Foundations for Designing Public Interactive Displays that Provide Value to Users

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ABSTRACT
Public interactive displays (PID) are a promising technology for providing information and collecting feedback in public spaces. Research on PIDs has shown that, like all public displays, their efficacy is reduced by display blindness. Rather than increase the visual attention-grabbing nature of PIDs, we propose that additional understanding is required around how and when these displays are able to offer value to users. We tackle this through a systematic analysis of PID studies published in the literature, which led to 9 aspects of value across 4 factors: people, location, community, and time. We discuss the identified aspects and their utility for the design of PIDs through a review of our own deployments carried out by 4 different labs across 5 countries. We conclude with a set of recommendations for identifying and optimising the intended value of future PIDs.

Author Keywords
Public interactive displays; Public displays; Value; Literature review; In-the-wild; Deployments; Design recommendations.

CCS Concepts
•**Human-centered computing** → **HCI theory, concepts and models;**

INTRODUCTION
With computing technology moving into the realm of public spaces [21, 23, 24, 56, 63], an increasing number of HCI researchers and labs across the world are conducting research on how to design the interaction between people and these new technologies. In the field of HCI, public interactive displays (PID) are a commonly used technology for enabling people to interact with dynamic information within public spaces, such as airports, shopping centres, and train stations. Over the past two decades, HCI studies have focused on topics, such as understanding the zones of interaction [59] and the behaviour of people around PIDs [8], designing intuitive interaction techniques [31], and defining models of engagement [46]. It has further been demonstrated that PIDs can provide a mechanism for engaging communities, allowing them to share information or feedback, for example, through digital noticeboards [3] and voting booths [32, 55].

The analysis presented in this paper builds on and extends this previous body of work developed over the past 15 years. It is motivated by two observations. Firstly, despite the potential of PIDs for empowering communities, it is often assumed that the deployment of PIDs in public space services the needs of all urban dwellers, taking a *one size fits all* approach, with little regard for the differences between the individuals who use the spaces [48, 50]. To disregard individual differences between people within a public space risks the technology becoming unused and can potentially contribute to what previous literature has characterised as "display blindness" [47]. It has been suggested that display blindness in PIDs is linked to people assuming that the PID is not offering any value matching their needs and situation [11, 19, 49]. This observation is further supported through studies on web advertising banners, finding that people ignore distractors that seem irrelevant when carrying out a particular task [10].

Secondly, many research studies have focused on studying the display blindness effect in public displays and PIDs [36,43,47], and mechanisms for overcoming display blindness, such as attracting the attention of passers-by through visual signals [1,2,39]. At the same time, more recent studies have found that not all public displays suffer from display blindness [18, 50], further supporting the observation that display blindness may not occur in situations where people find a perceived value – even if it is just watching animated advertising clips while standing on an escalator [50]. Building on these insights from previous work, the paper *aims to develop a structured understanding about the factors that affect the value PIDs provide to users*. We use the term "user" in this paper to refer to passers-by as well as those who stop to interact with a PID.

To achieve this aim, we carried out a two-stage analysis. First we conducted an extensive review of key work that involved in-the-wild PID deployments published in the HCI literature. This review led to the identification of 9 key aspects that contribute towards value across 4 factors. To illustrate these as-

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pects, we reviewed 5 of our own in-the-wild PID deployments through the lens of "value" and in relation to the identified aspects.

For the context of this paper, we define a PID as a form of public display that accepts some type of input, such as touch, mid-air gestures, voice, or through external devices like smartphones or RFID cards. This distinguishes them from other forms of public displays that are deployed for the sole purpose of distributing information without giving people a means to control the content. Although, non-interactive public displays (PDs) have also been studied in HCI, e.g. regarding engagement [36, 50], we focus on PIDs as it is the ability to interact with a public display which makes this technology particularly relevant for the HCI community. Furthermore, our own deployments included in the paper are based on PIDs as a technology, using various forms of input from touch to mid-air gestures to smartphones. Our definition of PIDs does not include displays that are: (1) a form of "mundane" technology [20, 30], such as parking meters, self-checkouts, and ATMs; or (2) large-scale displays, such as large banner displays [50] and media façades [29].

The contribution of this paper is an extension of previous work on PIDs broadly and the display blindness phenomena more specifically through developing a systematic understanding of the factors that contribute towards potential value of PIDs. To that end, we provide recommendations for identifying and optimising the value when designing, implementing and deploying PIDs.

METHODOLOGY

To systematically build up an in-depth understanding of how PIDs can be designed to provide value, we reviewed a representative set of papers from within the HCI community and then reflected on our own PID deployments. We describe the process for both the literature review and our own deployments below. The findings are presented in the following section.

Literature Review

To identify the papers for the literature review, we used a three-step process. First, we used the ACM advanced search feature to identify the venues in which public display research was most commonly published in the past 5 years. We chose this approach over a general search for papers, e.g. using Google Scholar, to ensure the reproducibility of our methodology. To identify the top venues, we searched for "public display" on ACM, yielding 328 papers. We used "public display" instead of "public interactive display" since PIDs are referred to using different terms and we wanted to ensure that our search was as inclusive as possible. A sampling of some of the well-known publications covering PIDs showed that each of those papers also used the term "public display". We downloaded the results as a CSV file and counted the number of papers published since 2014 per venue. We limited the search to the past 5 years as we were interested in understanding current trends. This resulted in a selection of the top 5 venues: CHI, PerDis, DIS, MUM, and Ubicomp.

