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Master thesis

Design and development of location-based mobile city dashboard

Rima Gebran

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Design and development of location-based mobile city dashboard

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Author:	Rima Gebran
Study course:	Cartography M.Sc.
Supervisor:	M.Sc. Edyta P. Bogucka (TUM)
Reviewer:	M.Sc. Moris Zahtila (TUD)

Chair of the Thesis
Assessment Board: Prof. Dr. Liqiu Meng

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Statement of Authorship

Herewith I declare that I am the sole author of the submitted Master's thesis entitled:

"Design and development of location-based mobile city dashboard"

I have fully referenced the ideas and work of others, whether published or unpublished. Literal or analogous citations are clearly marked as such.

Munich, 10.09.2019 Rima Gebran

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Abstract

The volume of open data produced by smart cities brings a fundamental challenge into the modern world. To address this problem a new form of data visualization emerged – a city dashboard. City dashboards transform heterogeneous data into a set of indicators and share it with citizens through online, interactive data visualizations.

The aim of this research is to build an urban dashboard prototype for the city of Beirut. The work begins with a literature review composed by a framework describing the characteristics of city dashboards and smart cities followed by a perspective upon urban transformations. Then an investigation of the role of existing dashboards is initiated by extracting displayed topics of existing dashboards. The next steps involve identifying platforms used to implement them as well as examining their usefulness by conducting a user questionnaire.

The results of these investigations are the basis for the conceptual development of an alternative to existing urban dashboards. A creative view of mapping in the context of urban transformation is explored due to the changing nature of spatial and temporal structures in today's world. The proposed prototype explores a new design space for city dashboards.

Keywords: dashboards; cities; city dashboard; indicators; visualizations; urban transformations; design

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1. Introduction

1.1 Motivation and problem statement

Urban dashboards have developed in the last few years as a visual language through which the smart city is represented. Stephen Few, founder of the visual business intelligence and sense making consultancy Perceptual Edge, defines the dashboard as a "visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance" (Few & Analytics, 2013). This information can be and often is a set of key performance indicators (KPI), defined as "a quantifiable measure used to evaluate the success of an organization, employee, etc. in meeting objectives for performance" (Oxford's English Dictionary, 2019).

Urban dashboards took the concept of cybernetic control centers, where operators could monitor the behavior of a city in real-time and react to stabilize unsteady situations (Adolfsson, 2014, Figure 1). Project "Cybersyn" was one such operation room established in the 1970s. It meant to serve the high-level bureaucrats to monitor all aspects of Chile's economy from a single chair (Medina, 2014, Figure 2). The following image exhibits the hexagonal room conceived by designers from Chile's industrial design group. A lot of cities maintain the traffic control centers occupied with television screens displaying data visualizations in order to detect road congestion and accidents. IBM evolved the concept into a massive control room in Rio de Janeiro, where the city can understand and control all emergency services (Batty, 2015, Figure 3).

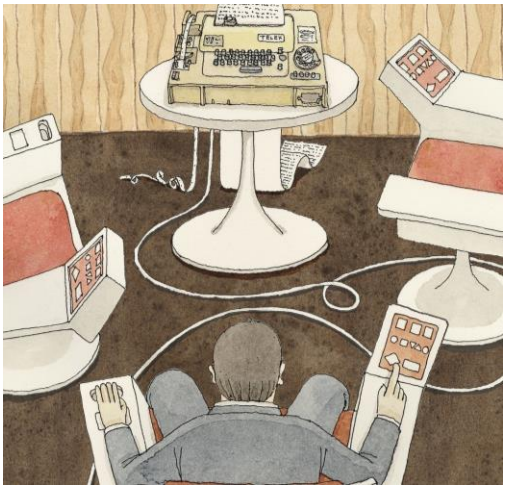


Figure 1: A futuristic room
(Adolfsson, 2014)

Figure 2: "Cybersyn" control room
(Fischer, 2014)

Figure 3: Rio city hall operations center
(The city of Rio De Janeiro, 2012)

The concept of the control room has been now taken out of the physical space and made available for anyone anywhere using their computer screens or mobile device screens. Nowadays, a city dashboard operates like a car dashboard or plane cockpit display providing critical information in a single view (Gray, Milton, & Hudson-Smith, 2013). These city dashboards display real-time and historical data visualizations together with interactive maps, what intends to help citizens with their own decision-making in the same way widgets representing a business's "key performance indicators": cash flow, stocks, inventory. However, an urban dashboard is not a display that is used for analysis, nor a report that people use to look up a set of information for hours. It should be thought of as an information display designed to allow people maintain situation awareness (Few & Analytics, 2013). Koolhaas (2014) argues, that these visual displays do not take into consideration the real needs of the citizens:

"(…) When we look at the visual language through which the smart city is represented, it is typically with simplistic, child-like rounded edges and bright colors. The citizens the smart city claims to serve are treated like infants. We are fed cute icons of urban life, integrated with harmless devices, cohering into pleasant diagrams in which citizens and business are surrounded by more and more circles of service that create bubbles of control (…)" (Koolhaas, 2014).

The ambiguous notion of a smart city makes it even more confusing to try to find out the correct way to measure the performance of a city. Many approaches have been developed so far to create urban dashboards and usually the existing indicators are often not standardized across cities. The variety of indicators lacks consistency and comparability (Mavric & Bobek, 2015). The lack of a clear and widely usable definition makes it difficult to compare urban dashboards and due to this fact, there is no one correct way to follow to build one.

Therefore, there is a strong need of research on how a city dashboard should be built, look and what other set of indicators it might need to achieve its main functionality. Several online-available dashboards are not visually pleasing, and it is unclear how and if the citizens are utilizing them in their daily life. Also, the map capability to display information is certainly not a new idea in the dashboard world, as it is one of the most familiar ways a user could look at data. However, how the user is supposed to use this information is still an open question. Sarikaya et al. (2019) point out the lack of further storytelling support in such dashboards, as current maps show an updated status-quo of different, rather technical aspects of the city (e.g. air pollution, stocks).

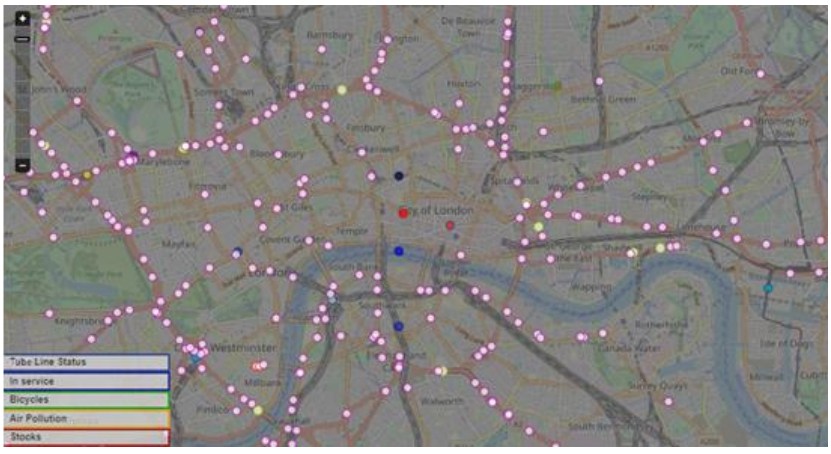


Figure 4: The London dashboard map
(Appendix A)

1.2 Research identification and research objectives

The main objective of this thesis is to propose an alternative to existing urban dashboards which gives a deeper insight into the evolution of the city and implements a bottom-up approach for informal exploration of the city according to the needs of people.

The main objective consists of two sub-objectives:

Sub-objective 1

To investigate the role of existing urban dashboards.

To address the sub-objective 1, the following research questions have been developed:

- RQ 1: What topics are displayed in existing urban dashboards?
- RQ 2: Do existing urban dashboards show urban transformations? If yes, how?
- RQ 3: What platforms are used to implement existing city dashboards?
- RQ 4: What aspects of urban dashboards do citizens find useful?

Sub-objective 2

To develop a new approach where urban dashboards inform the citizen about past, present and future scenarios transforming the city and offers the citizen the opportunity to be actively engaged in the planning of the city.

The sub-objective 2 consist of the following research questions:

- RQ 1: How to visualize existing small-scale urban transformations in urban dashboards?
- RQ 2: How to visualize current and future urban transformations in urban dashboards?
- RQ 3: What functionalities would allow an active participation of citizens?

2. Theoretical background and state of the art

This chapter presents a literature review that acts as a theoretical foundation to the development of this thesis. The chapter initiates with a brief description of dashboards and smart cities followed by the notion of dashboards in favor of smart cities. This section ends with providing insights concerning various aspects of city dashboards such as: dashboard indicators, dashboard visualizations and real-time dashboards. The second section act as an inspirational substance for the new approach by tackling notions such as urban transformations and hidden transformations. At the end of this chapter, a definition table is provided in order to explain redundant terms.

2.1 The genre of dashboards and its role for smart city services

2.1.1 Defining dashboard as a visualization genre

Visualizations effectively communicate the structure, pattern and trends of data. A visualization is not just describing or displaying the data, but it can also be used as a visual analytical tool to gather information and build visual models (Kohlhammer et al., 2011). Due to the immense amount of information that is created every day, it is challenging to find ways to make this information accessible and to make sense out of it (Tufte, 2015). One way is to adapt the continuously evolving cartographic animation techniques, yet, their ability to achieve success relies on the nature of transformations and the scale at which their taking place (Robinson et al., 2017). Displaying every possible transformation at once might result in a messy graphical presentation, however generating summaries might be the right solution (Robinson et al., 2017).

The term dashboard is widely used to refer to various kinds of creations, what causes problems in giving the term a permanent definition (Sarikaya et al., 2019). The countless visualization technologies available to the public has broadened the dashboard implementation to new domains. The dashboard concept has been evolving from single-view reporting displays to include interactive interfaces with many views and purposes, while holding to the notion of monitoring and decision support (Sarikaya et al., 2019).

On one hand, Few defines dashboards as: “a predominantly visual information display that people use to rapidly monitor current conditions that require a timely response to fulfill a specific role” (Few, 2017). Few’s definition supports the visual genre of dashboards – a single page dashboard, where visualized data is structured as a tiled layout of simple charts, graphs and numbers. On another hand, Wexler, Shaffer and Cotgreave provide a wider definition: dashboard is “a visual display of data used to monitor conditions and/or facilitate understanding” (Wexler, Shaffer, & Cotgreave, 2017). The definition of Wexler et al. supports the functional genre of dashboards, which involves interactive displays that enables real-time monitoring and embraces narrative visualizations.

A dashboard is an example of a powerful visual tool leading people toward effective decisions. Dashboards could possibly be part of the solution through their capability to stream visual summaries of geospatial big data (Few, 2006). A dashboard should support people’s visual capabilities by applying design principles of visual perception. As part of this challenge is the necessity for design guidelines for summary maps that could easily describe geospatial big data (Robinson et al., 2017).

2.1.2 Defining and quantifying the smart city

The concept of a smart city is relatively a new concept launched by a marketing campaign of an International Business Machines Corporation (IBM) in 2010. The campaign was the outcome of efforts of several large multinationals in order to generate a new city market for their technologies and services (Kitchin, Maalsen, & McArdle, 2015). It was, however, the final stage in the evolution of what has been developed since the 1980s (Graham & Marvin, 1999) and has variously labelled as ‘wired cities’ (Dutton, Blumler, & Kraemer, 1987), ‘cyber cities’ (Graham & Marvin, 1999), ‘digital cities’ (Ishida & Kyoto Meeting on Digital, 2000), or ‘intelligent cities’ (Komninos, 2013). Even though the definition of smart cities is open, questioned and challenged within the literature, the smart city promoters agreed on one definition. According to this term, the smart city uses Information and Communications Technologies (ICTs), associated big data and data analytics to expand city services and to create new ones. The aim of new services is to involve citizens, to resolve urban issues, and to stimulate innovation (Kitchin, Maalsen, & McArdle, 2015).

The limitless amount of urban data makes the selection of key performance a hard task. Therefore, smart cities utilize various indicators – quantitative, qualitative or descriptive measures (Huovila, Bosch, & Airaksinen, 2019). They have three main functionalities: quantification, simplification and communication (Huovila, Bosch, & Airaksinen, 2019). Indicators show trends and change when evaluated and monitored. Thus, city indicators support cities in tracking their performance and in setting their objectives (Huovila, Bosch, & Airaksinen, 2019). Another important utility in the use of indicators is to increase transparency towards citizens through city dashboards (Dameri, 2017). The quality of data provided by each indicator is of major significance. International Cartographic Association acknowledged the seven crucial data quality metrics, which are frequently used in urban dashboard in relation to spatial data: lineage, optional accuracy, attribute accuracy, completeness, logical consistency, semantic accuracy and temporal data (Guptill & Morrison, 2013).

The selection of suitable indicators depends on several aspects: spatial scale, time scale of evaluation and purpose of assessment (Huovila, Bosch, & Airaksinen, 2019). Cities should choose indicators corresponding to their own individual needs (Moreno Pires, Fidélis, & Ramos, 2014). But what happens when an interpretation based on quantifiable indicators gain control and becomes the key to knowing about what's happening in our cities today? De Lange (2018) argues, that if everything can be measured and quantified, some information is being excluded.

