e.g. the spaces within which the digital devices and artifacts are usable, and the information they discover and uses, which may influence their movement and behaviors. Here, the notion of place and its affordances, along with the affordances of the digital devices and the activities they support seem essential to the research (Fatah gen Schieck et al., 2006; O'Neil et al., 2006). In this paper, we build on their work and go a step further by emphasizing the importance of urban design theories and carrying out an in-depth analysis of the built environment, with its physical, spatial and social dimensions. Coupled with observational methods from ethnography and HCI, this study will capture and analyze specifically how the public interact with digital devices and react to other participants' interactions. Our case study focuses on InLinkUK kiosks with a network of public screens in the city of London.

In the following section, we motivate our work by addressing the various aspects we outlined above in detail and explain how we build upon relevant trends and developments in this research area.

2.1 Public Interaction with Screen Display

With the growing integration of interactive features to urban screens, Human-computer Interaction has become a main driven force in studying how people engage with the screens. Brignull and Rogers were early scholars that defined three typical pedestrian activities surrounding an interactive display: peripheral awareness activities refer to activities conducted by people who are aware of the display presence but know little about it, such as drinking and socializing; focal awareness activities represent activities associated with display, such as discourse about the content; and direct interaction activities that people participate in the displays directly (Brignull & Rogers, 2003). Reeves categorized people who conduct these activities into different roles- bystanders, audience and participants. He plotted the sequences of interaction which most pedestrians follow: bystander- audience- participant (Reeves, 2005). The model was later developed by Memarovic et al. based on Carr et al.'s depiction of human psychological needs in public spaces. Besides passive engagement (e.g. observation), active engagement (e.g. discuss display) and challenge (e.g. direct interaction), they defined a new type of interaction- "discovery" that people learn or prepare for interaction before participating in the display (Memarovic et al., 2010). In addition, they explored multiple interaction trajectories in which people transit between different roles. To understand how people get motivated to conduct direct interaction, Michelis and Muller conducted a case study of existing screen displays and revealed the existence of thresholds that pedestrians need to overcome before they could proceed to the next stage (Michelis and Muller, 2011). Concluding from preceding works, Wouters et al. proposed a comprehensive model of interaction process which depicts a variety of trajectories (Wouters et al., 2015). In this model, they looked into "honeypot effect", namely how people behave in space through observing or socializing with others nearby and discussed its effects on encouraging participation in the display.

2.2 The Influence of Public Space Characteristics on Public Interaction

Extensive HCI research has investigated how the surrounding environment affects the form and distribution of interactions with screen displays. Due to the complex nature of outdoor settings, most research focused on specific environmental factors. Some studies affirmed the significance of surrounding physical features in facilitating passive interaction with displays. Huang et al. discovered that the objects in the vicinity of the screen help to fixate pedestrian attention to the screen if they are posited in a certain order, for instance, close enough to be read in a line or a group (Huang et al., 2008). Dalton et al. further added that adjacent architectural features which follow fixation patterns (e.g. vertical pillar, ceilings) apply similar effects on surrounding people (Dalton et al., 2015). They also discovered that the spatial properties, such as the shape and visual stability of space could affect the number of display observers (Dalton et al., 2010). Apart from the physical and spatial settings of public space, many studies also explored the influence of social context, particularly the interplay between different activities and roles on user interactions. Valkanova et al. looked into the occasion of "social embarrassment" that many people expressed their awkwardness of performing in front of the public, which was largely triggered by the fear of being observed or inputting inappropriate data during interaction (Valkanova et al., 2013). Wouters et al. investigated in "honeypot effect" and observed how pedestrians get involved in the display through observing and discussing with other participants nearby (Wouters et al., 2016). Moreover, the social proximity or person-to-person distance seem to play a profound role in influencing the form of interactions with other people that are mediated through digital platforms (Fatah gen Schieck et al, 2008), and this in turn seems to influence people's perception of their personal space (Hall, 1966).

Fischer and Hornecker depicted where the screen-mediated interactions occur and explored how spatial layout influences the size and arrangement of interaction zones (Fisher & Hornecker, 2012). They found out that

protective features, such as walls, fences, and trees help to delimit a preferable activity space for onlookers. They also noted that, by setting public displays next to busy pathways, it would encourage more pedestrians to observe and engage with the display (Fischer & Hornecker, 2012). Later, in "Screen-in-the-wild" Project, based on Fischer and Hornecker's spatial framework, Behrens et al. compared the arrangement of public interactions in different outdoor settings and explored how interaction zones changed under different social conditions (Behrens et al., 2013).

While these results may seem conclusive, they do not provide a clear insight into how surrounding environment affects public interactions. Most research lacked an in-depth investigation on the affordance of public spaces with all possible influence factors. At the same time, due to the challenging nature of deploying screen prototypes in outdoor environment, many experiments were conducted on limited sites. These insufficiencies eventually led to an incomplete evaluation of the holistic parameters towards its effects on interactions. Within this context, it is necessary to clarify the possible environmental factors and examine them through outdoor studies. The following section will explain how this research extracts and establishes the framework of public space characteristics based on existing architecture and urban theories.