As a second step, we narrowed down the results to papers that described *in-the-wild* studies as these offer a higher ecological validity when it comes to assessing the value a PID offers within public spaces. The term, "in-the-wild", was chosen as we found it to be commonly used in public display research for describing PID studies in public space. We did also test this assumption by using alternative search keywords, including "field study" and "real-world deployment", and found that the majority of the results were already captured in our "in-the-wild" search term. Those papers that were not already included in our results did not meet our 3 inclusion criteria (which are outlined in the next paragraph). To narrow down the results using this term, we used the Google Scholar advanced search feature, which allowed us to confine the results to particular venues, using for example the following search term: *"in the wild" OR "in-the-wild" "public display" source:CHI*, and setting the custom range to between 2014 and 2019. This step yielded 145 papers across the five venues.

In the third step of the selection process, we reviewed each paper's title and abstract to see if it met the following criteria for inclusion: (1) contains an in-the-wild PID deployment that was (2) studied in a public space and (3) published as a full, peer-reviewed paper.

This resulted in a final collection of 25 papers that we included in our literature review (outlined in Table 1 and marked with an asterisk in the reference list). The papers all reported on in-the-wild PID deployments in public spaces across 8 countries. While each paper had a specific objective, such as evaluating an interaction method, they all offered general insights about their PID deployments in some form. The 25 identified papers were analysed in a two-stage process: First, one of the authors performed an inductive thematic analysis on their results, discussion, and conclusion sections in Nvivo. This led to an initial list of codes. In the second stage, the lead author together with one of the other authors performed a second round of analysis, this time by reviewing the papers and codes generated in the previous round to verify their relevance. Using affinity diagramming, they subsequently grouped codes into aspects, and aspects into factors. This analysis resulted in 9 unique aspects across 4 factors (people, location, community, and time).

PID Deployments

To gain further insights into the value that PIDs offer to users, we reviewed our own body of work, which involved 5 PID cases across 5 countries. Having been directly involved in those PID deployments allowed us to reflect on the value that each PID offered to users and how its design may have affected its value negatively or positively. We describe the cases briefly below; the insights from reviewing the cases through the lens of "value" and in relation to the 9 aspects identified from the literature review are presented in the following section.

Case A: *Transit Public Interactive Display*

This PID (Figure 1A) was deployed next to the main entry of a university building in Sydney, Australia, which is a busy thoroughfare for staff, students, and visitors. It was running 24 hours per day for 10 days, starting on a Tuesday and including the weekend. The PID was created to offer value to individuals by implicitly adapting its content to the goals of the person using it. This was achieved by including two elements. First,

Table 1. Overview of the papers included in the literature review and the cases.

Reference	PID Name	Study duration	Number of interactions	Type of location	Country
Case A	Transit PID	10 days	259	University campus (indoors)	Sydney, Australia
Case B	Media Ribbon	56 days	483	University campus (outdoors)	Sydney, Australia
Case C	MyPosition	5 days	217	University campus (indoors)	Berlin, Germany
Case D	Reveal-it!	16 days / 1 day / 3 days	172 / 28 / 52	Cultural centre yard (semi-outdoors) / Community centre lobby (indoors) / Community centre lobby (indoors)	Córdoba, Argentina and Barcelona, Spain
Case E	e-Campus and Tacita	2.5 years	130 users	University campus (indoors and outdoors)	Lancaster, UK
[4]	Station and Tablets	Station: 28 days / Tablets: 64 days	Station: 1397 / Tablets: 899	Airport (indoors)	Munich, Germany
[7]	Banner display	6 weeks / 5 weeks	1866 / -	City (outdoors)	Munich, Germany
[12]	Social NUIz	28 days	1065	University campus (outdoors)	Melbourne, Australia
[13]	Public visualisation	12 hours	-	City (outdoors)	Leuven, Belgium
[14]	Bicycle Barometer	6 days	53	urban / suburban area	Leuven, Belgium
[15]	N/A	4 days	153	Library (indoors)	Leuven, Belgium
[16]	N/A	2 days	215	Train station (indoors)	Leuven, Belgium
[17]	AR display	- / 3 days	- / -	Library (indoors) / supermarket (indoors)	Oulu, Finland
[25]	UbiOpticon	11 hours	38	City (outdoors)	Oulu, Finland
[27]	N/A	5 days	29	University campus (indoors)	Palermo, Italy
[28]	Game of Words	1 month	632	City (indoor and outdoor)	Oulu Finland
[34]	N/A	61 days	277	University campus (indoors)	Oulu, Finland
[35]	Roam-IO	6 days	231	Tourist office (indoors)	Madeira, Portugal
[38]	Ubi-display	26 weeks	-	Swimming hall (indoors)	Oulu, Finland
[40]	N/A	8 days	1418	University campus (indoors)	Oulu, Finland
[41]	Pinsight	2 days / 3 hours	77 / -	City (outdoors)	London, UK
[42]	Information Wall	-	-	University campus (indoors)	Tampere, Finland
[44]	Moment Machine	12 weeks	3390	City (outdoors)	UK
[45]	Funsquare	2 days	-	Library and market (indoor and outdoor)	Oulu, Finland
[51]	N/A	1 day	-	Train station (indoors)	Brussels, Belgium
[53]	N/A	3 days	-	Tourist centre (indoors)	Weimar, Germany
[55]	Vote with your feet	7 days	-	City (outdoors)	Brisbane, Australia
[58]	N/A	2 days	51	City (outdoors)	Enschede, The Netherlands
[61]	Encounters	19 hours	-	Outdoors	Melbourne, Australia
[62]	GazeHorizon	4 days	129	University campus (indoors)	Lancaster, UK