2.1.3 City dashboard as a platform to support the development of smart cities

As Goldsmith and Crawford write in *The Responsive City* (2014), today the capability to collect, analyze and to share information has an enormous potential to transform and to strengthen the governance of cities (Goldsmith & Crawford, 2014). Platforms such urban dashboards are one way to gather, process, visualize and share urban data. City dashboards are becoming more common as several cities adopted these platforms and invested in their development. City dashboards are focused on displaying data through graphics, maps, and 3D models to show information about the performance and trends of cities (Kitchin, Maalsen, & McArdle, 2015). The power of these dashboards is their ability to translate the complexities of cities to enable the citizens to know their cities as they are. However, dashboards suggest that the city is a simple system that acts in a rational,

linear and hierarchical way, which could be measured and controlled through algorithm, that could steer it much like a car is steered through its dashboard (Van Assche, Block, & Reynaert, 2010). Instead, cities are complex systems full of culture, social realities, discriminations, politics that cannot be easily controlled (Kitchin, Maalsen, & McArdle, 2015).

To capture one aspect of this complexity – real-time events – smart cities gained interest in developing real-time dashboards. Michael Batty mentions that until now there has been a limited progress in terms of shifting from real-time monitoring to some abstract interpretations regarding the mutating nature of a city over the long term (Batty, 2015). Algorithms detect what's unusual and standardize a response back so the unusual becomes homogenized and it is harder to notice any change. The fascination with real-time is hindering our full understanding of urban dynamics. Adam notes that the awareness of time is essential to understand how the social, the historical, the economic, the political and other aspects of our lives are interconnected (Adam, 2008). Architects, urban designers and urban planners aim at the creation of cities where the threat of spatial disorientation is almost non existing (Kevin, 2014). In contradiction, urban dashboards are advertised as stability and safety providers, while their added value depends on the growing speed of delivering information (Williams & Srnicek, 2013). This acceleration becomes an input for responsive or preventive actions instead of a way to better understand our cities and stimulate people's imagination (De Lange, 2018).

2.2 Urban transformations and their visualization

The city exists in its micro scale transformations, which interact, interconnect and interfere everyday forming the life of the city in its endless mutation, innovation and transgression (Iaconesi & Persico 2015). The present urban fabric is the result of successive generations of habitants who left their fingerprints in physical structure (Mishra & Pandit, 2013). People constantly reprogram spaces, time and relations forming a level of cultural biodiversity, which constitutes the prosperity and richness of the city (Iaconesi & Persico 2015). Gilles Clément describes the third landscape as an un-coded space, an inclusive model, a shared piece of a collective consciousness (Rocca, 2008). There are several physical informational elements which people experience when

interacting with cities such as visuals, architecture, sounds, smells and many others. Neil Postman argues that citizens are exposed to concerns such the quantity, the quality and the shape of information, whereas the problem is actually the impossibility to extract a meaning from the information and not the availability of information itself (Postman et al., 2013).

Transformations has strong spatial and temporal components. Physical transformations can improve the spatial quality of cities by applying a collective future vision and connecting long-term objectives with short term concerns (Beer, 2019). The online platform launched by “TransformCity” is a collective urban planning project which has benefited from donations from the municipality and the Dutch government (Bermond, 2017). The Dutch architect Saskia Beer explains that the platform enables everyone to suggest a project, to pin it on the platform map, to clarify the benefits and drawbacks and to discuss it with the authorities (Beer, 2019). The platform idea came from the initiative to revive the third district of Amsterdam– Amstel (Figure 5).

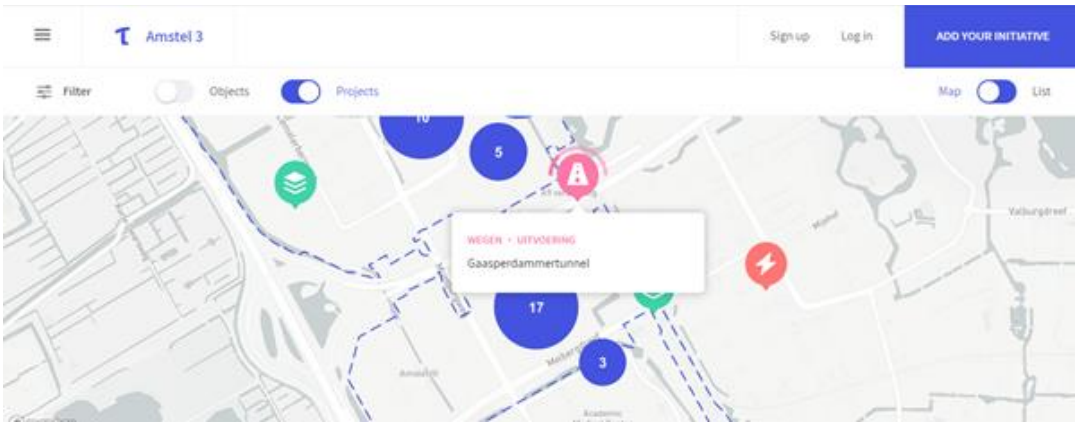


Figure 5: The view of the Transform City platform for Amstel 3 district
(ZO! City, 2019)

The spatial concept of a 'site' is shifting from simply defining parcels of land using geometrical dimensions of its corners. Instead, it is referred to as an active milieu, that has neither a beginning nor an end, and consists relations, extensions and potentials (Corner, 2002). Corner continues to wonder about the role of maps within the architectural imagination. He argues that for architects and urban designers, maps are sites for imaging and projecting alternative worlds, thus maps are in-between the virtual and the real (Corner, 2002). The map can display things which are currently invisible, but which

may appear. Thus mapping is not only an after process, but a process, which precedes urban transformations, searching and engendering new sets of possibility (Corner, 2002).

Urbanists such as David Harvey argue, that space is re-created constantly each time it's environment changes and each time it is encountered by new people. Thus, the experiences of space cannot be isolated from the events that occur in it (Harvey, 2010). Architect Peter Eisenman has worked on revealing the historical layers of transformations that are often visible in maps and not on the ground, Eisenman suggests that a project takes its future shape based on specific, unique local stories (Bédard & Balfour, 1994). One example of his work is the proposal of an art museum at the California State University at Long Beach, where he documented the site by searching through historical maps and discovering a number of significant historic events. He gathered these separate layers and transformed them into one composite assembly (Figure 6). Eisenman wites: "One recognizes in this project that architecture is about telling stories, and this stone text that is being written, this fiction, might tell a very different story about Long Beach than has ever been recorded before" (Bédard & Balfour, 1994).

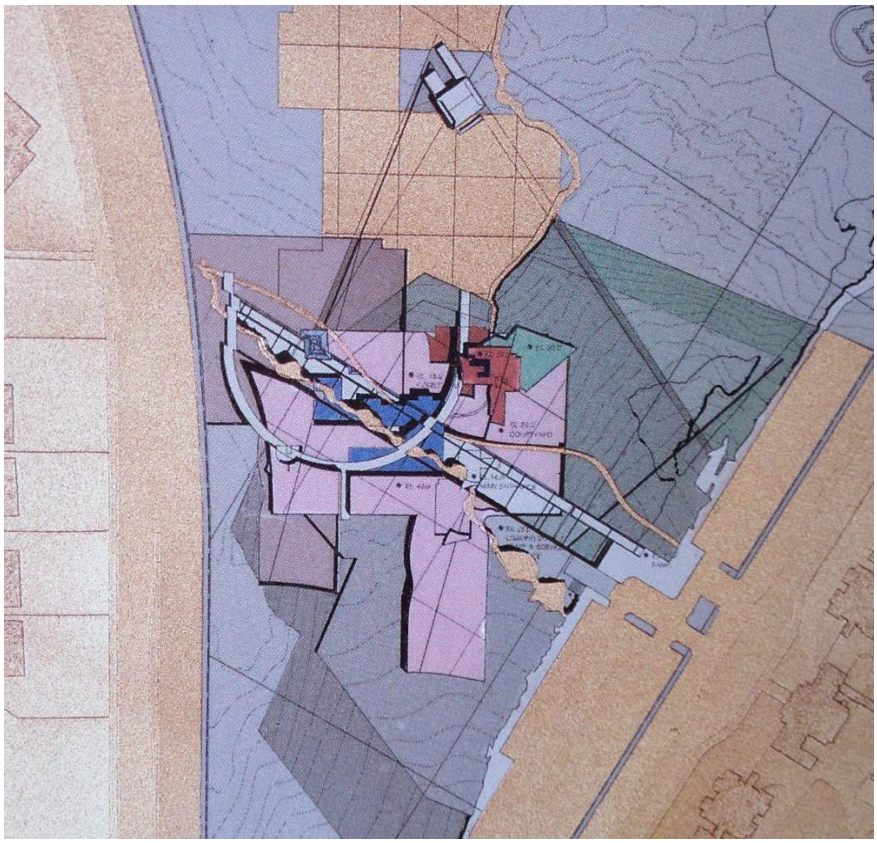


Figure 6: University Art Museum plan
(Eisenman, 1986)

2.3 Table of definitions

The table below explains the terms which are commonly used in this thesis.

Table 1: Table of definitions

Term	Definition	Source
Location-based service	"Location-based services (LBS) are computer applications (specifically, mobile computing applications) that provide information depending on the location of the device and the user, mostly through mobile portable devices (e.g., smartphones) and mobile networks"	(Huang & Gartner, 2018)
Mobile application	"The mobile application is a software application that is developed specifically for use on small, wireless computing devices, such as smartphones or tablet"	(IBM, 2019)
Neighborhood	"The medium-to-large sections of the city, conceived of having two-dimensional extent, which the observer mentally enters 'inside of,' and which are recognizable as having some common, identifying character. Always identifiable from the inside, they are also used for exterior reference if visible from the outside"	(Kevin, 2014)
Web application	"A web application is an application that runs on a server and presents its services to users through a web browser. The user interface consists of web pages, and the interaction is done via hyperlinks and web forms"	(Pop, 2002)

3. Methodology

The development of this thesis consists of three phases – from understanding the current design space of urban dashboards (A), through conceptual development (B) to implementation of the prototype of the new dashboard design (C). The purpose of these phases is to answer the research questions and to meet the main research goal of the thesis. The adopted methods for addressing research goals and research questions are performed in the following order and explained in subsections below:

A. Understanding the current design space of urban dashboards.

1. Comparative study: investigating the content of existing urban dashboards through collection of representative dashboard samples, data coding and data analysis.
2. User questionnaire: investigating the usability of existing dashboard products.

B. The discovery and the conceptual development through generating new urban dashboard designs and their representations.

C. Materializing:

3. Assessing the proposed concepts with the user evaluation.
4. Physical implementation: creating a final prototype.

3.1 The comparative study

The comparative study is conducted in order to investigate the role of existing urban dashboards and consists of three steps: (1) data collecting, (2) data coding, (3) and analyzing data. The results of the comparative study provide answer to research question 1 (sub-objective 1), research question 2 (sub-objective 1) and research question 3 (sub-objective 1) by completing the following milestones:

a) Data collection: gathering raw data on all possible implementations of urban dashboards. This step does not include any filtering, organizing or analysis processes.

b) Data coding: according to Corbin and Strauss (1990), coding is the process of concept labelling and categorizing, where ideas with identical phenomena are clustered into a category. Through the process of coding, the meaning of the data is grasped. The data coding phase consists of several stages:

- Stage 1: Initial coding.

  The process focuses on filtering large quantity of raw data. The procedure involves comparing data and continually asking question on “what is and is not a valid city dashboard?”. Thus, at the same time the identification of different invalid categories is performed.

- Stage 2: Theme-indicator coding.

  In the next step data are pieced together in new ways by allowing connections between categories. This is achieved by asking questions such as: “What is the content of collected dashboards?” and simultaneously making comparisons between different dashboard designs. This step results in extracting topics and topic indicators typical for urban dashboards.

- Stage 3: Focused coding and category development.

  The process results in identifying and choosing core categories by systematically connecting thematic coding classifications. This step involves validating similarities and relationships between dashboards and then completing the final definitions of categories.

c) Data analysis: further analysis emerging from thematic coding and category development is needed in order to answer to research question 2 (sub-objective 1) and research question 3 (sub-objective 1).

3.2 User questionnaire

The purpose of this questionnaire is to determine what aspects of urban dashboards citizens do find useful and therefore what are the needs of the citizens. The results of this questionnaire are used as requirements for the conceptual development of the mockup. The conducted questionnaire is a web-based survey and takes into consideration five methodological components of online survey: (1) presenting questions in a logical manner (Pitkow et al., 1996), (2) collecting quantified selection, option answers and narrative option answers (Yun & Trumbo, 2000), (3) supporting multiple platforms and browsers (Yun & Trumbo, 2000), (4) preventing numerous submissions (Yun & Trumbo, 2000), (5) and providing a thank you feedback (Smith, 2006). This form of gathering user’s feedback has been chosen due to the fact that web-based surveys offer the capability of conducting large-scale data collection (Couper, 2000).

3.3 Conceptual development

The conceptual design of the location-based mobile city dashboard is based on the questionnaire results and conclusions resulting from the comparative study. Therefore, this phase consists of prototyping an early design using previously mentioned insights to guide the design and development process. The conceptual development phase, the user evaluation phase and the physical implementation phase work altogether in order to answer sub-objective 2 in the best possible way.