3 DISSECTING PUBLIC SPACE CHARACTERISTICS

The concept of affordance was initially introduced by Gibson (Gibson, 1979), which suggested that the affordance of environment refers to the possibilities for actions enabled through the environment. In the Theory of Affordance, Gibson analysed various aspects of an environment, such as surfaces, objects and other living creatures, and outlined what possibility of actions they represent and how they imply the affordances to the people through optic sensation. His theory later inspired a number of urban design research to dig into the connection between urban public spaces and user experience, such as Carr's model of human psychological needs for public spaces.

In Gibson's theory, apart from human and animals, he resolved the natural environment into three aspects: the surface (interface between any two objects), substance (rigid matter inside the objects) and medium (air or water enclosed by the surfaces of objects which allow people and animals move in between) (Gibson, 1979). In the context of built environment, the existing body of research focused on three aspects of outdoor spaces: the properties of physical substances which frame the space, the layout and configuration of the space, and human that use the space. These aspects orchestrate the physical, spatial and social dimensions of public space characteristics and together decide the core qualities of public spaces (Rapoport, 1977; Carr et al., 2002). The following section will look into these categories of characteristics and explain how they support user experience through enhancing the core qualities.

Drawing on the preceding urban design theories, Project for Public Space's (PPS) pioneering work concluded four core qualities of a public space that attract people to visit and stay, including accessibility and linkage, use and activities, comfort and image, and sociability (PPS, 2000). To be more specific, people prefer to conduct activities in spaces that offer- convenient access and close linkage to its neighborhood; high affordance to cater diverse activities and social interactions; and a positive mental image with a sense of comfort. Within this context, we suggest that public space characteristics that strengthen the core qualities have strong prospects to facilitate the interaction with screen displays as well.

3.1 Physical Characteristics of Public Space

A number of studies have evidenced the capability of physical characteristics in creating a comfortable urban environment and accommodating diverse activities and social interactions. In the Theory of Affordance, Gibson

stressed that the configuration of physical segments, for instance, its shape and material, is key to implying the possibility of actions in the environment. Lynch further explained that, from the perspective of an individual object, these properties present what the object is and how to use it, which will be concluded as the function in this research; at the same time, the overall layout of these objects help visitors to orchestrate a mental image of the space and decide how to use the space (Lynch, 1960). Based on Lynch's study, this research will focus on these two aspects of physical characteristics along with their relation to user experience.

Function of Physical Segments: Existing studies categorize the physical segments in public spaces in three groups according to their functions: 1) surrounding architecture; 2) infrastructure, e.g. streetlights, utility boxes; and 3) landscape, e.g. plantings, street furniture. Although it is argued that all segments are pertinent to the user experience, there are certain elements that play a more significant role than others. In terms of surrounding architecture, some studies underpinned the contribution of the lower floor uses, entrances and the design of facades in arranging human activities. They agree that having a mix use of commercial, a prominent entrance, and facades that provide shaded edges would encourage a longer stay in space (Gehl, 1996; Carmona, 2008). Department for the Environment, Transport and the Regions (DETR) and Campaign for Architecture and Built Environment (CABE) noted that the ability to sustain diverse outdoor activities is also enhanced by versatile infrastructure and landscape, such as street facilities (e.g. bus stop), street furniture (e.g. outdoor bench) and green spaces (DETR & CABE, 2000). Burton & Mitchell shared a similar view in the ranking of seventeen physical features that support street space use. In their analysis, they added the smooth and uncluttered footway, clear signage and landmarks as necessary factors for the navigation in space (Burton & Mitchell, 2006).

In this respect, when it comes to interacting with media infrastructure in the urban setting, we also look into the "affordance" of screen itself. The concept was extended on the original notion of affordance and introduced by Norman to HCI to address the ways in which physical artifacts suggest how they should be used (Norman, 1999). . In this research, the "affordance" of screen is highly relevant to how people use and interact with it.

Space Image: Many urban theories noted that people appraise the environment through perceiving the space image orchestrated by physical segments in situ, and the key factors to compose the image are the size, shape and position of these segments. Regarding its relationship with user experience, Lynch is one of the early scholars who systemically discussed how the space image shapes human behaviors. Initially, Lynch prioritized the wayfinding over other psychological needs in public space, and considered the high legibility, specifically that the components are clearly ordered in the space as the vital quality of the image (Lynch,1960). Later, as he revalued the appreciation and exploration of space as the same important as navigation, it raised the awareness that public spaces should provide a sense of mystery and surprise (Lynch, 1981). Building on Lynch's work, Kaplan & Kaplan concluded that, a clear and identical place image helps to create the immediate appreciation of the environment; however, in the longer term, the illegible part of the image is key to retain user's interest and activities in space, which is manifested through the order of sequences of physical components (Kaplan & Kaplan, 1982).