it offered bus times from the nearest bus stop. As the bus stop served multiple bus lines, the user could choose their destination suburb from the available twelve options represented by buttons for quick access. Depending on the selected suburb, the PID showed information about the fastest transit options (bus and walking) to the selected suburb. Second, as a form of "implicit personalisation", the PID also showed information in the lower part of the screen about the three most highly rated locations of interest in the selected suburb. The PID allowed users to manually filter this information by four categories: restaurants, bars, shopping, and cafés. The displayed information included the name of the place, opening hours, address, and a 5-star scale rating.

The *value proposition* for this PID is that it offers implicit, device-free personalisation with content (bus times and locations of interest) that is relevant to the general area it is located, the current time, and what the user interacted with.

Case B: *Media Ribbon*

The Media Ribbon (Figure 1B) was an outdoor PID, implemented through a projection (composed of two projectors side-by-side) on a glass wall of a university building, next to a courtyard shared by a theatre, located in Sydney, Australia. This PID supported exploration of hierarchical information displayed in the form of a ribbon that people could browse through using mid-air gestures. The implementation used a Microsoft Kinect depth camera recognising left and right hand swipes to move within the current level of the hierarchy, and raising or lowering either hand to move up or down the hierarchy. Users could "like" individual pieces of content by raising a hand while viewing an item. Additionally, the PID displayed an on-screen representation of the user, mirroring their actions. This was important for helping users learn the gestures. To ensure consistency and symmetry in the gestures, the swiping gestures were only detected for one direction for each hand. Data was automatically logged for each user interaction over a period of 56 days, with 190 sessions involving 483 detected people. We also recorded the depth camera video stream for each session, which we used in the subsequent analysis.

The *value proposition* for this PID is that it allows for playful interactions while providing serious content related to the area it is located, such as current and future events happening in the University and adjacent theatre.

Case C: *MyPosition*

The MyPosition PID (Figure 1C) displayed urban poll visualisations on local issues. The system consisted of two short-throw projectors and two Kinect cameras. It allowed people to walk up and give their opinion on a topic by selecting one of four pre-set answers (strongly disagree, disagree, agree, and strongly agree). To select their response, the user had to position themselves in front of their desired answer. The PID compared three different voting mechanisms: using (1) colour, (2) the user's contour, and (3) the user's mirror image as indicator for a submitted vote. A field study was conducted with this PID, where it was deployed in the foyer area of a university cafeteria in Berlin, Germany for 5 working days. The topics on the screen were locally relevant to the university, such as asking whether degrees were important for getting a job. To confirm the answer after standing in front of the screen, the user needed to raise their hand. As the location was within a university the main user base were staff and students.

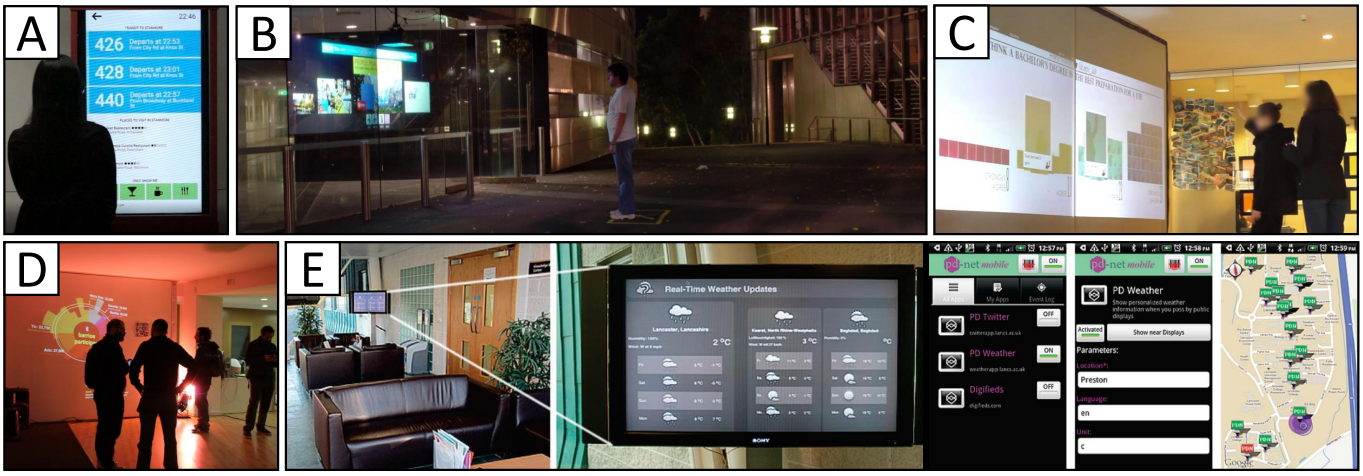

Figure 1. Our PID deployments: (A) Transit PID; (B) Media Ribbon; (C) MyPosition; (D) Reveal-it!; and (E) e-Campus and Tacita.