The basic scheme for developing new ideas consists of concept generation and design representation. The creative process of concept generation involves the clarification of requirements and the recombination of ideas generated through the collection of information regarding the problem. The design representation includes selection of a design language such as sketches and prototypes. At this stage of the creation, different ways of innovation are considered. The main sources of innovation are stimulated through the users' needs and new technologies. Innovation might be for instance achieved by adopting a new form of technology.

3.4 Concept evaluation

After complementing the conceptual phase and before starting the physical implementation of the mockup, an online survey took place to collect feedback from the target users. Nielsen's (2009) influential work on usability engineering emphasizes the importance of iterative evaluation and revision during user-centered design. The user evaluation comprised a series of questions which revise the interface, the usability and utility of the conceptual design which is evaluated by acquiring feedback from the target users. According to Nielsen's definition (2019), a participatory design recruits a representative set of target users to take part in the conceptual design of the interface and the user requirements. And based on it, the research proceeds into the physical implementation.

3.5 Physical implementation

The last step consists of the practical development of the prototype. Prototyping creates a static or an interactive mockup of the interface which is referred to as “alpha release”; a partially-functional prototype, while a fully-functional prototype is referred to as a “beta release” (Nielsen, 2009). This phase revolves around the physical implementation of the conceptual design of phase B while taking into consideration phase A, to develop an alpha release in the form of a mobile device application.

3.6 Intended end-users

The intended users of the dashboard are the citizens, who are interested in finding what is happening in their city. The app can be accessed by every citizen who owns a smartphone. The implemented urban dashboard is citizen-centered and allows a direct communication between citizens and urban managers. It provides urban planners, architects, city managers and investors information to understand the citizen’s local needs.

4. Case study

This chapter focuses in applying in practice the steps described in the methodology chapter. As a case study for this thesis serves the city of Beirut.

4.1 Comparative study of urban dashboards

4.1.1 Dashboard sample selection

To conduct the study, a selection process was required as a mean to capture the variety of existing urban dashboard applications worldwide (Figure 7). The search in the Internet was conducted using the keywords “urban dashboard” and “city dashboard”. After performing the search, each dashboard was retrieved and inspected to make sure it was not out of scope of this research. Dashboards which did not communicated the city indicators and focused on isolated visualizations instead of connected multiples were excluded from the samples. Moreover, a sample dashboard was discarded if:

- it was still under technical construction,

- there was a lack of credibility, e.g., displayed data was not up-to-date,

- the tool was not accessible online or was of a very low quality e.g., constant site error.

In total 50 dashboards were obtained by running the query in the database. Out of these 41 dashboards passed the filtering process to the conceptualizing stage. The results of the selection process are presented in Appendix A.

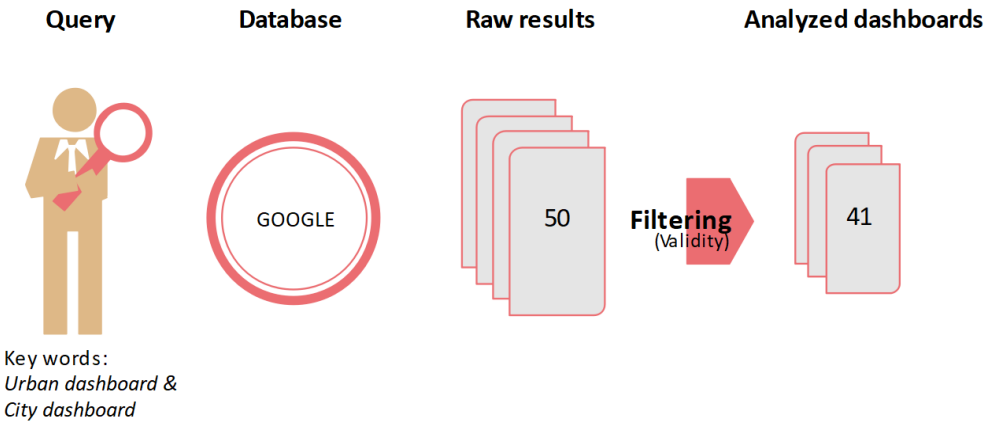


Figure 7: Selection process

4.1.2 Topics and indicators extraction

A data coding process was followed to depict the topics displayed within each dashboard. The result of this process is a defined set of topics and indicators which communicate the key dimensions of urban life: economic, social and environmental. Figure 8 presents the list of topics introduced in sample dashboards to communicate the performance of a city. The distribution of these topics among sample dashboards is presented in Appendix B.

Figure 9 briefly presents the topics which appear the most and the least often in existing city dashboards. The results show that existing urban dashboards cover mostly the environmental topics (80% of dashboards). Only slightly less important was the problem of livability (78%) and the third most popular topic was transportation and mobility (70%). The urban transformations have less significance and impact on the content of urban dashboards. Detailed indicators which were used to build the existing city dashboards are listed in the Figure 10.

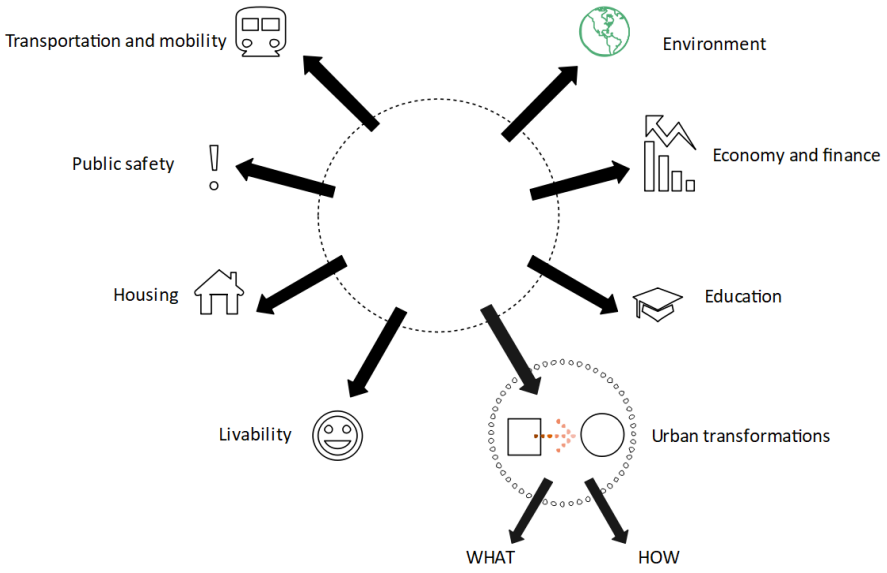


Figure 8: Topics covered in existing urban dashboards

	%
Transportation and mobility	70
Environment	80
Public safety	48
Economy and finance	41
Housing	19
Education	34
Livability	78
Urban transformations	12
	100

Figure 9: The coverage of topics in existing urban dashboards

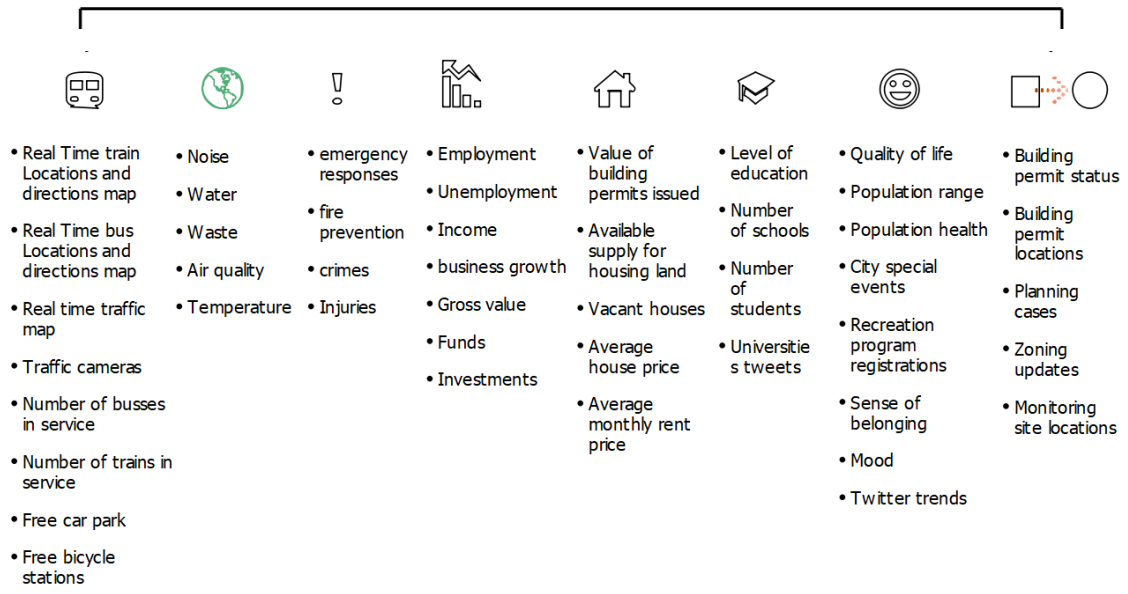


Figure 10:Typical indicators for each of the topics in the existing urban dashboards

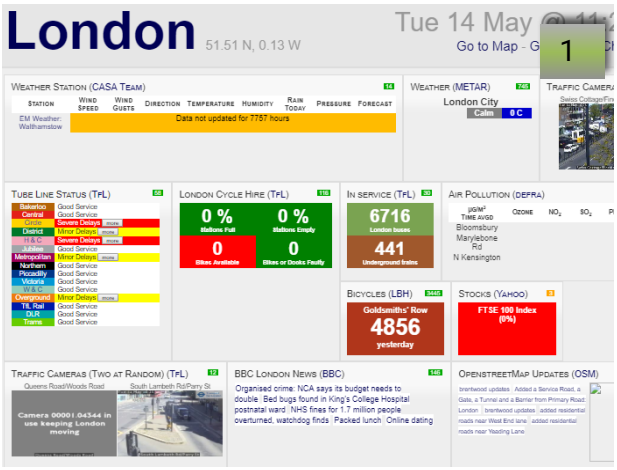
4.1.3 Typology of urban dashboards

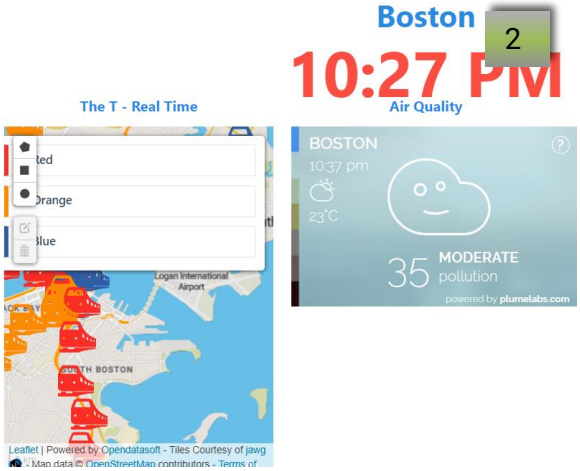
The selection of 10 different types of urban dashboards was based on the dashboard's content characteristics, understood as the kind of information delivered and the choice of the visual approach. These two components provide the user the chance to monitor the performance of the city. Table 2 presents the description of different types of existing urban dashboards, followed by one visual example from each category (Figure 11).

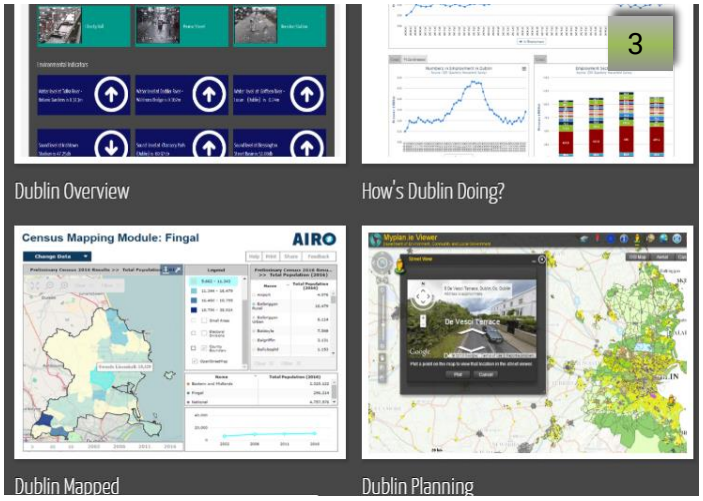
Dividing the cluster of dashboards into several dashboard types helped setting up the structure of the online survey that took place after the comparative study. To measure the usefulness of city dashboards, participants had to answer several questions. These questions made use of the main groups of urban dashboards to show tangible examples on existing dashboard types. The main part of the survey consisted of topic, visualization and usability questions. Topic questions made use of types 1,6,9 and 10. Visualization questions made use of types 4,7 and 8. Usability questions made use of type 3. (fig.11 the survey structure).