3.2 Spatial Characteristics of Public Space

Spatial characteristics support the space to be visited and used mainly via securing its sense of safety and comfort and enriching the linkage with the neighborhood. These benefits are manifested from three aspects- degree of enclosure which refers to the human sense of enclosure in space, accessibility that expresses the ease of reaching certain locations from other points of space, and visibility of space that represents how clear a location can see or be seen within a larger environment. The following section will explain their relationship with individual public space experience in detail.

Degree of Enclosure: Sitte asserted that a strong sense of enclosure is the primary spatial factor to lead a comfortable stay in urban spaces (Sitte, 1889). In the study of open spaces in New York, Whyte verified that the key to create a sense of enclosure is the size and edges of space. Instead of large open spaces, pedestrians prefer to use relatively small sub-spaces that are divided and enclosed by clear spatial boundaries (Whyte, 1980). Whyte defined rich types of edges that help establish a sense of enclosure, such as walls, fences and grass verge. According to Zucker, the space-defining elements, besides the floors and vertical structures, also involve the visible sphere of sky overhead- the less sky view could be seen from space, the more enclosure it will create (Zucker, 1959). Another approach to stimulate this sense is to adjust the relationship between the size of space and surrounding architecture. In terms of street space, as the space is identified by two sides of surrounding buildings, the degree of enclosure is largely decided by the ratio between surrounding building's height and street width (or distance between two buildings). Through an empirical study of alternative streetscapes in global cities, Ashihara defined the ratio that, a strong sense of the enclosure occurs when the ratio is 1:1, and descends to a more comfortable level between 1:2 to 1:2.5 if the visual field of the street is more dominant than sky view (Ashihara, 1983).

Accessibility of Space: Physical accessibility and visibility as key characteristics in public space design, have been studied extensively in relevant disciplines. For instance, the established architectural theories have provided an innovative insight to measure and visualize the spatial relationships (Hillier & Hanson, 1984). The commonly used variables to measure accessibility are Connectivity and Integration. A consistent relationship has been discovered between the spatial integration of the space and the observed movement flow within it, which in turn seem to impact people's experience in public space (Hillier et al., 1993). Later, several studies indicated a positive correlation between Connectivity and pedestrian activities (Wineman et al., 2012). Concerning the psychological needs of public space, a few research suggested that high Connectivity and Integration may be closely associated with user perception of a space (Sarkar et al., 2013; Knöll et al., 2015).

Visibility of Space: In terms of the visibility of space, existing research asserted that, from the perspective of a pedestrian, the size, shape and stability of visible area are important to secure visitors' sense of safety and comfort (Appleton, 1975), and further influence their decisions in navigation and exploration in space (Benedikt, 1979). The size of visible area defines the amount of unobstructed area people could see from a location, while the shape and stability of the visible area describe the complexity of the visual environment. From the perspective of a location, the intervisibility, namely its exposure in a larger environment is decisive in seducing more visits from its neighborhood (Hillier & Hanson, 1984) (Table 1).

Media Architecture scholars have addressed the role of spatial configuration in informing the decision on screen placement in urban public spaces. Specifically, Fatah gen. Schieck et al. attempted to offer an understanding of how the spatial and visual properties of the layout within the study area correspond to the social usability, co-presence and movement activity (Fatah gen. Schieck et al., 2013). They then applied the analysis results to the site selection process for two touch-based screens in the real urban setting. The outcome indicated that the properties of the spatial configuration may play an important role in influencing the interaction with screens. However, they highlighted, in particular, the dynamic and interconnected nature of this mediation is defined together through the spatial layout, people, type of social activities, and time of the day (Fatah gen. Schieck et al., 2013).

3.3 Human activities

In analyzing the influence of social context on individual behaviors in public spaces, existing research stressed the importance of identifying co-present users, such as gender, age, cultural and economic background, along with their activities. However, in this research, since the case study sites are mainly street spaces, which contain a more

dynamic social environment than other types of public space, e.g. community garden, this research will mainly focus on pedestrian activities and analyze its interplay with screen-mediated interactions.

Existing literature contributes to categorizing human activities in public space from different perspectives, such as motion status (Whyte, 1980), psychological needs (Carr et al., 1992), travel purpose (Franck & Stevens, 2007), etc. In regard to the interplay with other co-present behaviors in space, Gehl classified human activities based on the demand of the surrounding environment and people, including 1) necessary activities- activities take place regardless of the quality of surrounding environment, like walking to work, waiting for a bus; 2) optional activities- activities would be conducted if the time and place is conducive, e.g. sitting on a bench and window shopping; 3) social activities- activates largely depending on the presence of other people in space, e.g. casual conversations, communal activities (Gehl, 1996). In other words, people who tend to conduct optional and social activities, such as sitting on a bench or having a conversation with surrounding people, allocate more attention to surrounding environment, which are more likely to engage with objects and other people in situ; while the necessary activities that require less attention of environment are less likely to involve the users in the interaction with surroundings. In addition, Gehl noted that, having enough proportion of optional and social activities in space helps to create a lively environment that attracts visitors to stay and use (Gehl, 1996).