However, there were also times where members of the local community would visit to dine at the cafeteria and therefore the topics may not have been relevant to everyone at all times.

The *value proposition* for this PID is that it allows for people to playfully vote on a topic using their whole body. The results from all the votes are visualised publicly on-screen to show the collective sentiment around the topic.

Case D: *Reveal-it!*
This PID displayed the power usage of people in the area the PID was deployed (Figure 1D). People could submit their information, such as their name, the amount they paid in their last electricity bill, and the number of inhabitants in their household, through a tablet application which was provided near the PID. Based on this data the PID showed a visualisation allowing individual participants to compare their energy usage against each other. The more participants contributing to the PID, the more the visualisation grew. This PID was deployed in three locations: (1) the city centre of Córdoba, Argentina, for 16 days; (2) a neighbourhood in Barcelona, Spain, for 1 day during a festival of arts and technologies; and (3) a second neighbourhood in Barcelona, Spain, for 3 days during a local meeting on renewable technologies.

Like case C, the *value proposition* for this PID is that people can collectively contribute their personal information (in this case power bill), causing the data visualisation to grow over time and provide an overview of the total data collected from a community of users.

Case E: *e-Campus and Tacita*
The e-Campus system is a network of over 65 public displays deployed on a university campus in Lancaster, UK. It has recently been enhanced with an implementation of the Tacita architecture that enables users to personalise proximate public displays using a smartphone app (Figure 1E). Using Tacita, staff and students can express preferences for and parametrise the type of content they wish to see (e.g. specific bus timetables or weather for a specific location). When a user enters the proximity of a display their smartphone forwards a request for content to trusted third-party content providers (such as Facebook or Google), which act as mediators. These content providers then request screen real-estate from the display network and show the requested content. This use of third-parties has two benefits. Firstly, it ensures that user privacy is preserved since no information regarding a user is ever disclosed to the display network. Secondly, it means that display networks only need to trust content providers rather than individual users – making it more likely that they will show the content selected. The system has been in operation for 2 years and had 130 users.

The *value proposition* for this PID is that people can provide their personal preferences through a smartphone app to implicitly see content that is of value to them on nearby displays in the network.

FINDINGS AND RECOMMENDATIONS

The literature review resulted in 9 unique aspects that contribute towards value across the four core factors: People (5 aspects), location (1 aspect), community (2 aspects), and time (1 aspect). As illustrated in Figure 2, these factors are all intertwined, with people and location creating community. The time factor is all encompassing, affecting each of the other three factors. In this section, we discuss each of the identified aspects grouped by the core factors. We use our own PID deployments to illustrate the aspects and how they contribute towards the value provided to users. The section also introduces design recommendations (DR) emerging from our findings across the literature review and our own PID deployments. Table 2 provides an overview of the link between the findings, recommendations, literature, and case studies.

People

This factor describes the individuals or groups of people that may engage with a PID and the value it offers them. This factor includes 5 aspects: Trust, privacy, relevance, appropriation, and ownership.

Trust
A PID's value can be affected by how much the user trusts

Table 2. How the design recommendations, factors, and aspects relate to each other, and what literature and case studies they are based on.

Design recommendation	Factor	Aspect(s)	Literature	Case studies
Awareness of users' goals	People	Relevance	[4, 12, 28, 42, 53]	Case A, Case E
Balancing privacy and relevance	People	Privacy, Relevance	[4, 12, 13, 28, 42, 51, 53, 55]	Case A, Case C, Case E
Allowing users to create their own value	People	Trust, Appropriation, Ownership	[14, 25, 34, 35, 38, 44, 51, 55]	Case A, Case B, Case D
Capitalise on Permeability	Location	Location	[4, 7, 14, 17, 40, 55, 58]	Case A, Case B, Case D
Responding to communities	Community	Identity	[28, 41, 45, 55]	Case D
Involving communities	Community	Collaboration	[13–16, 27, 55, 61, 62]	Case B, Case C
Promoting conversations	Community	Collaboration	[13–16, 27, 55, 61, 62]	Case B, Case C
Changes over time	Time	Time	[14, 35, 45, 51, 61]	Case A, Case B, Case C

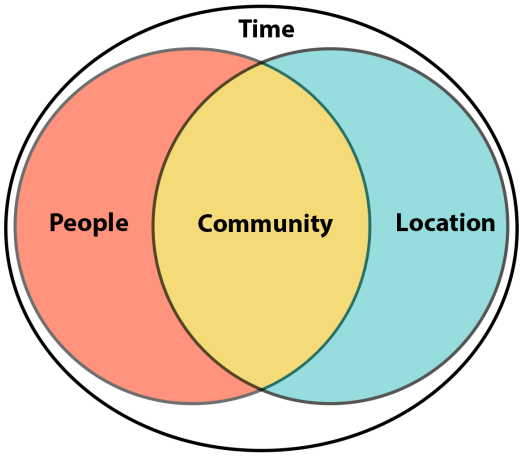

Figure 2. The key factors found in our analysis: People, location, community, and time.