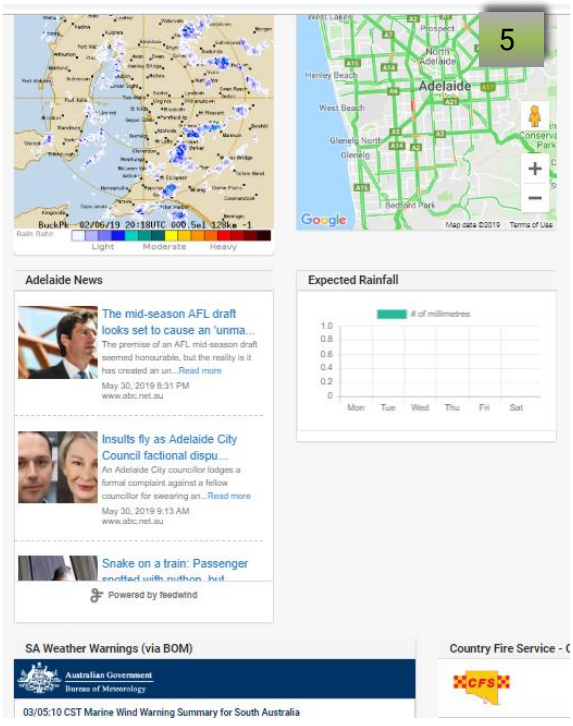
Table 2: Main groups of urban dashboards

TYPE 1	- All of these city dashboards share both a semiotic and a semantic aspect. - They aim to summarize quantitative data in a single screen. - Live feeds of real time data are being communicated to citizens. - The user has the ability to access a link provided by each module which links him to the initial data provider.	London Birmingham Brighton Cardiff Edinburgh Glasgow Leeds Manchester Sydney
TYPE 2	- All of these city dashboards provide a live, colour-changing visual data. Rather than simply providing the raw data, these sites produce visualisations that aid the interpretation process.	Florence Pisa Hong kong Boston
TYPE 3	- Both city dashboards were designed so that all available open data about the city. - The user is able to download data to do their own analysis or build their own apps. - Modules are first divided according to the different ways of data collection and then according to the different topics.	Cork Dublin
TYPE 4	- Both city dashboards provide three kind of data visualizations: tables, maps and charts. - Offer the user the freedom to navigate to the one of the visualization option he would like to explore, it depends if the user is trying to understand a relationship between a data set or he is looking into a single value.	Brussels Bristol
TYPE 5	- All of these city dashboards introduce scrolling into the dashboard layout. - The dashboard flows vertically not horizontally. - The dashboard introduces spacing between dashboard modules thus higher ratio of blank space.	Adelaide Canberra Gladstone Osaka Tokyo Taipei
TYPE 6	- All of these cities provide a performance dashboard with statistical data. -The dashboard is developed as a list of indicators. -The information is presented in an infographic format.	Dallas Guelph Syracuse Berkley Boulder San Diego Muskegon Niles Hamilton Toronto
TYPE 7	- This city dashboard is different from the others considering its use for gauges to visualize data. - Gauges track single metrics that have a clear objective. They compare a current value and a target value, which often indicates whether the progress is good or bad.	Lake Oswego
TYPE 8	- Both city dashboards use a map to analyze data across a city. - The dashboards require heavily the user interaction with the map. - It is possible to lay out all filtering options on one map.	Townsville Paris
TYPE 9	- Both city dashboards examine how an area is performing on different metrics and compared to other areas within the same city. - The type of data provided is not updated regularly compared to all other types of dashboard such as New York dashboard which is updated every 2 years.	Galway New York
TYPE 10	- Both city dashboards provide the citizens the opportunity to track the progress of infrastructure projects going on in the city. - An interactive map communicates building permit applications.	Columbia Raleigh









Municipal Performance Dashboard

6

Fiscal Stability

	2016	2017	Progress
Annual general fund expenditures per capita	$600	$626	↑
Fund balance as a percent of annual general fund expenditures	43.7%	42.6%	↓
Unfunded other post employment benefits (OPEB) liability as a percent of annual general fund revenue	53%	78%	↑
Debt burden per capita	$596	$470	↓
Percentage of road funding provided by the general fund	3.1%	3.6%	↑
Ratio of pensioners to employees	1.34	1.29	↓
Number of services delivered via cooperative venture	0	0	→
Unrestricted Net Assets as a % of Total Net Assets	14	-3	↓
Bond rating (Standard & Poor's)	N/A	N/A	

Public Safety

	2016	2017	Progress
Violent crimes per thousand	13.9	13.9	→
Property crimes per thousand	43	39	↓
Traffic injuries or fatalities	77	82	↑
Code Enforcement Related Property Inspections	3,429	3,340	↓
Building, Electrical & Mechanical Safety Permits	469	519	↑

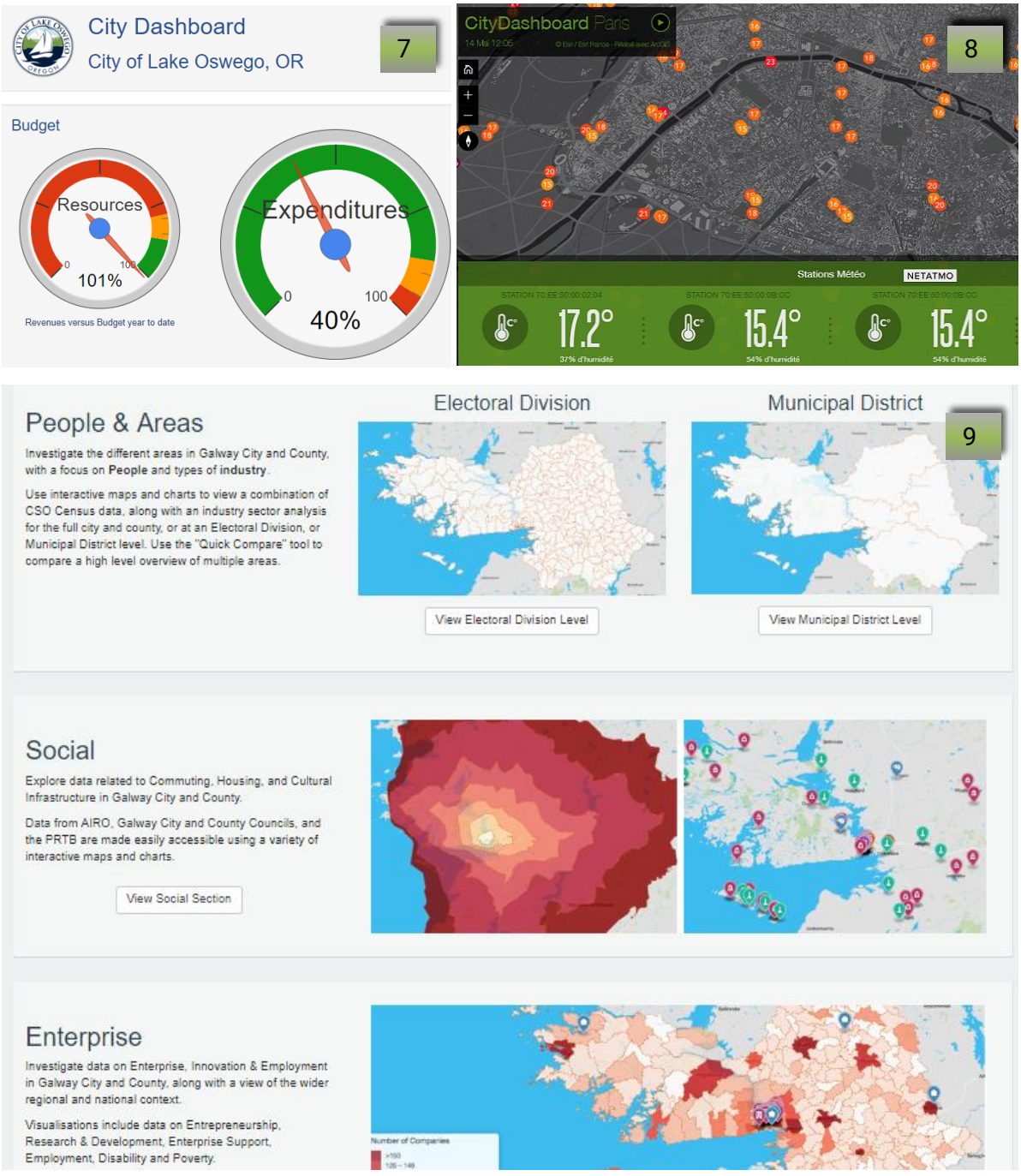


Figure 11: Collection of existing urban dashboards
(Appendix A)

4.1.4 Visualizing urban transformations in dashboards

A further analysis took place to gather data regarding urban transformation indicators. 5 dashboards out of 41 are displaying urban transformations taking place in the city. On Figure 13 the cities concerned are presented, followed by a short description of the transformation content. The images below provide a notion about the way these transformations were visualized.

Each of these dashboards show a different aspect of an urban transformation, either the legal aspect or the physical aspect or the functional aspect. None of them combine all aspects in a single view. All these examples use a map-based visualization in order to visualize urban transformations. The maps are tailored for this purpose, some use a pin to display the location of a transformation and others highlight the whole footprint of parcels in transformation. Paris, Cork and Dublin dashboards display these transformations as one indicator among a lot more. On the other hand, Columbia and Raleigh dashboards focus only on projects and developments, they provide information on approved cases, denied cases and cases under review. They fulfill a single aim which is informing the citizen about urban transformations. The content of urban dashboards is not compulsorily consisting of several unrelated topics; it is possible for a city dashboard to target one topic in detail.

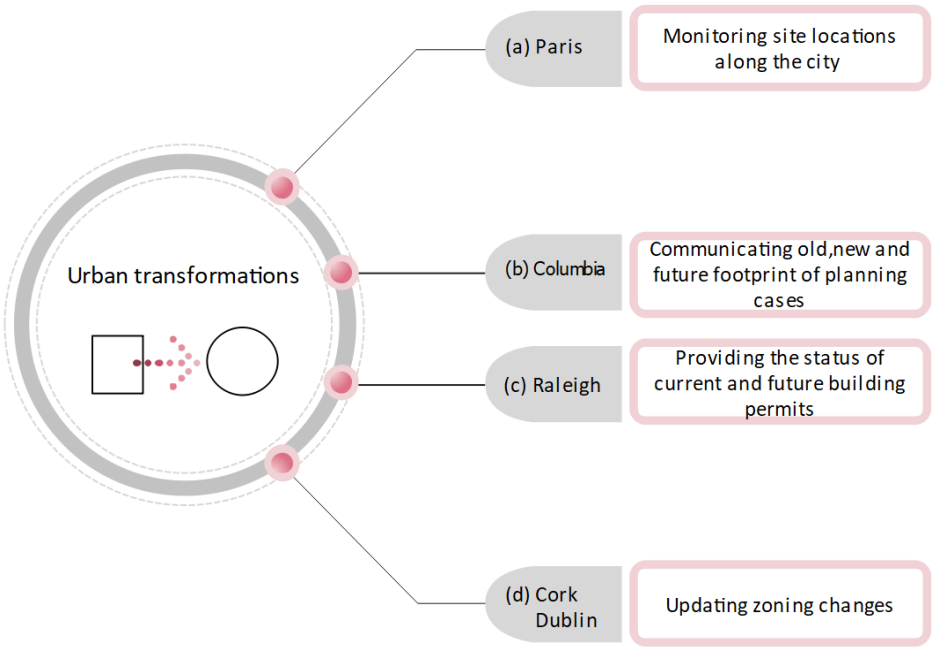


Figure 12: Urban transformations in existing urban dashboards

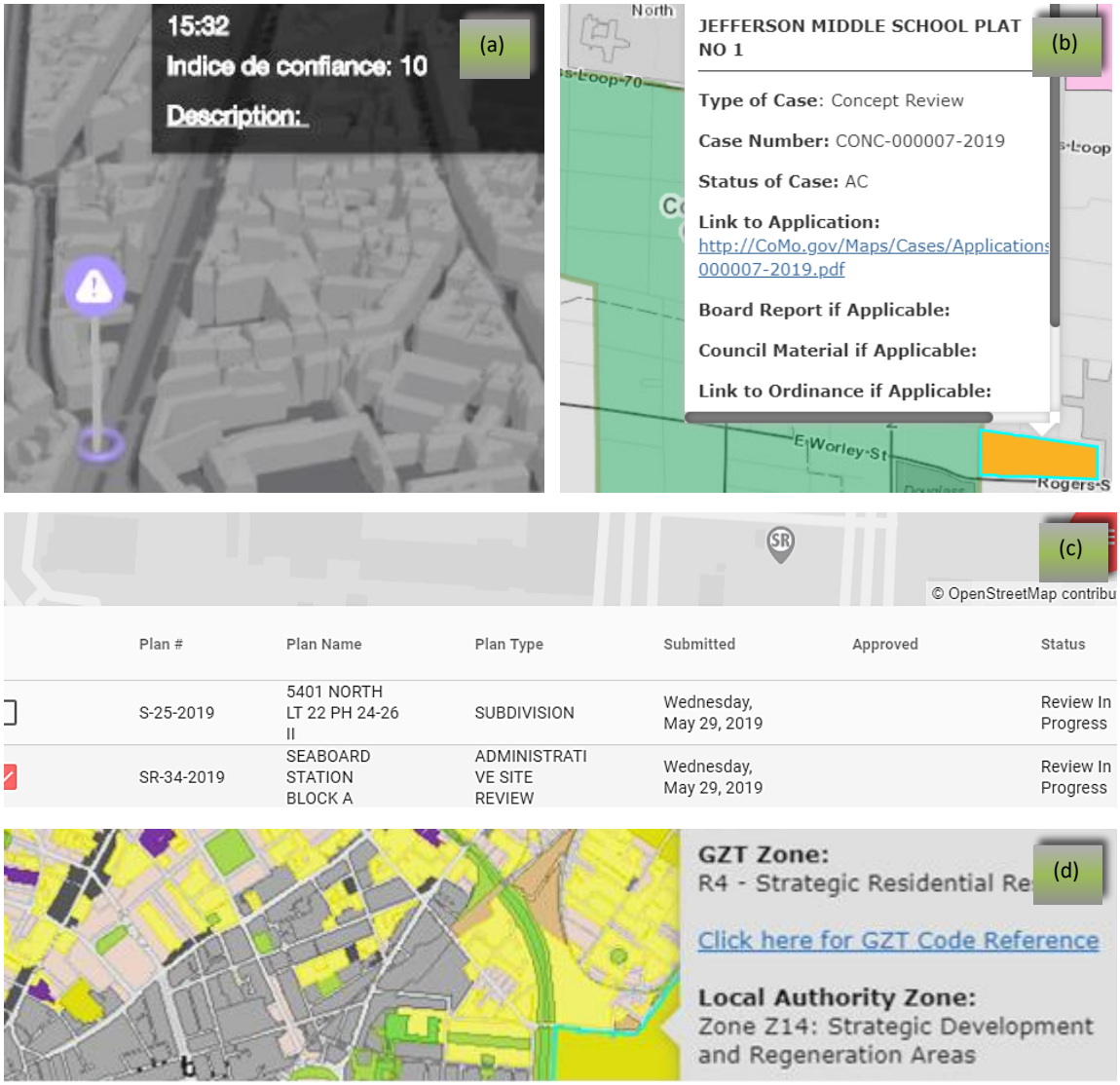


Figure 13: Collection of existing urban dashboards displaying urban transformations (Appendix A)