Drawing from existing theories of urban design, as the first step of the research, we established a framework of public space characteristics that generally facilitate people's experience in public space. Seeing their impacts on human activities, we suggest that these characteristics can be considered with high odds to support human interaction with screen displays (Table 1). The framework and its parameters will then be tested through our case study of InlinkUK screens network in London, and a comparison will be carried out between the results of selected nodes.

Table 1: The framework of public space characteristics with high odds to support screen-mediated interactions

Physical Characteristics	**Spatial Characteristics**	**Social Characteristic (Human Activity)**
Function of Physical Segments • Function of lower floors in surrounding buildings • Function of infrastructure • Provision of shaded area, street furniture, sitting surface, plantings and other attractive features	**Degree of Enclosure** • Size of space (Division of space) • Spatial boundaries • Distance between adjacent buildings/ Building height (D/H)	**Necessary Activities** • Walking to work; • Waiting for bus; • Shopping for groceries, etc.
Place Image • Size, • Form, • Layout of physical segments	**Accessibility of Public Space** • Connectivity • Space integration	**Optional activities** • Window shopping; • Sitting on the bench; • Looking at phone, etc.
	Visibility of Space • Visibility field • Shape of visibility field • Visual stability • Intervisibility	**Social activities** • Talking with others; • Communal activities, etc.

4 CASE STUDIES OF INLINKUK KIOSKS IN LONDON

To identify the influence of locations on public interaction with media infrastructure, we carried out a comparative study of an emergent media infrastructure network- InLinkUK kiosks, within selected nodes in London. This analysis covers the various factors which were identified in Table 1, including diverse physical and spatial characteristics and human activities. Apart from these main factors, the display content (on the side screens) which has been proved important for user interactions by preceding research, will also be involved and analyzed in this paper.

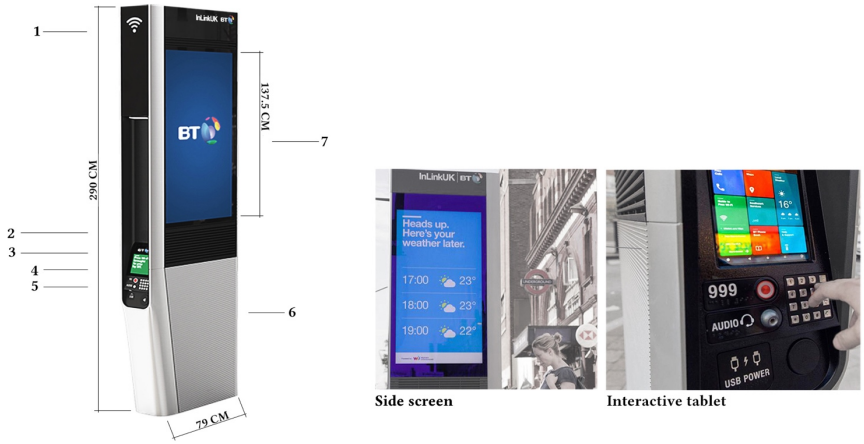

Fig 1. The figuration of InLinkUK kiosks. An InLinkUK kiosk provides the following free services: 1) Wi-Fi, 2) phone call and phonebook, 3) map navigation, 4) Council services, 5) charity helplines, 6) weather report, 7) emergency call, 8) USB charging ports and 9) local information display.

InLinkUK is a nationwide new communication infrastructure carried out by British Telecom to replace over 1,000 outdated payphones in major cities across the UK. Each InLinkUK kiosk is equipped with two display screens and one interactive tablet. The display screens mainly project services promotion, advertisement, local news and public notices, while the interactive tablet provides a range of free services, including phone call, phone book, map navigation, local Council services, etc (Fig 1). By October 6th 2020, there have been over 200 kiosks installed in London (Fig 2) (InLinkUK, 2019).

The case study involves two stages of field study. Initially, three nodes were selected from existing sites to conduct field observations, including Shoreditch High Street (Site1), Southwark Station (Site2) and Elephant & Castle Station (Site3). These sites are distributed in different parts of London (North East, Central and South East), and are distinguished from physical, spatial features and pedestrian activity patterns (e.g. high visibility field vs. low visibility field). The aim of this field study was to discover the influences of different characteristics on public interactions through the comparison between the results of selected sites. According to the results of first stage investigation, Shoreditch High Street (Site1) was selected for a further field study with the emphasis on individual experiences and the distribution of these interactions. It involved onsite observations along with street surveys, which aimed to uncover participants' opinions towards the InLinkUK kiosks, including passers-by, onlookers, direct users and local workers.