the PID and the type of content it displays. Out of the 25 papers in the literature review, 7 were deployed in a university campus and may have benefited from being located in a more controlled environment in terms of users' trust. Hosio et al. [34] further reported that users need to trust the organisation behind the PID, particularly if it is collecting data. They recommended to make PIDs more transparent about their intentions to increase participation. Similarly, Memarovic et al. [44] found in a study of a selfie display that it is important to make it clear where the data is stored. Houben et al. [35] proposed that the data collected on their PID through a questionnaire be shared publicly and made freely available in order to increase transparency. However, this approach should be carefully used and only for non-identifiable data. Foth et al. [25] found that trust was also linked to the age of participants. In their study, they discovered that older citizens were more suspicious and were concerned about their privacy.

In case A, during our interviews with participants after using the PID we asked them what information they would be comfortable to share with a PID. The responses we received indicate that the main barrier people have for sharing their information is the unknown entity – if the display does not look official or does not have a brand that they 'trust' and 'recognise' then they are less inclined to share personal information. This points to both an opportunity as well as a responsibility: By clearly stating the organisation managing a PID deployment, trust can be reinforced; at the same time, it is important to ensure that participants are not misled. For example, one of the participants in case A noticed the 'powered by Google' logo on the bottom of the screen, which was placed there since the system was using the Google Maps API, assuming that this deployment was in some way linked to Google.

Privacy

Related to the issue of trust, the value of a PID can be affected by an individual's perception of privacy. For instance, a number of studies reported that certain content can lead people to not engage or to engage in unexpected ways, such as topics of a personal nature or topics that trigger divided opinions like politics, immigration, and crime [13, 51, 55].

In our own PID deployments, we found that privacy requirements amongst individuals can differ and change based on the particular context. For example, in case A, after interacting with the PID a participant expressed concerns about using the PID for finding the next bus to their home suburb at night, as others viewing the information could find out where she was going. In case C, the voting interaction was public which meant that users would often be observed by others while voting. We observed that at times passers-by would comment on someone's vote or discuss the results displayed on the PID. We further found that the condition in which people's votes were represented through the person's mirror image (i.e. fully identifiable) led to fewer votes being submitted compared to the other conditions. At the same time, the increased identifiability of users positively impacted the engagement with and the social debate around the PID.

Relevance

Content on a PID should not only be relevant to the space in which it is situated [28,42], but should also relate to an individual's current needs and goals [4] – such as reaching the exit of the airport once they have their bags. We also found examples in the literature suggesting that users constantly reevaluate the value of a PID while interacting with the system. For example, Carter et al. [12] reported that over 60% of interactions with their PID that asked quiz questions only lasted for one round and users would leave once they found out the answer. Sahibzada et al. [53] discovered in their study that advertising breaks in the content can cause users to disengage with the PID. They recommended that advertising should instead be integrated with the main content and interaction.

The PIDs in cases A and E both approached making content relevant to individuals differently. Tacita (case E) used a smartphone approach, where nearby displays would respond with personalised information according to the preferences the users entered in their smartphone app. The Transit PID (case

A) implemented an alternative device-free approach using only the explicit actions of the user to determine their interests and adjust its content accordingly. Both approaches have their limitations: The smartphone approach can enable a deeper level of personalisation with the user's interests and history, but excludes those who do not own a smartphone and further involves a start-up cost of setting up the app. The device-free approach requires no external devices or pre-configuration, but is limited in what it can recommend to the user as it lacks fine-grained data about them. This meant that the content was only adapted to suit the user's destination but did not consider other criteria, such as their interests.

Appropriation
PIDs can offer value to individuals or groups of people in a more peripheral way. For example, Jurmu et al. [38] studied the use of a PID as a tool for distracting young children. People have also been observed to create their own extension for how to interact with a PID. For example, Parra et al. [51] observed users attempting to create their own content using their hands (to create a heart) and performing non-standard interactions, such as touching each other's representations on the screen. Foth et al. [25] found that people were interested in appropriating PIDs, which showed live surveillance around the city, to fit their own agenda, such as utilising PIDs with video streams during festivals and being able to have a window into other cities.

In case B, despite being designed for serious use (exploring interesting content), we often observed users performing playful gestures around the PID such as waving, posing, dancing, and shadow boxing through their on-screen avatar representations. Interestingly, in many cases, these playful interactions eventually led users to more seriously exploring the content represented in the PID.

Ownership
Giving users the ability to contribute data, and that way instilling a sense of ownership, can add to the perceived value of a PID – particularly if the system allows users to compare their submission against the submission of others. For example, Steinberger et al. [55] found that users were generally interested in comparing their own opinion on particular topics with those of others. However, not everyone needs to contribute to get value out of the content. Claes et al. [14] also found an occurrence of a "lurker" , which is someone who observes but does not participate [5]. They developed a voting PID targeted at cyclists; however, some of their participants were only interested in finding out how people voted.