4.1.5 Platforms adopted for urban dashboard implementation

This section describes the adopted platforms, where the existing urban dashboards are implemented. All examined city dashboards are web-based dashboards - several have been implemented as web-applications and several as stand-alone websites.

A web-application is an interactive web-based dashboard consisting of separate, independent modules, for example, the Dublin Dashboard is organized into 12 modules. Each module contains embedded links to other portals, which provide access to the data from Dublin. Hence, the city dashboard of Dublin visualizes data collected and stored from various sources and gives the user access to the original sources. Web-application

dashboards integrate interactive web maps allowing the user to change zoom levels and to add and remove data layers (Figure 14).

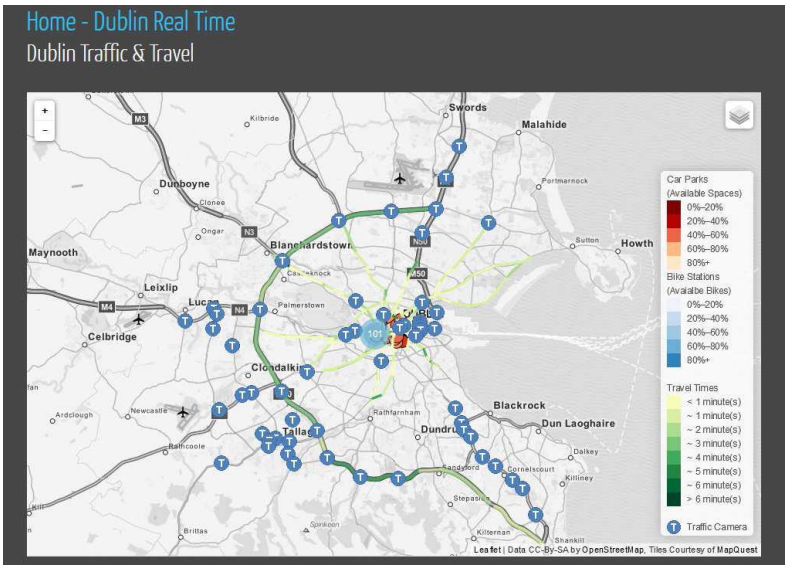
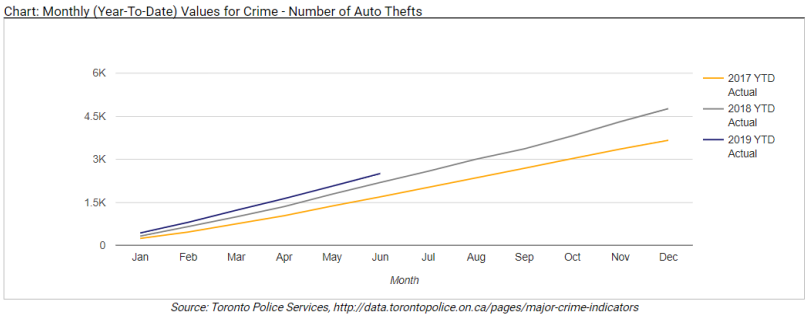


Figure 14: Real-time travel map for Dublin
(Appendix A)

Dashboards organized into a website assemble information for the users - they extract significant knowledge that meets users' needs and are easy to read. As an example can serve a city dashboard of Toronto. The dashboard measures the performance of a specific indicator in order to identify if the city is doing well or not. The dashboard includes the latest available data and compares it to previous years and provides the user the ability to request the output (Figure 15). Toronto's dashboard is far less responsive to user actions than Dublin's dashboard. Nevertheless, both dashboards are accessible via a web browser.



Source: Toronto Police Services, http://data.torontopolice.on.ca/pages/major-crime-indicators

Data Table: Monthly (Year-To-Date) Values for Crime - Number of Auto Thefts

Export Data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2017 YTD Actual	235	464	746	1,032	1,371	1,689	2,021	2,354	2,686	3,021	3,352	3,662
2018 YTD Actual	322	652	992	1,346	1,782	2,186	2,581	2,999	3,363	3,812	4,312	4,766
2019 YTD Actual	429	797	1,217	1,627	2,060	2,501						

Figure 15: Toronto's dashboard
(Appendix A)

4.2 The design of the user questionnaire

The user-questionnaire was conducted in order to assess the usefulness of existing urban dashboards and select the indicators that matter to the audience and to the defined goals (Figure 16, Appendix C). First, the questionnaire collects demographic data related to the user's age, sex and the city he lives in currently. The survey core consists of three-parts: topic questions, visualization questions and usability questions. Part 1 investigates the selection of proper indicators. This selection is crucial for the effectiveness of the dashboard and the data collected need to be comprehensive and representative so that the real world is described (De Marco, Mangano, & Zenezini, 2015). Part 2 investigates visuals, since one of the main tasks of building a dashboard is to choose the visualization that makes the given data meaningful. If the visual representations are not the correct ones, the dashboard is unable to be informative and useful. Part 3 investigates the dashboard usability. The accessibility of each indicator should be simple, easy to understand, and intuitive. Finally, at the end the survey people are invited to share their personal experience and feedback concerning city dashboards. The survey questions made use of the different types of analyzed dashboards as a way for the user to answer the questions based on the real-life examples. Various types of questions were implemented: close-ended questions (multiple choice, dropdown selection), a set of questions using a 5 and 7 point Kunin scale (from strongly disagree to strongly agree), a set of questions using the slider (labels at the slider ends min/max), a set of questions using the image scale (star rating) and a set of open-ended questions (free mentions). The questionnaire was deployed on the SoSci Survey platform and was distributed to many people regarding their age, their nationality or their profession.

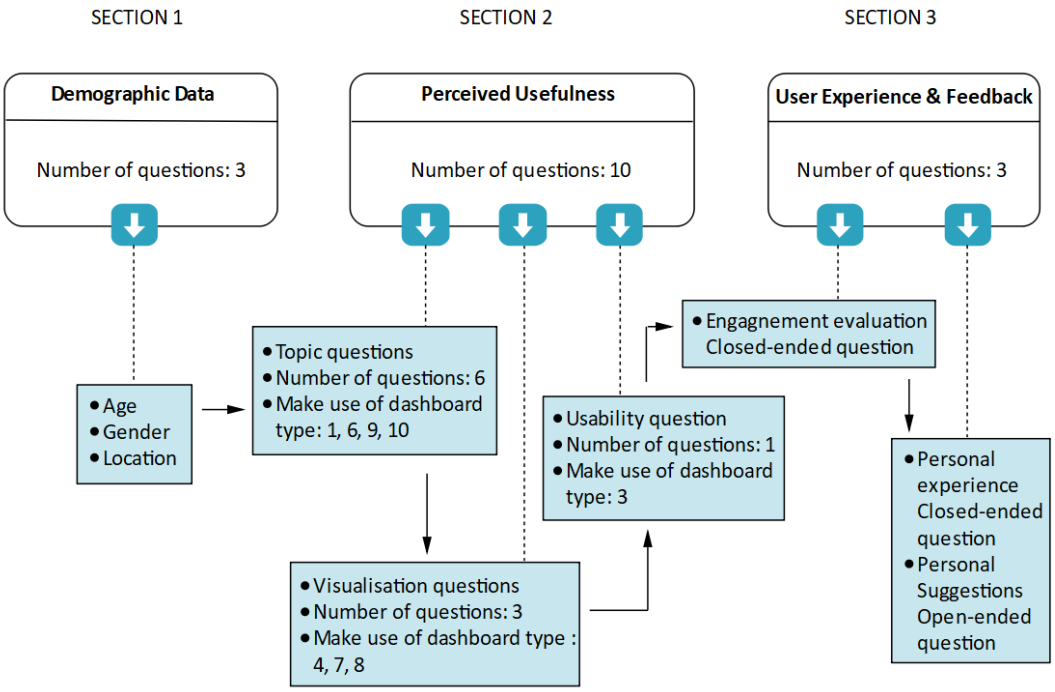


Figure 16: The structure of the user questionnaire

4.3 The case study of Beirut

The culture of Beirut has evolved under the influence of many civilizations including Phoenician, Greeks, Romans, Arabs, and Ottomans. According to archeologists, Beirut was destroyed and rebuilt seven times during its 5,000-year history. Archaeological excavations have been mushrooming across downtown Beirut over recent years, providing a glimpse at how the city looked and functioned in ancient times (Figures 17, 18). Khoury (2015) states: "Historically, most of what surrounded the former historical central district of Beirut was agricultural land. When a farmer passed away, his plot was divided four, six, or eight times, depending on how many children he had. And those plots would become further subdivided, cut deeper and deeper into smaller parcels. This is how a lot of this fabric was generated."

Beirut is a city full of contrasts and not just when it comes to cultural diversity and unstable political circumstances. Also, architecture and urban planning are influenced by several aspects such as the economic aspect and the historical layering of the city (Springer, 2013). All of these factors are responsible for shaping Beirut today and for stimulating a rapid urban change with drives of completely different nature. These unique

features make Beirut an interesting case study for developing a citizen-oriented urban dashboard.

Figure 17: The site located in Downtown Beirut
(Kathryn Romeyn, 2017)

Figure 18: The site near Martyr's Square in Downtown Beirut
(Kathryn Romeyn, 2017)

5. Results

5.1 The questionnaire results

5.1.1 Demographic data

In total 48 responses were received. Responses consisted of 28 female users, 16 male users and 4 users who didn't specify their gender. Table 3 presents the percentage of participants per gender and table 4 presents the percentage of participants per age category.

Table 3: Percentage of participants per gender

Sex	*Percentage %*	*Number of respondents (total number =48)*
Female	58.33%	28
Male	33.33%	16
Not specified	8.34%	4

Table 4: Percentage of participants per age category

Age	<18	18-25	25-35	35-45	45-55	55-65	>65
Percentage	0%	21%	52%	6%	10.5%	8.5%	2%

Each city is individual and unique. Different people living in different places have different values and it is impossible to find a common way of measuring performance of all cities. Big cities have different characteristics from the small ones. With this in consideration, the survey has been filled from users all over the world and took into account different locations, people and cultures. The survey was completed across 17 cities (Figure 19). It was filled in Germany, France, United Kingdom, Austria, Lebanon, Saudi Arabia, Australia, Canada, United states and Mexico. Table 5 presents the percentage of participants in each of these countries.

Figure 19: Home cities of the survey participants

Table 5: Percentage of participants per country

Germany	France	United Kingdom	Austria	Lebanon	Saudi Arabia	Australia	Canada	United states	Mexico
23%	12.5%	2%	4%	35.5%	4%	8.5%	2%	6.5%	2%

5.1.2 Perceived usefulness

The participants were asked to have a look on the urban dashboard for London (question 4) and to pick up to three most relevant topics from this city dashboard that they would like to have access to in their own city dashboard. Results show that the three most relevant topics picked up consecutively by participants were the weather feature, the traffic cameras and the air pollution status.

In question 5 participants were shown an image presenting the urban dashboard for Sydney and they were asked to pick the topics that they consider insignificant to be displayed in a city dashboard. According the participants selection, the most insignificant feature was a tie between Sydney universities' news and Sydney Twitter news.

The participants were also asked to rate the usefulness of the displayed numbers, percentage values and arrows in giving an overview of the performance of a city (question 3). Numbers and percentages were rated of medium usefulness and arrows were rated of high usefulness.