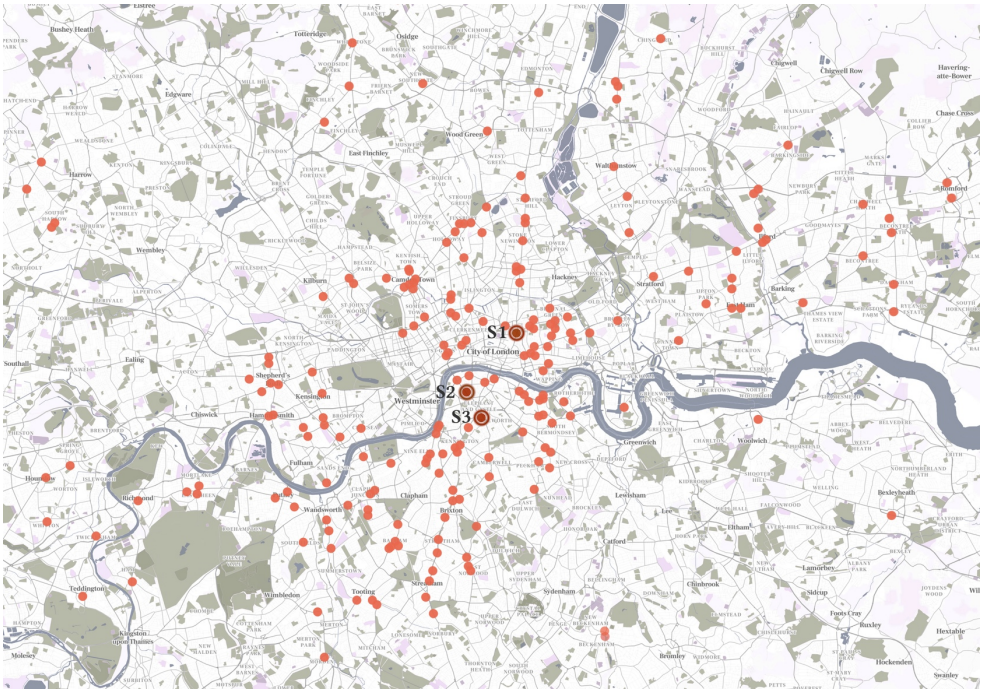

Fig 2. The Distribution of InLinkUK kiosks in London (by October 6th, 2020)

4.1 Field Study of InLinkUK Kiosks on Selected Sites

In the first stage of the field study, the field observation was conducted on each site (Site1, Site2, Site3) for 1 weekday and 1 weekend day in winter 2019. The observation recorded occurred interactions with kiosks. After the analysis of field study results, an in-depth field study was proceeded on Site1 for 4 days in 2019 summer (3 workdays and 1 weekend day), which consisted of onsite observation and street survey with 40 participants on the street. The survey constituted 13 multiple choice and scoring questions in relation to participants' impressions and experience with the kiosk. The detailed field study methods are presented in Table 2.

Table 2. The applied methods in field studies

Field Study	Sites	Length	Timespan	Data Collection Methods	Recorded Data	Data Collection Procedures
First Stage	Site1, Site2, Site3	2 days (1 weekday, 1 weekend day)	2 pm-6 pm of a day	Field observation	time, number, form and length of interactions with kiosk, side screen content	Each hour: field observation (45 mins), counting side screen content (5 mins) and pedestrian flow (5 mins)
Second Stage	Site1	4 days (3 weekdays, 1 weekend day)	10 am-9 pm of a day	Field observation	time, number, form and length of interactions	Each hour: field observation (15 mins), street survey (15 mins) and counting pedestrian flow (15 mins)
				Street survey	services used, impression, and concerns of kiosk	

4.1.1 The Context of Field Study Sites

Based on the framework of public space characteristics in Table 1, we selected three locations for comparative analysis (Table 3). In order to capture more interaction behaviors for analysis, all selected sites are located on busy streets with heavy pedestrian flows. In terms of spatial characteristics, the study calculated the degree of enclosure, accessibility and visibility through empirical observation and mapping.

Shoreditch High Street (Site1)- Site1 is surrounded by versatile commercials that sit on the south, including some restaurants and retails. There are also several street facilities sitting close to the kiosk like cycle racks and streetlights. The clear arrangement of these facilities enabled a large visibility field and high exposure of the kiosk on site. A railway bridge from nearby railway station goes above Site1 and blocks the sky views, which creates a shaded space that attracted many pedestrians to use (Fig 3). Thus, besides walking, other activities such as standing next to the wall and talking on the phone were frequently witnessed on Site1.

.Fig 3. The street view and floor plan of three field study sites: (a) Site1- Shoreditch High Street, (b) Site2- Southwark Station, (c) Site3- Elephant & Castle Station.

Southwark Station (Site2)- Site2 sits in a relatively open environment next to office buildings. There are a few street facilities and sidewalk trees arranged along the curb. Due to the spatial arrangement and weather reason, these components did not create much visual obstruction to the kiosk, which guaranteed the high visual permeability of the space. In contrast to Site1, the facades of surrounding architecture on Site2 are composed in a clear order. With the slight shades coming out from the second floor, the building next to the kiosk provides a small area, which was mostly used as a rest space by the staff.

Elephant & Castle Station (Site3)- Comparing to other sites, Site3 sits in an open area. Similar to Site1, Site3 was surrounded by versatile commercial and street facilities. With rich street furniture and plantings, Site3 has the capability to sustain diverse activities. However, due to the weather reason (winter), we did not capture many other pedestrian activities besides walking by the area, standing and drinking outside the pubs nearby. In addition, seeing from a distance, the spatial arrangement of these tangible components to a certain extent influenced the visual stability and reduced the exposure of the kiosk on site.