In case D, we found that the ability for users to submit their electricity consumption to the PID not only led to a sense of ownership (by having contributed to the overall visualisation) but also increased engagement through being able to compare their data with the data submitted by others. Case D highlights how individual and community content can come together. Namely, while the user is interested in viewing where they stand against everyone else, they are incidentally contributing to the crowdsourced data visualisation. However, submitting data is linked to the issues of trust and privacy, and it is important to make it clear who owns the data that is contributed to a PID [44].

DR1 - ***Awareness of users' goals*** Individuals in public spaces may have many different goals and these may change over time. Users' goals, therefore, should be considered not only in the design of PIDs but also in how the content is delivered in operation and adapted over time. PIDs can draw from a number of options available for distinguishing and identifying users to personalise information, which in turn may increase the PID's perceived value. PIDs can further adapt content to make it more relevant to users' goals through explicit or implicit goal identification. In systems that make inferences about the user, it is critical to allow people to scrutinise these and alter them.

DR2 - ***Balancing privacy and relevance*** This issue impacts the previous recommendation, which requires knowledge about certain aspects of individual users. While personalising PIDs can add value, it is also important to consider the impact on privacy requirements when identifying the user or their goals. Individuals have different privacy requirements and these can change with context. An individual's privacy preferences can potentially be discerned from the type of context (such as location and situation) and the people around them (who is in the space and number of people). PID designers can further consider methods to block onlookers, such as blanking out parts of the screen the user is not looking at [9] or using mobile augmented reality [6, 49].

DR3 - ***Allowing users to create their own value*** People commonly engage with a PID differently than intended. Rather than preventing this from occurring by prescribing particular ways of interacting with a PID, we suggest that PIDs should be designed with a certain level of appropriation in mind. This highlights that content itself is not the only valuable aspect of a PID, and that interactions and the overall experience are equally important contributors for the perceived value that a PID provides to users. It is also important to consider user trust in a PID. If a user deems a PID untrustworthy, then they might be less inclined to engage and provide data. While the visual presentation of a PID may have some impact on user trust, such as branding and level of refinement, the location may also have some impact. We found from our cases that users were generally trusting primarily due to the PIDs being located in a controlled environment, such as a University.

Location

This factor describes the composition of the physical location and how the aspect of *location* affects the value of a PID. The PIDs included in the papers from our literature review were deployed in both indoor and outdoor environments across 8 countries and our own PID deployments were across 5 coun-

tries, also indoor and outdoor − offering insights from across a diverse range of locations.

Various studies argue that it is important to consider the location carefully and to use locations in which people would have more time and are captive, such as waiting areas, escalators, elevators, queues, etc. [4, 17, 55]. How crowded a location is equally plays a contributing role, and PIDs should be designed accordingly to accommodate this. This can lead to social interactions [14] while people are using the PID or waiting to use it. However, it is also important to ensure the content is not affected environmental factors, like noise [40], and that there is enough physical space in front of the PID [58], particularly with multiuser PIDs. To help guide and distribute users around the interaction space on-screen visual stimuli could be used, as demonstrated by Beyer et al. [7].

We found that in our Transit PID study (case A) the perceived value of the PID was negatively affected by its location, as it was deployed near the exit of the university, which was in close proximity to a bus stop but not directly at a bus stop. For case B, the PID was deployed on a glass wall of a university building facing a courtyard shared with an adjacent theatre. The patrons in the area primarily changed based on the type of event being held at the theatre. For instance, a technology conference resulted in a playful exploratory audience that was curious about the technology. We therefore designed the PID to offer content relevant to this physical location, i.e. items relating to university research, upcoming and current events at the theatre, and other university-based material such as the winning entries from an alumni photo competition. In case D, we deployed the PID across three locations. The first two deployment locations (in an exhibition area and hosting space respectively) were more successful at engaging people as they offered people a destination and an opportunity to linger. In contrast, the third location was situated in a busy thoroughfare near a meeting event, meaning people had less time to stop and engage with the PID.

DR4 - *Capitalise on Permeability* The value offered to users greatly depends on the physical placement of a PID and how the physical space is used. Although it has been widely reported that placing a public display in areas with a lot of foot traffic increases engagement [36, 60, 61], this is not always done in practice [50]. Before deciding on the placement of PIDs, it is important to first survey and observe the space in which the PID will be deployed to see how urban dwellers use that space and its permeability (how people move through it). The choice of a PID's location should therefore take into consideration how these change over time. An effective approach is to position PIDs where there is a high likelihood of opportunistic interactions, such as nearby the entrance to the space or in an area where people are waiting, such as near cafeteria lines or escalators.

Community

This factor describes the community, i.e. the collection and type of users found in a particular space in which the PID is situated. As such, this factor sits at the intersection of people and location. The composition of a community may change over time, for example, at noon on workdays the community might include office workers from nearby businesses, whereas on weekends the community might predominately consist of families that live in the area. This factor includes 2 aspects: collaboration and identity.