In question 7 users had to assess how frequently they would check the content of Galway city dashboard for their own city. Results showed that 6% of the participants would check it every day, 10.5% every week, 19% once a month, 12.5% every six months, 21% once a year, 25% never and 6% did not specify (Figure 20).

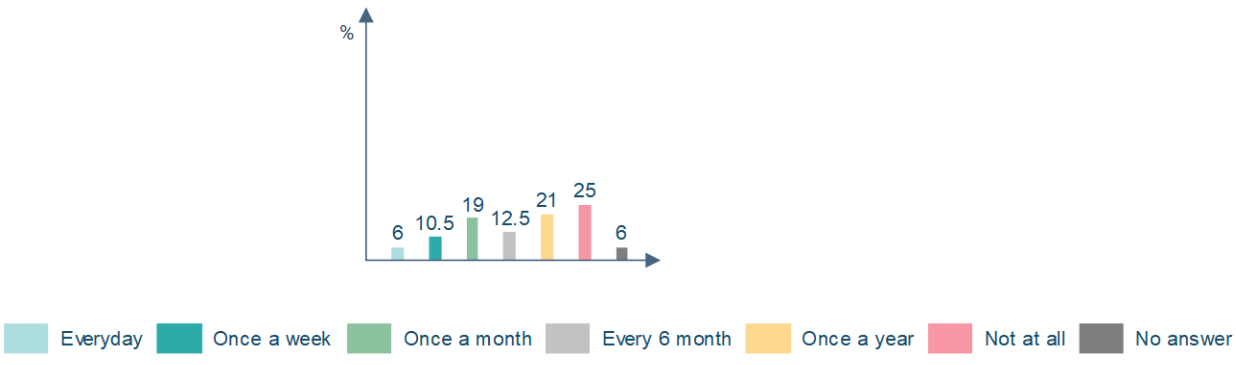


Figure 20: Results of the question 7 – "How frequent would you check the content of this dashboard?"

The users were asked to rank the following San Diego dashboard features according to their necessity to track the changes of the city (question 8). Figure 21 presents the ranking result of the following features. The results show that the highest number of participants ranked public safety on the first place and transportation and mobility on the second place. Users were also asked about the importance of a dashboard displaying the current transformations and future projects taking place in the city. 65% of the users was on average interested in showing urban transformations in the dashboard (Figure 22).

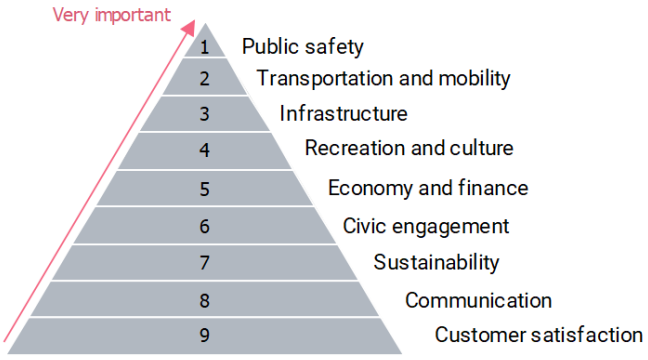


Figure 21: Result of Question 8 – "Please rank the following aspects according to their necessity/importance to track the changes of the city"

Figure 22: Result of Question 9 – "How important to you would be a dashboard displaying the current transformations and future projects taking place in the city?"

In question 10 users had to choose their preferred data visualization for Brussel's city dashboard for the parking spaces for disabled people. Results show that 10.5% chose the table, 56.5% chose the map, 27% chose the chart and 6% did not specify. In the next question users were asked what they think about the visual representation of a gauge dashboard. Most of the users chose the neutral face.

The participants were also asked if they see benefits in using a map-based visualization for urban dashboards. 55% of participants thought that the usage of a map in urban dashboards was appropriate, only 5% said the opposite and 40% didn't specify. Figure 23 lists the benefits written by the participants who answered "yes".

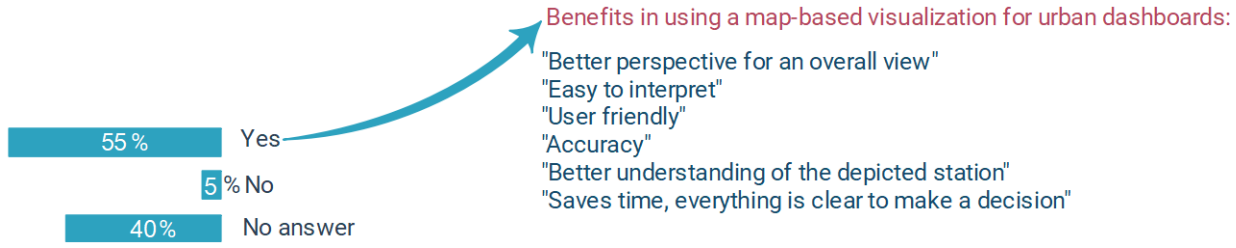


Figure 23: Result of Question 12 – "Do you see benefits in using a map-based visualization for urban dashboards? If yes, please indicate them"

Finally, in question 13 users were asked to find a free parking space for their car using the Dublin dashboard and to rate their experience afterwards. Most users rated their experience of medium complexity, clearness and smoothness.

5.1.3 User experience and feedback

The participants were asked if the previously shown urban dashboards offer the citizens the opportunity to participate in making decisions regarding their cities. 11 participants selected "yes, it does", 21 selected "partly", 12 selected "no, it doesn't" and 4 did not specify. In the next step users were asked if they have ever used a city dashboard. Looking at the percentage results, most of the participants in the online survey have never used a city dashboard. Figure 24 displays the percentage of yes, no and unspecified answers.

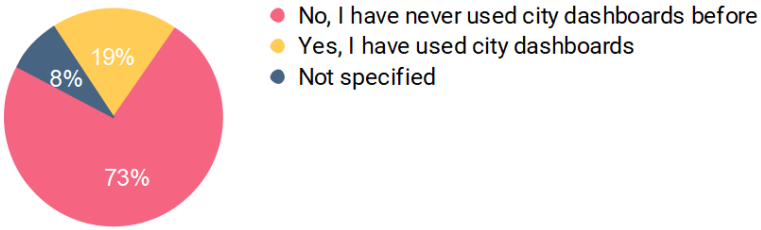


Figure 24: Result of Question 15 – "Have you ever used a city dashboard?"

Finally, the users were asked to elaborate on what kind of information they would you like to see on their own city dashboard. Figure 25 summarized the most common suggestions.

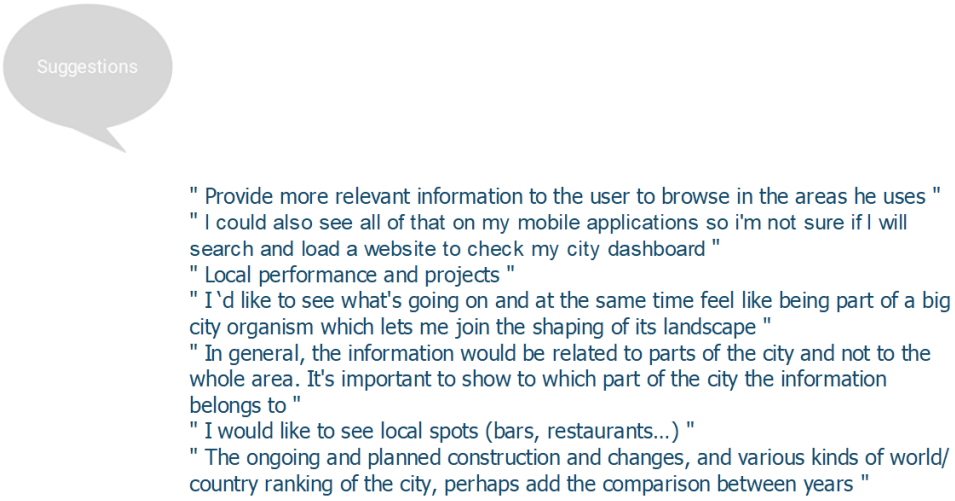


Figure 25: Participants' suggestions

5.2 Requirements emerging from the comparative study and the survey

At the end of the survey users elaborated on what kind of information they would you like to see on their own city dashboard. It was possible to divide these suggestions into four categories which are part of the main thoughts taken into consideration while creating the mockup. Figure 26 displays the four divisions based on the key terms mentioned by the users.

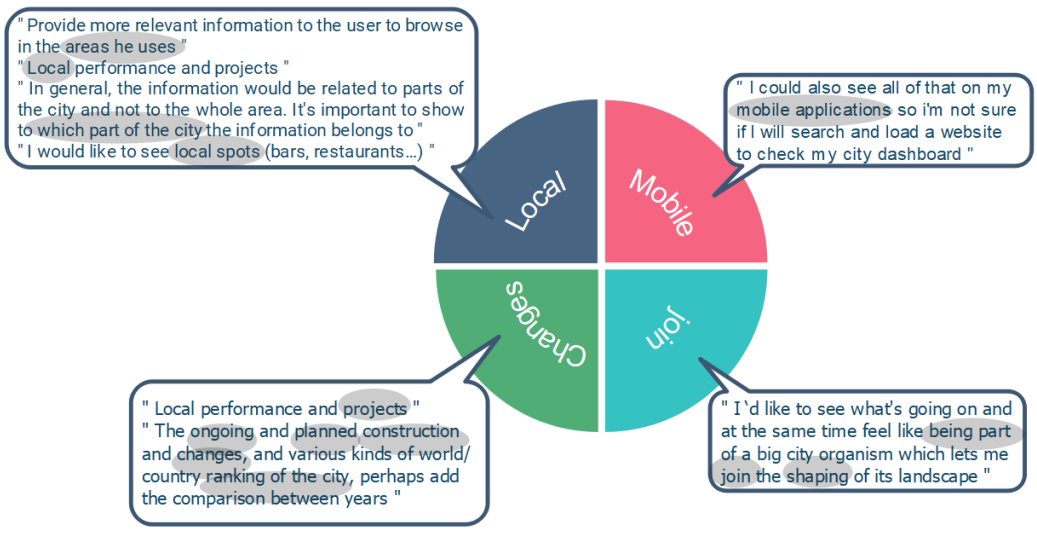


Figure 26: Main thoughts taken into consideration while creating the mockup

The repetition of the term “local” confirms that the user is interested in his own surroundings. His interest in his own sphere of influence suggests that knowledge is more of importance or necessity if it’s directly related to the immediate environment (Figure 27). Neighborhoods are the places where the everyday practice of life happens, they are geographical units that are essential to people’s lives. People associate these living environments to their identity and therefore, neighborhoods become personally meaningful (Wilson, 2009).

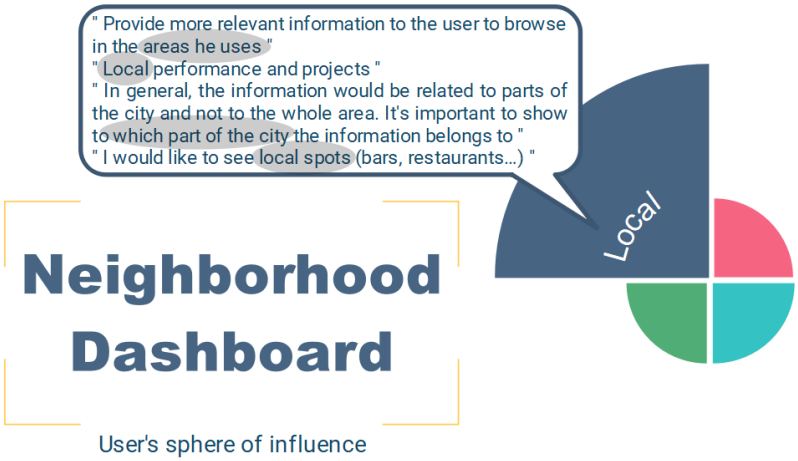


Figure 27: User requirements – a neighborhood dashboard

The suggestions concerning monitoring physical changes and the percentage of participants interested in displaying these transformations confirms, that urban transformation might be an interesting topic to be represented in a city dashboard (Figure 28).

Figure 28: User requirements – showing urban transformation

Regarding the participation feature, the user who wrote a demand concerning the participation feature is the same one who had no interest in the civic engagement feature and ranked it at the end of the list as number 8 out of 9 (Figure 29). This correlation implies that the user didn't understand the purpose of this feature while ranking it. The question is how to allow an active participation of citizens and how to integrate it in a user friendly way. Involvement creates a sense of belonging to an area, which can serve as a mechanism to gather residents together, draw attention to their issues, highlight what their neighborhood has to offer and what contribution they could make for a better neighborhood.

Figure 29: User requirements – a participation dashboard

Concerning the comparison made by the user between the access to city dashboard portals and to mobile applications, the results suggests that the user would prefer to have a fast, easy access through a specific application which is permanently available on his interface where the city dashboard loads in one click without any further research (Figure 30).