Table 3. Initial evaluation of public space characteristics of Site1, Site2 and Site3 (The distinguished features are highlighted in grey)

Characteristics	Site1	Site2	Site3
Physical Characteristics			
Surrounding function	- Diverse lower-floor uses (commercials); - Rich street facilities; - Vines and map totem.	- Simple lower-floor uses; - A few street facilities - A few plantings	- Diverse commercials; - Rich street facilities; - Rich plantings, street furniture and signage
Position of components	- Broken order of facades; - Uncluttered space	- Clear order of facades; - Uncluttered space	- Broken order of facades; - Cluttered space
Spatial Characteristics			
Degree of enclosure	- 2 small sub-spaces; - Clear spatial boundaries (Shaded by railway bridge) - D/H = 1	- 1 open space; - Unclear spatial boundaries (winter) - D/H < 1.5	- 1 large open space; - Unclear spatial boundaries - D/H > 2
Accessibility	- High accessibility	- High accessibility	- High accessibility
Visibility	- Large visibility field - Low visual stability	- Large visibility field; - High visual stability	- Large visibility field; - Low visual stability
Human Activities (Frequency)			
Necessary activities	- Frequent (e.g. walking, waiting for traffic)	- Frequent (e.g. walking)	- Frequent (e.g. walking)
Optional activities	- Frequent (e.g. eating out, waiting);	- Rare (e.g. phone calls, smoking);	- Occasional (e.g. phone calls, smoking);
Social activities	- Occasional (e.g. talking)		- Rare (e.g. talking outside pub)

5 DISCUSSION

5.1 The Overview of Field Study Results

Through the field study on three sites, the most frequent interaction captured is passive interaction (e.g. passers-by observe the kiosks and user interactions) (Fig 4). In respect to direct interaction, the time the users spent on the tablets varied from minutes to half an hour. However, most direct interactions were ended within 3 mins. The frequently used services are the phone call service, Wi-Fi, city map, and charging ports. Comparing the results of winter field study, Site1 demonstrated higher numbers of each type of interaction. Site2 recorded more direct interactions than Site3, but similar in the number of passive interactions. Besides direct and passive interactions, the field studies also captured a few interactions that are irrelevant to kiosk services, such as using the kiosk as

cycle racks to stop bikes, putting rubbish next to or attaching flyers on the kiosk. Comparing with winter field study on Site1, the result of summer study presented a similar pattern of recorded interactions.

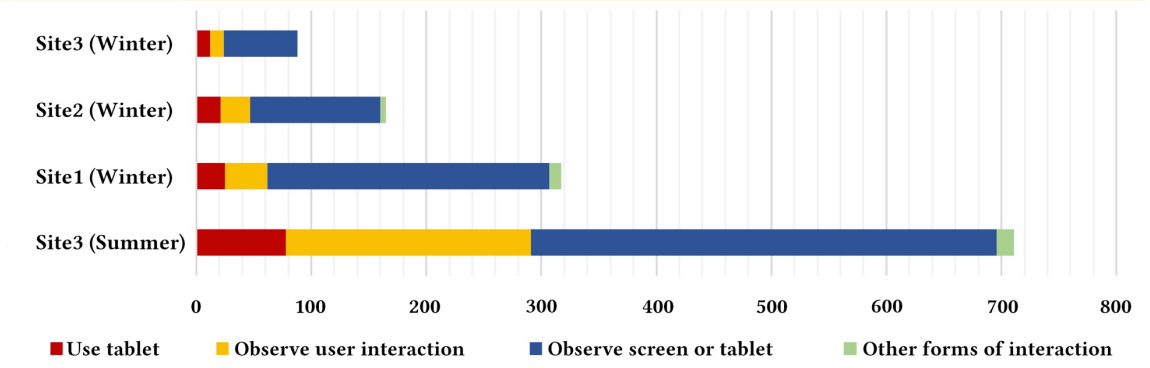

Fig 4. The recorded interactions on Site1 & Site2 & Site3

Comparing the recorded interactions and location settings among three sites, there are several public space characteristics considered to facilitate interaction patterns, as outlined in the following sections:

5.2 Influence of Physical characteristics

5.2.1 Position of kiosks in space

One distinct behavior among kiosk users is that they were more cautious of the immediate environment - they kept looking around as they interacted with the kiosk. To a large extent, the main incentive for this behavior is the position of kiosks in space. As all kiosks sit at the curb facing the pedestrian pathway, during the interaction, users were standing with their back to the passers-by. This spatial arrangement exposed the users to the chances of being observed or the risk of danger from behind, which largely evoked their concerns for privacy and safety. Thus, during the interaction, they need to keep looking around in order to gain a control of surrounding situation. The behavior can be explained through the 'prospect-refuge' theory, which is applied to environmental preferences in architecture and urban design. The theory was introduced by the geographer, Appleton indicating universal preferences for certain landscapes, where people feel safe in occupying environments that offer both views and a sense of enclosure (Appleton, 1975).

