Evidence based urban design and planning support benefits from providing designers with multi-source, multi-scale and multi-time information, which is both 'big' and 'small', and quantitative and qualitative. We are developing a platform, namely Informed Design Platform, that adopts a (big) data driven approach to derive insights and principles in order to adaptively design or re-design various forms of urban public spaces based on usage patterns and perceptions of the public. This platform is designed using a four step methodology of data collection, integration, analysis, and visualization. Multi-source data is integrated based on three analysis dimensions: place, time and people; and four analysis pillars: utilization, activity, opinion and sensing. This paper describes the aims, the design principles, and partial results of development of this platform.

Keywords: Evidence based urban design, Multi-modal data, Information modeling, Information visualization

INTRODUCTION
This paper presents the design of a digital platform, namely Informed Design Platform (IDP), for offering designers and planners a deep understanding of use and usage patterns of pedestrian public spaces in a dense urban environment.

The use of data in the building and urban design processes is not new, as design is a highly data and information driven and complex process, where the data entails many relationships and interdependencies. Furthermore, many actors and disciplines contribute their specific knowledge and information in these processes. Designers must consider a large number of issues belonging to a wide spectrum. Technology is more than ever available for providing designers with real-time data and information about many aspects of our environment, with the potential of being used in design processes to improve our built environment (Batty, 2013). The term 'smart cities' has become widely familiar in the last years among designers, planners, engineers, and policy makers (Albino et al., 2015; Kitchin, 2014). Some literature portrays a cheerful vision of a city that employs wireless and internet-enabled technologies to promise good performance and effective use of resources. In this view, smart cities are considered to foster new knowledge-based economies that are en-
environmentally and socially sustainable, well governed, and resilient. However, technology itself can’t automatically transform and improve cities and the lives of their inhabitants.

The use of ‘big data’ as an enabler of the smart city vision is a reality in our cities. Some of the characteristics of big data are volume (a huge amount of data), variability (heterogeneous and often unstructured formats of data), and velocity (an almost real-time processing of incoming data) (Laney, 2001). We claim that the most important characteristic of big data in the context of design support is variability, as designers switch between various scales, frame and solve various problems consecutively, and even simultaneously. Therefore providing designers with multi-source, multi-scale and multi-time information, or evidence, is an important contribution of big data to design support.

When designers make design decisions, apart from their knowledge and experience, they rely on assumptions about users and use cases. Evidence based design support is a field that is often used in urban design (Faludi and Waterhout, 2006; Chong et al., 2010; Khan and Kiani, 2012). Designers use evidence from existing situations in projects in order to gain insights to improve these projects and gain insights for new designs. However, having an access to evidence related to certain design needs and requirements does not lead to a linear translation of evidence to design solutions, as design is an open ended endeavor with many unrelated inputs and many preconceptions. Evidence based design support can, however, replace some of the assumptions made during design by grounded evidence. For instance, having an access to multimodal data on an analysis of user, usage, and perception information of public places in dense urban environments can provide designers with valuable evidence. Rather than considering a typical user, we can have evidence about a whole number of users with their own preferences, desires and behavioral patterns, such that a public space design can be responsive to each and every one of these users, at the same time or over time. The research challenge lies in finding out which behavioral hypotheses can be drawn from specific urban data sets and their combination, and understanding the relationship of these hypotheses with spatial and organizational aspects of urban spaces.

Urban big data encompasses various sources for data, including sensor data for all types of urban infrastructures, real-time transport tracking data, social network data containing information about events or opinions, public app data, phone data, and open data provided by government agencies, such as air pollution data, crime data, meteorological data, and land usage data. Additionally, user volunteered data, including geographic data, contributes to the bottom-up formation of publicly available data sets (Mark, 2013). Such new data sources enable new and innovative ways of urban analysis and design support, complementing conventional sources such as behavioral surveys (Balaban and Tunçer, 2016; Tomarchio et al., 2016; You and Tunçer, 2016).

Our approach is to use these technologies to foster evidence-based design, and translate the rich and varied information sources into design support means. Another goal is to use these technologies to increase public participation in decision making in a meaningful way, taking subjective perceptions and opinions of users into account, together with measured and objective facts (Mark, 2013). We aim to take advantage of new and abundant forms of data, sensing technologies, and possibilities for interaction among people, communities and their physical environments.