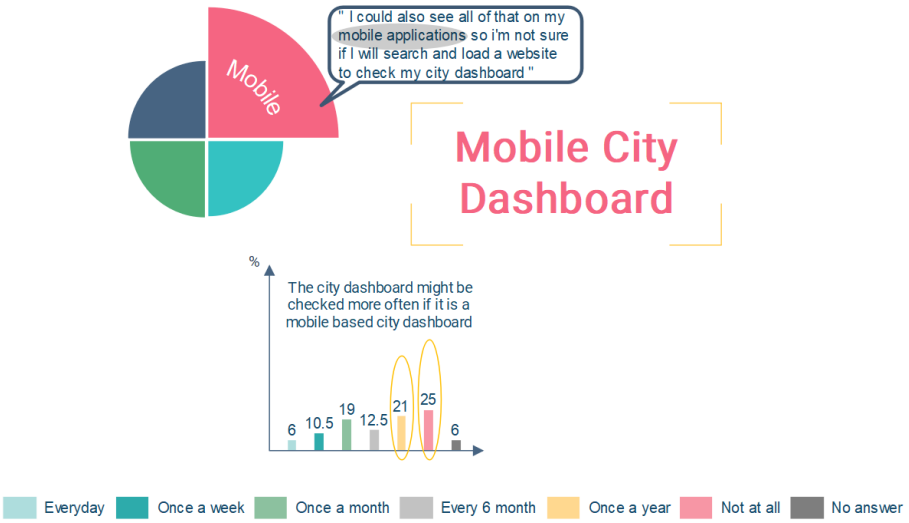


Figure 30: User requirements – mobile city dashboard

Based on existing dashboards content, 80% of these dashboards integrated features related to the environmental aspect of the city, which is ranked in the survey as number 7 (Figure 31). The public safety was unexpectedly ranked as first feature, but it is integrated in 48% of existing city dashboards (Figure 31). The following visual examples display the way public safety is integrated in existing urban dashboards. The first example consists of a table where several public safety topics are listed and compared individually such as the number of property crimes and traffic injuries (Figure 32). As for Toronto dashboard, a bar chart visualizes the changes of a specific topic over time such as the number of robberies in 2017, 2018 and 2019 (Figure 33). The third example is Brussel's city dashboard where public safety feature could be displayed on a map such as pointing out the location of police stations in the city (Figure 34).

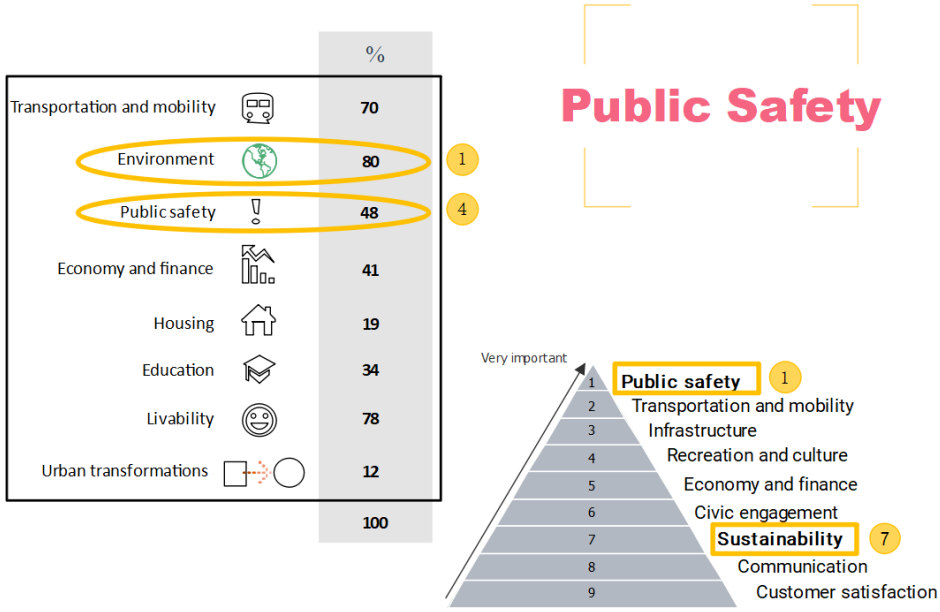


Figure 31: User requirements – a public safety dashboard

Public Safety			
	2016	2017	Progress
Violent crimes per thousand	13.9	13.9	
Property crimes per thousand	43	39	
Traffic injuries or fatalities	77	82	
Code Enforcement Related Property Inspections	3,429	3,340	

Figure 32: Muskegon's dashboard
(Appendix A)

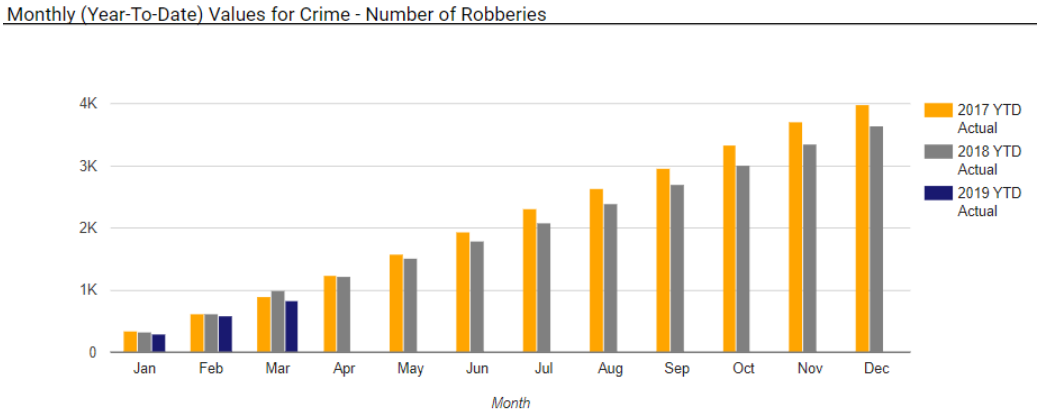


Figure 33: Toronto's dashboard
(Appendix A)

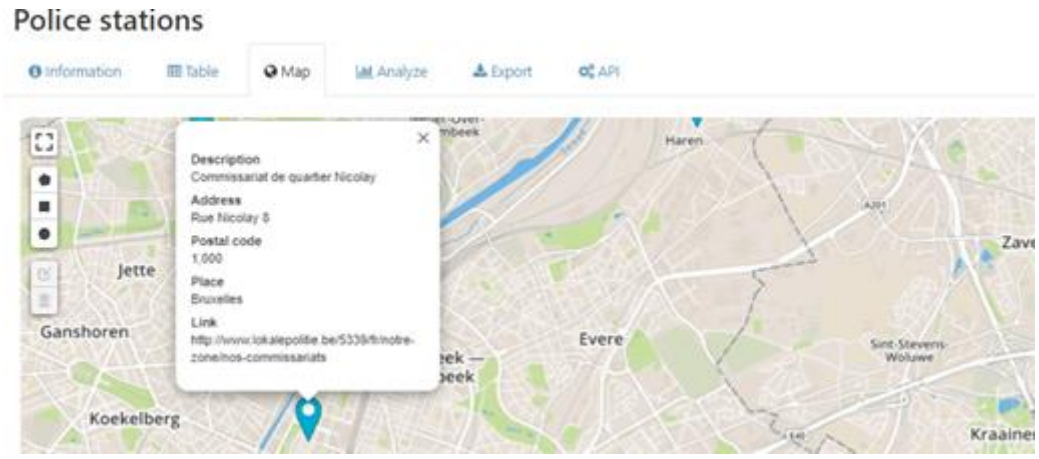


Figure 34: Brussel's dashboard
(Appendix)

Concerning data visualization and to due to most responses, a map-based visualization should be taken into consideration while designing the mockup (Figure 35). In order to visualize the process of development and transformation of a city the map is an adequate medium. Maps are one of the most powerful ways to understand cities and a powerful form of everyday communication (Janković, 2018).

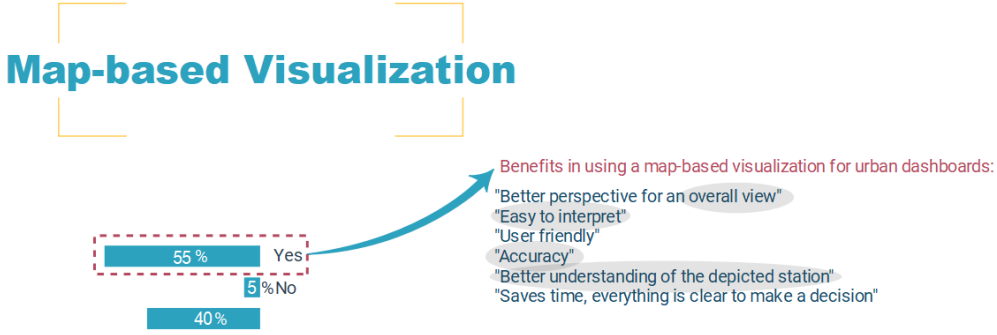


Figure 35: User requirements – a map-based visualization

5.3 Conceptual development

This section consists of the first draft of ideas and sketches on how the prototype could work. The following wireframes correspond to the skeleton of the app. Each frame is used to describe the functionality of a feature as well as relations between separate views.

5.3.1 Neighborhood analysis

This feature provides a land use classification in order to reveal the transformations in the urban fabric of a specific neighborhood (Figure 36). The user is able to detect the direction of change and ask questions such as “Has urban change been mostly industrial? is the neighborhood subject to decay?” The Feature allows the citizens to participate in improving their own neighborhood. It offers them the opportunity to be part of urban change. The user can for instance pin a suggestion and check other people’s suggestions as well as to vote on suggestions. Suggestions are ranked according to their popularity. Whenever a suggestion reaches a certain number of votes it will be sent to the municipality as a petition form to address ongoing discussions among planners, architects, politicians and citizens in Beirut. According to Springer (2013), the question on how to deal with Beirut’s cultural heritage in terms of renovating, reprogramming, reusing or demolishing is quite problematic due to the existence of several diverse opinions.

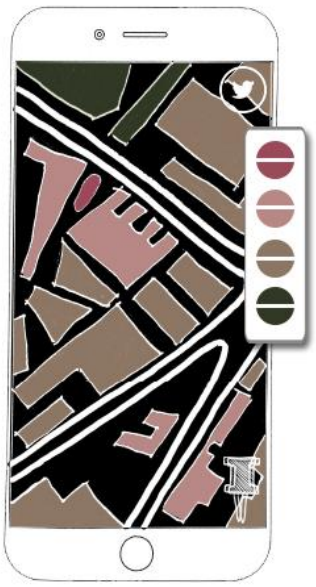


Figure 36: The wireframe for the neighborhood analysis

5.3.2 Current and future transformations

This feature provides a visual highlight for current and future pop-ups in a specific neighborhood (Figure 37). Beirut residents can check the details of future projects taking place in their neighborhoods. A 3D model consisting of two level of details, LoD 1 and LoD 3 will display the existing neighborhood (LoD 1), and the final state of the new project (LoD 3). LoD 1 consists of a cuboid model without roof shapes, simply extruded footprints. LoD 3 consists of a neat architectural model.

Figure 37: The wireframe for the current and future transformations

5.3.3 Hidden transformations

This feature provides the locations and the stories of hidden transformations (Figure 38). The map highlights these specific spots and offers detailed cross-section drawings of the hidden transformation. This feature would be very important for cities like Beirut, which have very rich underground stories. The user will be able to have a deeper look into the physical aspect of the project as well as the conceptual, historical or philosophical aspect behind a certain transformation.

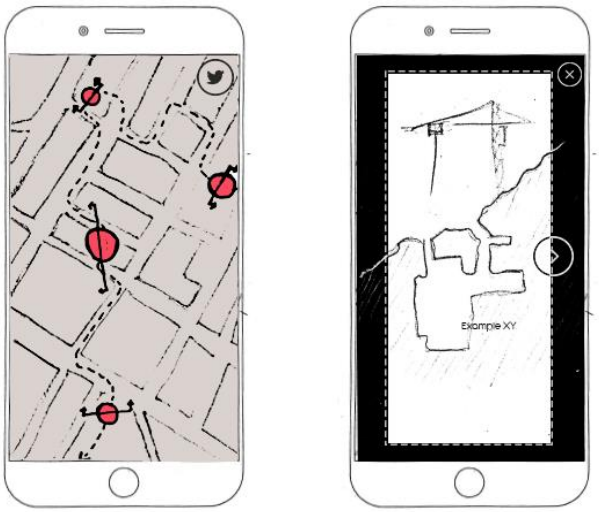


Figure 38: Wireframes for hidden transformations

5.3.4 Public safety in favour of urban transformations

This feature allows the user to have access to real time geo located ISF Twitter feed (Figure 39). ISF is the internal security force in Beirut. The ISF has a Twitter account where it is possible the check the latest news and events happening in Lebanon. For example, ISF Twitter feed could notify the user about a Protest Alert taking place in his neighborhood. The user can check the latest ISF feed on all the previous features before deciding to visit a neighborhood to check out a new project. The feature doesn't provide a visual highlight for safe and dangerous streets neither a percentage of safety in a neighborhood, to avoid any misleading conclusions. It only provides the user ISF twitter feeds and let the user decide for himself without any further influence.