5.3 Influence of spatial characteristics

5.3.1 Narrow pathway versus wide pathway

Fischer and Hornecker suggested that, screen displays should be deployed near the pedestrian flows to enhance the capability of attracting pedestrians to observe and engage with the display (Fischer & Hornecker, 2012). In the case of Site1, the kiosk sits on the narrow pavement where the distance between passers-by and the kiosk users is significantly reduced. According to the field study results, this aspect did encourage more observation of user interaction, however, it also enacted certain negative interplay in between. Specifically, the narrow space caused a big overlap between the interaction zone and movement space, which resulted in that interactions could be easily noticed by passers-by. Combined with fact that the kiosk users had to turn their back to the pedestrians during the interaction, it intensified the users' concerns of being observed, which their interactions could be easily interrupted by surrounding passers-by (Fig 5). This was confirmed by the further street survey outcome carried out on Site1.

Accordingly, quite a few tablet users, especially people who used the phone call service, expressed their feelings of discomfort when using the tablet in front of the public. This suggested that 'honeypot effect' is not desired in all situations and seems to depend on the type of services offered at the media infrastructure- for instance, in the case of phone call, since it is private, carrying out this activity in this type of narrow public space could easily create tension and raise a question about the design of the kiosk (in terms of the type of services on offer and its placement), which doesn't seem to afford compatibility.

Fig 5. A quick encounter between users and pedestrians- as Observer2 moved towards the kiosk, he was attracted by the interaction at the kiosk and stared at the user. The user immediately noticed that he was being observed and stared back at Observer2, who quickly turned his head back and walked away. This encounter further triggered Pedestrians3&4 to observe user interaction (as Observer3&4).

5.3.2 Shaded space versus open space

On Site1, the kiosk sits with the side tablet facing the street corner. Enclosed by walls and shed from the railway bridge above, this space was widely used by pedestrians and local workers (Fig 3- (a)). When people move in this space, their views are vertically limited to the ground floor scenes by the bridge. As the only illuminated and flashing object on site, InLinkUK kiosk creates a strong visual stimulus in a relatively dark environment that helps to attract pedestrian attention. In contrast, the openness on Site2 and Site3 provides rich visual stimuli from both horizontal and vertical dimensions, which makes it difficult for pedestrians to notice the presence of the kiosks (Fig 3- (b)(c)).

5.3.3 Low visual stability versus high visual stability

Dalton et al. noted that low visual stability in indoor space helps pedestrians to notice the existence of the display (Dalton et al., 2013). This field study suggested that this effect is similar in outdoor settings. In this study, all sites offer a wide and stable viewshed for pedestrians, except the south side of Site1. Due to the tree branches and leaves and the wall next to the pathway, the viewshed from south of Site1, especially the visibility of kiosk is largely occluded (Fig 6-(left)). However, based on the field study results, the south side was the most popular spot for observing the kiosk. When pedestrians passed through the branches, their viewshed immediately broadened to the full appearance of kiosk and enclosed corner. As pedestrians relocated their attention, the tall and flashing kiosk standing in front of pedestrians was a key item to be noticed.

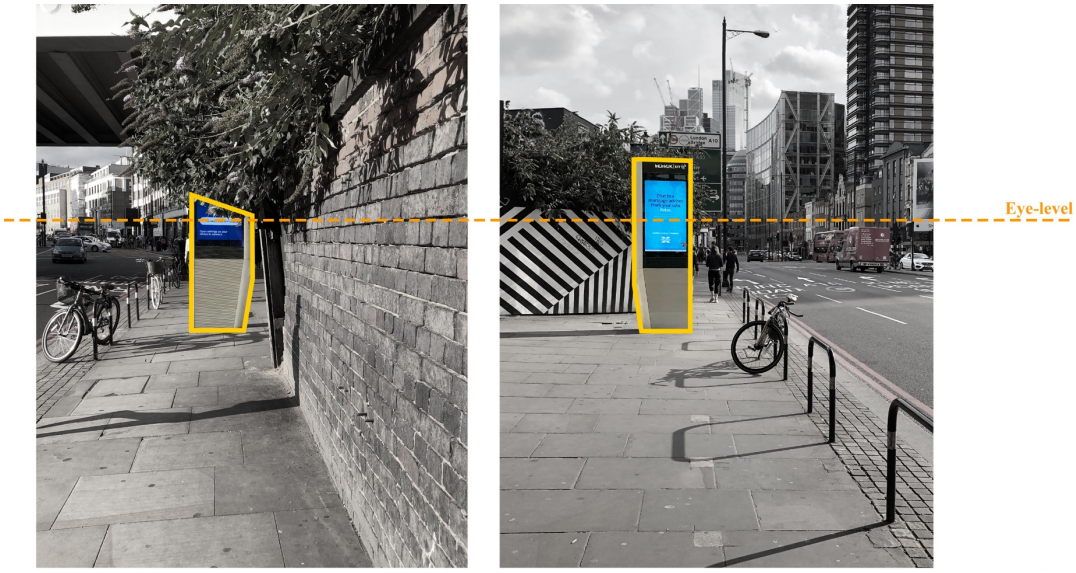

Fig 6. Eye-level view of kiosk from the opposite direction on Site1- south side (left) and north side (right)