This research project is carried out by a multidisciplinary group consisting of architects, engineers, data scientists, and social scientists. The project has a site that consists of residential, transport and commercial zones, that we use as a test-bed area for this research.

INFORMED DESIGN PLATFORM
This section describes IDP, which presents 2D Maps and 3D models, information visualizations, and is supported by an information model that integrates
multi-source, multi-scale, multi-time data, that is both ‘big’ and ‘small’, and both qualitative and quantitative. The project as part of which IDP is developed adopts a (big) data driven approach to derive insights and principles in order to adaptively design or re-design various forms of urban public spaces based on usage patterns and perceptions of the public. The ultimate goal is to improve the quality of public space by improving the current and future use, function and usability of spaces.

Therefore, we have defined three sub-goals:

1. Create support for designers: We collect multi-modal data about people’s use of spaces, people’s perception and opinion of spaces, and physical conditions of spaces. We integrate this data, and derive insights relevant for designers related to these spaces, and visualize these in the Informed Design Platform (IDP) prototype that we are developing.

2. Develop methods and techniques: Multi-source, multi-scale and multi-time data collection and analysis for design support and deriving design related insights is a field that is little explored. Many research efforts focus on a single or a few data sources in support of design. In this project we are exploring how various rich data sources can serve designers in a meaningful way.

3. Contribute to scientific knowledge: We are contributing knowledge in the field of evidence based design support, specifically related to the relationships between use of space, users’ opinions about space, and physical conditions of space.

When designers design urban spaces, they build on a number of factors, such as site, brief for the project, existing space network, characteristics of potential users, climate patterns, landscaping options, etc. We have conducted in depth interviews with experienced designers of public spaces, and these have revealed that designers take a number of factors into account when adaptively (re)designing public spaces, such as climate and weather, cultural factors, demographic factors, physical characteristics of the space, environmental/situational characteristics, and users’ impressions of the space.

IDP integrates data collected from a variety of sources and presents 2D maps, 3D models and a number of information visualizations (Figure 1), addressing questions that designers are likely to ask, such as:

- Which spaces are being used, how, how much, by whom (demographics)?
- Do the spaces contribute to their users’ perception of livability?
- Are any spaces over- or under-utilized?
- What can be additional/alternative uses for spaces that increase liveliness and user appreciation?

In this context, the methodology that we follow in this research project concerns four main steps.

Step 1 is **data collection**. We mainly focus on three categories of data. The first one is user behaviour and opinion data. We use big and small data to understand how users utilize and behave in urban public places, using social media data, mobile phone data, sensor data, app data, observations, workshops, and interviews. The second one is data on physical comfort of users of urban public places. This relates to thermal comfort and environmental comfort. This is measured using specifically collected data sets of climate and environmental parameters, obtained by a variety of sensors, in addition to questionnaires and workshops. The third and final data category is urban analysis and mapping of functions and physical characteristics of spaces. This involves conducting spatial analysis and mapping, and examining the typologies of urban public spaces, using analysis methodologies such as space syntax, catchment area analysis, and functional analysis. Additionally, we analyse individual properties of places, such as the placement of urban greenery, furniture, shadow studies, etc.
Specifically, IDP uses the following data:

1. We have conducted questionnaires, interviews and workshops with users on site.
2. We have established a sensor network on various points of interest on the site. The sensors are weather, environmental, and people counting sensors.
3. We have developed a smartphone app, which tracks the mobility and activities of its users. This app also has an active data collection portion, where users are able to rate spaces according to various dimensions of our inquiry into livability, in order to receive a subjective perceptual evaluation of public spaces that users visit.
4. We have access to mobile phone data, in order to detect coarse population-level human flow patterns on site, footfall in selected areas, and associated demographic attributes.
5. We collected social media data (currently Twitter and Instagram) and perform sentiment analysis (positive, neutral, negative) on the geo-tagged feeds.

Step 2 is **data integration**. Multi-source data are integrated based on three analysis dimensions, namely Place, Time and People.