Collaboration

People in the community can have an impact on the value of a PID, for example, through social interactions taking place around the PID before or after a user interaction. Steinberger et al. [55] reported in their study of a voting PID that people would often discuss the questions together − with friends or strangers − before providing an answer. Similarly, Claes et al. [14] created a voting PID targeted at cyclists. Their observations indicated that groups of people would discuss their opinions together and collaboratively to come up with solutions to an issue. In another study, Claes et al. [15] investigated data visionalisations on a PID, observing that people worked together to make sense of the graphs being displayed. Additionally, Wouters et al. [61] noticed experienced users guiding new users through the interactions and content of the PID, thus shaping a new user's experience. Users helping each other understand a PID was also observed in Gentile et al. [27] and Zhang et al. [62]. We also observed this occurring during the deployment of the PID in case B. Furthermore, the PID managed to attract multiple users, despite being originally designed for single user interaction. Multiple users also meant longer engagement.

In case C, we found that people would discuss with each other elements of the PID, including: the visualised voting topic and their personal preferences, the voting results, and data privacy issues. It has been documented that for PIDs to be more successful at sparking conversation, they need to be designed to support multiple types of interaction [13]. However, work by Coenen et al. [16] highlighted that making the interaction accessible is not enough, focus should also be paid towards the content and compelling a user to interact.

Identity

The content on a PID can say a lot about a location and the people in it, representing a community's identity. For PIDs that accept user-generated content, the community can drive its message and bring people together. Giving citizens control over the content on PIDs can further be an effective way to keep content relevant and to give people in communities an accessible platform to reach out to one another, for instance, by allowing viewers or stakeholders to post and moderate content. Steinberger et al. [55] reported that user-generated content not only benefits existing members of the community in keeping track of local information, but also new members or visitors who want to get a sense of the community and its current sentiment. This crowdsourced knowledge gradually builds up and ongoing dialogues can emerge as people engage with each other's content [41]. Memarovic et al. [45] suggested that PIDs could be appropriated by the community to run events to bring people together. What these examples show is that PIDs appropriated by their respective local communities can

collect current, natural, and in-depth information about their communities and display it in potentially meaningful ways.

However, careful community moderation and selection of a more public location could be required to ensure participants do not impact each other negatively [28]. This type of behaviour can also be reduced by linking users' identity to the content. For example, we implemented this in case D, where in one of the conditions users' votes were represented through the user's mirror image. Although this led to fewer interactions, it also reinforced accountability and those who did vote were found to take their response more seriously. In retrospect, the PID from case A lacked a connection to the community within which it was situated in terms of the value offered through the PID, resulting in content that was not always perceived to be of value to passers-by and consequently negatively impacting user engagement.

DR5 - ***Responding to communities*** A challenge for PIDs is their integration, or situatedness [37], within the respective communities and gaining relevant information about them, such as local events being held and the demographics of the people that make up the communities. PIDs should be designed so that they are more attuned to the communities in which they are situated, which may also require for the PID to adapt as communities change over time.

DR6 - ***Involving communities*** Giving members of communities some control and ability to provide information enables PIDs to have greater knowledge of their respective communities and the associated preferences, giving them a greater pool of data to draw from when deciding what content to display. To give communities control from the outset, researchers and practitioners could follow a co-design approach [22, 52], where community representatives and other stakeholders are actively involved in all stages of the design and development. In the case of PID deployments, co-design needs to be a continuing process before and after the PID is deployed. Because of their public nature it may further be necessary to involve authorities (which are in charge of public space regulations and approvals) as well as community representatives in the process [26].

DR7 - ***Promoting conversations*** Designing PIDs in a way that sparks discussion among users and bystanders can lead to increased engagement, augmenting the value the PID can offer. For example, asking users for responses on locally relevant topics can help spark discussion [14–16, 55]. It is also important to design PIDs to better accommodate users conversing with each other with a larger physical space in front of the PID for engagement [58] and multiple modes of interaction [13].

Time

This factor captures the fact that public spaces and the people within them change throughout each day, month, and year [57]. The value that a PID offers to users is therefore linked to the aspect of *time* and the PID's ability to adapt over time.

Time affects the people, location, and community factors. In terms of an individual user, their goals or needs may change over the course of the day, month, year, or season – thus affecting how and when they need to interact with a PID and what value they receive from the interaction. For instance, a user's interest in interacting with a PID may change depending on other priorities – for example, they may be more inclined to participate in discussions about local topics on weekends when they are more likely to have time to spare [32]. Additionally, suburban environments may contain more passers-by that have time to spare compared to urban city environments [14]. The location and community factors are affected as space changes over time [35, 45, 51, 61], for example, due to community-run events, shops closing, etc.

The content on the PID featured in case A changed over time, displaying bus times and recommended places of interest that were open at the particular time it was being interacted with. This meant that the PID was always up-to-date and allowed users to access the information at any time. However, participants in the study commented that they would like to have had the ability to see content related to things happening in the near future, such as local events. The reason for this is that users might already have a set goal or plans in mind when catching a bus to their destination. In contrast, the study in case B showed future events coming up in the area. Furthermore, the study also showed that the demographic of users changed over time, particularly during the theatre show times. The demographic interacting with the PID was at times mostly university staff and students, but at other times, it was patrons visiting the theatre that were typically waiting for the start of performance bell or meeting friends before going inside. Similarly, it was found in case C that despite the PID being situated in a university and asking questions about university-related topics, the cafeteria also attracted people who were not affiliated with the university and therefore not able to receive any value from the PID.