5.4 Influence of human activities

Based on the field study, there are several cases of "honeypot effect" witnessed on Site1 and Site2 in which pedestrians were motivated to interact with the kiosk after witnessing other people using the tablet. However, in most cases, pedestrians noticed the interactions within a short distance; as they observed how users manipulate the tablet, they then quickly left. The main attraction that turned the pedestrians into observers were user postures or the sound leaked from the kiosk. Due to the design of kiosk, the tablet was embedded in a relatively low position. In order to see the tablet clearly, most users need to bend over or lean on the kiosk (Fig 7). These postures are quite uncommon on the street, thus could quickly attract pedestrians' attention. In addition, when the users were making a phone call via tablet, the leaking sound from speakers also triggered the curiosity from pedestrians nearby who tended to seek the origin of the sound.

Fig 7. Common postures by kiosk users- Site1 (left), Site2 (right).

5.5 Other influence factors- display content on side screens

Besides the physical, spatial characteristics and human activities, the case study also uncovered other factors that influenced public interaction with kiosks, especially the display content on the side screens.

In the winter study, the research investigated the arrangement of side screen content on three sites between 2-6 pm. Since the display content of each kiosk followed a repetitive pattern which changed hourly, the research recorded the content for the first 5 minutes of each hour to compare its arrangement and public interaction on different sites in different slots. The winter study identified that, between 2-6 pm, the kiosks on three sites projected mainly commercial advertisements and services promotion. While public information on each site, such as news review, seasonal events like love letters for Valentine's Day, and local venues like reading club recruitment, counted less than 10% of display time.

This content arrangement obviously influenced how pedestrians perceived the kiosk. According to the street survey of 40 participants, concerning the witnessed content on the screen, all participants reported that they have seen advertisements on the screens, and 10 of them remembered to have seen kiosk promotions. While only 6 participants, mainly kiosk users and local workers, have witnessed public information. Pedestrians and passers-by who mainly remembered the scrolling of advertisements on the screen were more likely to consider the kiosk as simply a billboard and ignored the existence of interactive tablet. Accordingly, they tend to have lower expectations of the kiosk and question its functionality. While people who were more frequently exposed to the kiosk, such as users and local workers, held more positive attitudes towards the installation of this type of infrastructure on the street.

6 CONCLUSIONS

In this paper, initially, we developed a framework of physical, spatial characteristics and human activities based on urban design knowledge. This framework was then applied to the case study of InLinkUK network of kiosks in 3 selected locations within London. The case study indicated that, among three selected sites, there are certain public space characteristics that facilitate public interactions. The spatial characteristics- such as the degree of enclosure, physical characteristics- such as the position of kiosk in space and the provision of shaded area, created a big impact on direct and passive interactions. Human activities, especially the interplay between the tablet users (for phone calls) and passers-by behaviors, triggered further interactions such as raising the curiosity of kiosk, and how the position of kiosk evoked users' concern of being observed by pedestrians without consciousness. Spatial characteristics, however, seemed to have a big potential to affect interactions, particularly the size of space (narrow or wide pathway) and visual stability, which requires a further study to determine the extent of this influence.

Apart from the initial findings, there are several limitations of this field study. First, due to the weather conditions, not many pedestrian activities were witnessed during winter, thus it brought difficulties to define their impacts on public interactions. There were also other factors that offered a strong possibility to influence public interactions, in particular the presence of other types of street infrastructure like the bike docking stations and bike racks. For instance, several cyclists might have mistaken the kiosk on Site1 as a bike stop and lean the sharing bikes on it as several cycle racks sit nearby. However, due to the small number of recorded behaviors, in particular, the ones that correlate with the presence of surrounding objects and street infrastructure, more systematic observations are needed to cover the range of possibilities. At the same time, since the accessibility and visibility-related metrics are captured through empirical observations, which were only carried out during certain time slots in a limited number of days, the result could not accurately present these properties of the selected sites and define their influences on screen-related interactions. In the next stage of the research, building on the outcome of this

study, we aim to: 1) carry out a spatial analysis and map existing urban functions (e.g. transportation hub or residential area), in addition to visibility and accessibility. For the local area around the kiosk beyond the immediate environment, we aim to address other factors (Table 1) which have not been covered in this study, such as the effect of different urban functions in the vicinity of kiosks. Accordingly, the field study sites will be expanded to cover different aspects of listed characteristics in Table 1, and more detailed measurement of public space characteristics should be delivered before the data collection stage; 2) map the various stakeholders who are involved in the decision-making process of the placement of InLinkUK kiosks and identify the extent to which these physical and spatial characteristics contribute to the decision-making; and 3) identify the type of business model behind the management of screen content, and how this potentially affects the decisions on the placement of this media infrastructure in the urban space.

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