Step 3 is **data analysis**. We defined four analysis measures, namely Utilization, Activity, Opinion and Sensing. Based on the three analysis dimensions, related analysis is made to mine insights from the data for informed design.
This structure enables users of IDP to explore the site and the body of evidence derived on the site in various ways (Figure 2). Users may start from any of the analysis dimensions, place, time, or people. Place can be a specific location (e.g., a covered pavilion) or place type (e.g., all covered pavilions). Time can be a specific day and time range (e.g., June 6, 2017, 2-4pm) or a predefined time range (e.g., weekends). People refer to demographic attributes, such as age ranges, gender, and ethnicity. Users may also select any combination of these three dimensions, such as places and time (e.g., playgrounds during weekday afternoons between 3-5pm), places and people (e.g., covered pavilions, people above 50 years old), time and people (e.g., women, Mondays), or place, time, and people (e.g., a specific playground, children under 15 and elderly above 50, and weekday afternoons between 3-6pm).

After this selection, users may combine this selection with one or more analysis pillars. The specific selection made above will determine the filtering of data for each analysis pillar selected. Utilization selects data related to the utilization patterns. Activity selects data about activities of users. Opinion data selects user opinions. Sensing data selects environmental and weather related information. The only combination that will not generate results is people and sensing, as demographic data of users about sensor data is not available.

Figure 3 presents the various data sets that contribute data for the analysis pillars, and a subset of available information categories. App, survey, social media, and workshops contribute to activity. Sensor, app, survey, workshop, phone, and social network data contribute to utilization. App, survey, workshop, and social network data contribute to opinion. Sensor data contributes to sensing.

Insights related to places and place types are integrated in IDP. We derive these from the individual insights from various data sets, as well as a combination of data sets using the above model. These insights are produced using multi-dimension and multi-measure analysis methods.

For example, a combination of People, Places, and Utilization produces insights related to which places (or place types) are utilized by which demographics (age, gender, ethnicity), and the derived insights include additional information regarding family structures associated with such demographics. A design insight from this is the comparison of presumed design intent of a specific place or place type in terms of target users compared to actual use by demographics.

We have demonstrated analyzed data and derived insights from various data sets regarding the place type "coffeeshop". As described above, in IDP we integrate all data and insights using the analysis data model presented in Figure 4. For the coffeeshop, we present all opinion data (survey, workshop, app, social network) together with the utilization data (sensor, app, social network, telco) through the configuration of time and people analysis dimensions. We derive insights about coffeeshops related to:

- their proximity to other amenities (e.g., grocery store, playground, clinic) related to their utilization volume and frequency
- usage patterns related to insights about social behavior occurring there derived from group configurations and activities, and demographics
- design and maintenance recommendations derived from opinion data related to temporal utilization distributions
Figure 3
Various data sets that contribute data for the analysis pillars, and a subset of available information categories.
Step 4 is **data visualization**. Insights are visualized through intuitive analysis charts and analysis maps implemented by IDP. The IDP interface consists of 3 parts, 1) on the left, there is a list of analysis measures for users to select; 2) on the top, there are three configurators for users to set values of “Place”, “Time” and “People” analysis dimensions; and 3) in the middle, there is an analysis chart on the right and an analysis map or model on the left to present extracted knowledge intuitively (Figure 4).

The visualizations that we use to represent all this information and insights are at the moment being implemented. In addition to charts and dashboard type panels, we are using various data visualization techniques: heat maps, 3D surface plots, animated visualizations for trajectories and many other time sequence related information.

**CONCLUSION**

This paper advocates the view that urban design support benefits from providing designers with multi-source, multi-scale and multi-time information, which is both ‘big’ and ‘small’, and quantitative and qualitative. IDP is currently under development, and aims to provide designers with evidence in order to adaptively (re)design public spaces. A description and evaluation of the use of IDP in a real design context will be provided in a future paper.

This approach has many limitations. The data collected may not represent all users of the selected site. Additionally, the evidence and insights derived don’t shed light on many design parameters that are very important for design. However, in order to have a deep understanding of both real and perceived utilization and appreciation of existing public spaces, and starting to relate these to physical attributes of places is a promising direction, and developing the methodology and technical infrastructure for this is an important contribution.

A future research direction is the formalization and encoding of a part of the insights and evidence derived from the data collection, integration and
analysis process into a design environment, where designers can use this evidence in the design of new public places within similar contexts.

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