DR8 - ***Changes over time*** It is important to understand the impact of time on the physical space and place, the people who use the space, and how these changes may affect the perceived value of a PID. While showing current up-to-date information can make the content more relevant to people, it is also important for PIDs to have temporal flexibility, where both current and future information can be accessed. Additionally, PIDs need to be aware of a user's time and adapt according to the time constraints the user has – for instance, if the user needs to be somewhere in a hurry, the PID should optimise speed and present quick snippets of information. Conversely, users with time to spare, such as a tourist, can likely spend more time with the PID and take in more information. This consideration of time offers further opportunities to make PIDs relevant to users and their individual needs, goals, and characteristics.

DISCUSSION

Novelty of Design Recommendations

With the rapid increase in the number of interactive displays being deployed in public spaces it is becoming increasingly critical to understand how the perceived value of these displays can be maximised. Existing research on public display audience engagement has highlighted that in many situations, people do not notice the display or decide not to engage with it [36, 43, 47]. It has been suggested that this may be linked to the fact that people fail to see the value they would receive from engaging with the PID [11, 19, 49]. Many HCI studies have investigated these challenges and focused on coming up with mechanisms, for example, for overcoming the display blindness effect that has been used to explain users' lack of engagement. The study presented in this paper is the first to systematically review previous work alongside our own case studies across five countries. As such, the paper extends previously published in-the-wild studies of PIDs, which usually report on the findings from one particular study.

Through our systematic analysis of literature on PIDs and a review of our own PID deployments, we uncovered 9 aspects that contribute towards value. All the studies included in our literature analysis involved an in-the-wild deployment of a PID. Each of the studies had their own goals and used different methods of evaluating their PID deployments. This included evaluating an interaction method (8 papers), user engagement (12 papers) − understanding the honeypot effect, display blindness, user behaviour, text readability, and the effects of a narrative −, community engagement (4 papers), and crowdsourcing content (1 papers). To achieve their goals, these papers used a variety of research study methods, such as interviews, observations, and questionnaires. In-situ observations were the most commonly performed, followed by interviews and video observations.

Through the identified design recommendations, our study contributes to a wider body of work that has developed models for the design of public displays and PIDs [33, 54, 57]. Each of those models capture particular concerns that contribute to the success of public displays and PIDs, such as optimising them for community participation [54], considering the physical context [57], and the practicalities of deployment [33].

The requirement for a PID − like any other interactive system − to offer value to its users, is inherently common sense. However, getting this right is especially challenging when designing systems in urban environments such as PIDs given the complexity of public space, and the transient nature of space and the people passing through it. As such, the novelty of the identified design recommendations is their ability to provide synthesised, structured guidance. The design recommendations highlight the importance of placing the value that a PID delivers at the centre of the design and deployment process, while offering grounded guidance for achieving this.

Relevance of PIDs for Communities

From the reviewed literature and our own cases it appears PIDs have demonstrated potential at being a useful for communities, giving the people within them a tool to collaborate with others and creating a visual identity for their respective communities. Specifically, PIDs have been appropriated for community activities such as collecting opinions from locals around a topic that affects them [14, 41, 55], providing information [42], and bringing people together through playful interactions [45, 61]. Furthermore, PIDs have the potential to reach broader cross sections of the community [32], giving a voice to people who do not actively participate in community events and those who may not have access to other mediums, like smartphones and the internet.

Limitations

Despite our best efforts to include relevant HCI studies of PIDs, we may have omitted some studies due to our selection process. The factors, aspects and design recommendations presented in this paper are limited by our selection process, of both the studies from the literature as well as our own case studies. Adding further studies to our data set may reveal additional factors, aspects and design recommendations. As such, the design recommendations are not generalisable, but rather present a current snapshot with its boundaries being determined by our methodological approach. Furthermore, given the wide range and types of PIDs used in HCI studies (Table 1), not every design recommendation is necessarily relevant for each PID design and deployment. Like other design recommendations for in-the-wild situations, our recommendations can only provide guidance but are not able to replace the need for carefully considering and understanding the particular context of a PID deployment.

CONCLUSION

In this paper we presented a thematic analysis of previous in-the-wild studies of PIDs, which led to the identification of 4 overlapping factors: people, location, community, and time; and 9 aspects: trust, privacy, relevance, appropriation, ownership, location, collaboration, identity, and time. Through these factors and their associated aspects, we derived 8 design recommendations with the aim to offer a tool for identifying and maximising the value that PIDs offer to their users. As such, the paper contributes to HCI research on PIDs by (1) synthesising related work and (2) deriving design recommendations. The recommendations extend previous work as they are based on a systematic literature review as well as 5 of our own PID deployments. They offer a more holistic and broader consideration compared to other, previously published design recommendations for PIDs, which are usually based on the findings from one particular study. Our analysis particularly revealed that previous work as well as our own case studies often explore the use of PIDs for or within communities. Our design recommendations, and their focus on considering the value of a PID, offer guidance for how such community-oriented PIDs should be designed and deployed to remain relevant to a local community.

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