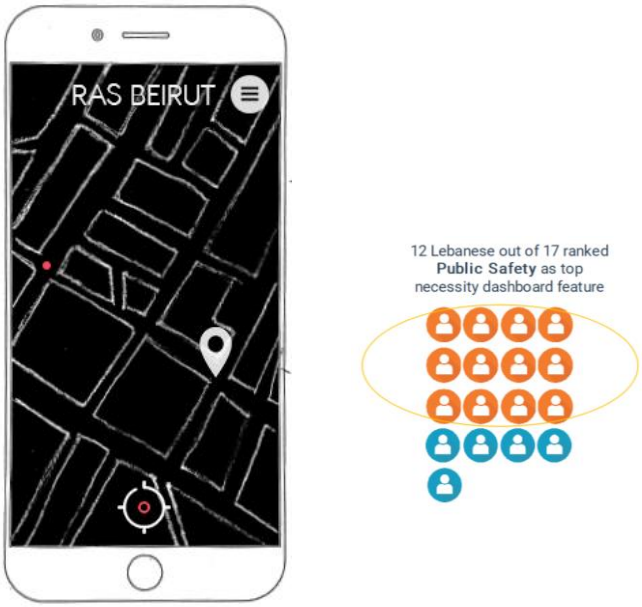


Figure 39: The wireframe for the public safety feature

5.3.5 Search page and home page

The first frame consists of the search page which allows the user to select the neighborhood he wishes to monitor (Figure 40). Beirut neighborhoods are divided according to Beirut twelve districts with a total of 85 km^2. The user will be able to see Beirut district's map in order to make his selection. The second frame is the dashboard home page which consists of a visual display arranged on a single screen so the information of a specific neighborhood can be monitored at a glance.

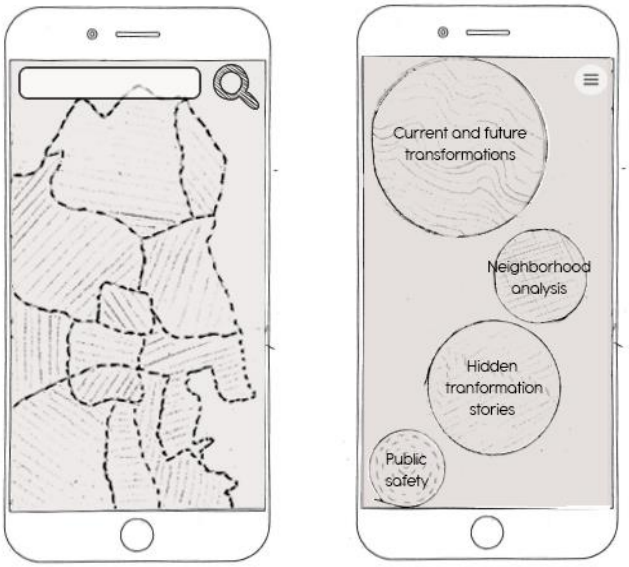


Figure 40: Search page and home page

Beirut dashboard is a location-based mobile city dashboard. Digital platforms such as smartphones can enable a richer dialogue between the user and real time services. The mobile app is a key innovation which contributes to smarter urban dashboards. There is no point in creating dashboards if nobody sees them and reacts to them. The app allows citizens to view data and to communicate their needs. Instead of displaying visualizations for the entire city on one dashboard web page, the app focuses visualizing the user's neighborhood information.

The proposed map-based interactions benefit from the smartphone's core functionalities. The app makes use of the user's current location, it also allows push notifications that will keep him informed on relevant information.

5.4 User evaluation

In order to assess the proposed map-based functionalities and prior to any further mockup development, a user evaluation survey took place (Appendix D). The survey was filled in by fourteen participants living in Beirut – the target group originates from the city being the case study of this thesis. Firstly, a video demo explains the conceptual approach of the proposed urban dashboard and displays the wireframe structure of the app. After watching the three-minute video, participants had to answer eight questions concerning the features of the dashboard. The users evaluated the preliminary interface. The answers

collected between the sketches and the final mockup phases serve as a feedback on how to implement the dashboard features, what to add and what to remove. The evaluation has been deployed on the SoSci Survey platform.

The users were asked first to imagine themselves using this app and then to choose what would be their preferred way of making city-related suggestions. Seven participants chose to sketch their suggestion, six preferred to write their suggestion and one participant chose to alter land use classification. In question 2 users had to answer “yes” or “no” concerning their interest in rating the urban solutions suggested by citizens. All participants would like to rate the suggestions made by other residents and ten out of fourteen would like to keep track of the suggestions popularity.

In question 3 users were asked which way was the best for them to understand statistical information, for example about the land use of your neighborhood. Half of the participants chose percentages (e.g. 5% green space, 10% parking space), four participants chose counts (e.g. 3 parks, 6 parking areas) and three chose graphical representation (e.g. bar charts, line graph). In question 4 users had to select what information interests concerning a new project popping up in their neighborhood. Users were interested mostly in the project functionality, the project due date and the impact of the construction phase on their daily lives.

In the next step users were requested to imagine themselves wanting to discover some possibly exciting locations in their city which they don’t know yet because they are ‘hidden’, how would they prefer to do it. Five users decided on playing a game like treasure hunt, another five decided on receiving an automatic notification when they are close to the hidden location such as a radius of 200 meters. Three users selected to the option of receiving informative notification a day such as an animated feed or a 60 second story and one user did not specify any of the previous options.

Through question 6 users were demanded to state if they would check the public safety feature for consistently updated geo-located events before visiting a certain neighborhood in Beirut. All fourteen users answered “yes” to this question. In question 7 users were asked if they would enable the push notification to receive messages from ISF. Ten users out of fourteen would like to enable the push notification to receive messages from ISF.

Finally, users were asked if it would be meaningful to add some more options to the app or do something in a different way. Few participants had some ideas which they found useful to add to a certain feature such as the suggestion made concerning the current and future transformations feature: “I would like to have a filter option to be able to search for a specific project functionality in a certain region (e.g. new rooftop bars in Saifi)”. An additional suggestion was made regarding the hidden transformation feature: “Beirut is a historical city. A notification about the street/neighborhood we are crossing, concisely telling any relevant historical information related to the street name or eventually to the street historical events. This will let us position the new change and events in the very important historical setting of several corners in Beirut.”

6. Mockup implementation

This chapter focuses on developing a high-fidelity mockup. Colors, fonts, symbols, texts and images are added to shape the mockup wireframes. Each feature is designed taking into consideration the outcomes of the user evaluation survey. Implemented functionalities give a feeling of using a real app by connecting the static images. Low level interactivity is applied in order to give the user the ability to navigate through static material at they own pace.

6.1 Data and tools

The data processing pipeline is presented on Figure 41 and explained in sections below. The analysis layers, maps, models, images, icons, textures and drawings used in the thesis are referenced in detail in Appendix E.

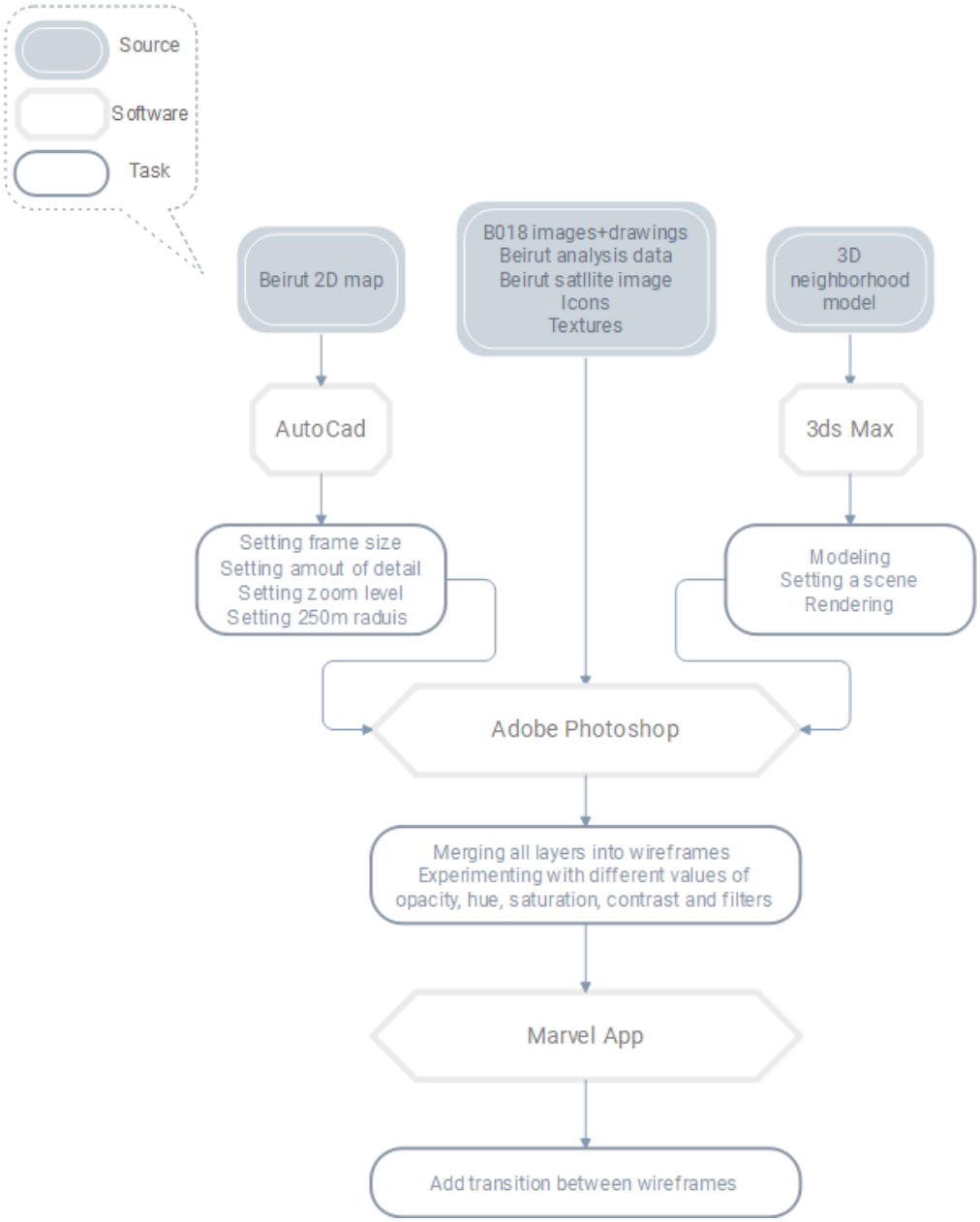


Figure 41: A workflow showing all the technical steps to implement the high-fidelity mockup of Beirut's city dashboard

All displayed maps were initially DWG files, where the frame, the amount of details, scale, zoom level and measurements were executed using AutoCAD. Afterwards maps were imported to Photoshop as a PDF file holding to their sketchy, drafting effect obtained from AutoCAD design software. The map becomes the base layer for every wireframe, further layers are added with high sensitivity while experimenting with different values of opacity, hue, saturation, contrast and filters.

The main cartographic design principles for thematic map design (Dent, Torguson, & Hodler, 2009) were considered while building the maps and the layouts. Legibility, visual contrast, figure-ground, hierarchical organization, and balance work all together to achieve a better understanding of the whole page. Without these the map reader fails in finding what he needs, it makes it harder for him to go through the content of the map and to define the importance of things.

The displayed view for current and future transformations is rendered based on the 3D model of the buildings and their surroundings. Using 3ds Max, a 3D computer graphics program, it was possible to model the 3D object, to orbit around it and to select a scene to render. Although the chosen project has been already accomplished, it clearly shows how similar current and future projects could be visualized. Data implemented for the neighborhood analysis are based on an existing land use study accomplished by two researchers at the American University of Beirut (AUB Neighborhood Initiative, 2015). The study took place few years ago, therefore the obtained classifications might be slightly altered at the present time. The hidden transformation feature exhibits an existing project located in Beirut. The project name is “B018”. The feature integrates a timeline to display the selected images, drawings and descriptions of the project and its context.

The final design of the static wireframes was accomplished in Photoshop. Transitions and animations have been added in the Marvel App.

6.2 Color palette

The overall color palette aims to give the user an inspirational sense of creativity and imagination framed by a blend of elegance and smoothness in the interface design. The dashboard app combines warm hues with cooler ones. It contrasts warm beige and brown against cool navy and dark shades of red for a bold, dynamic effect. Color selection is about the feeling a shade evokes, changing the hue or saturation of a color can bring a completely different feeling for the entire app.

A brownish beige is used in the background with a paper texture trying to give a warm tan background color which feels modern without being too minimalistic. Beige takes on the characteristics of the surrounding colors combining the warmth of brown and the coolness of white. Brown is associated with the earth, wood, and stone which helps to bring a feeling of home and coziness to the design. White usually creates a sophisticated layout feeling while helping to convey cleanliness and simplicity. This blend merges into a retro and hip style.

Blue brings a refreshing feeling to the app as it is associated with water and the sea. Navy blue is used in order to convey strength and appears as an accent color throughout the rest of the interface. Red is a color commonly used to portray importance in the design. The dashboard interface instead embraces a reddish purple which draws attention to important page elements, buttons and badge icons.

6.3 The structure of the app

Figure 41 presents the narrative structure of the app. The user flow of Beirut mobile city dashboard displays the various scenarios that the users will encounter while navigating through the app. The diagram consists of the sequence of tasks that the user could perform and the different app pages he could access. The prototype of city dashboard for Beirut consists of 47 screens, accessible on Marvel App through the following link: https://marvelapp.com/1g41ab5g.

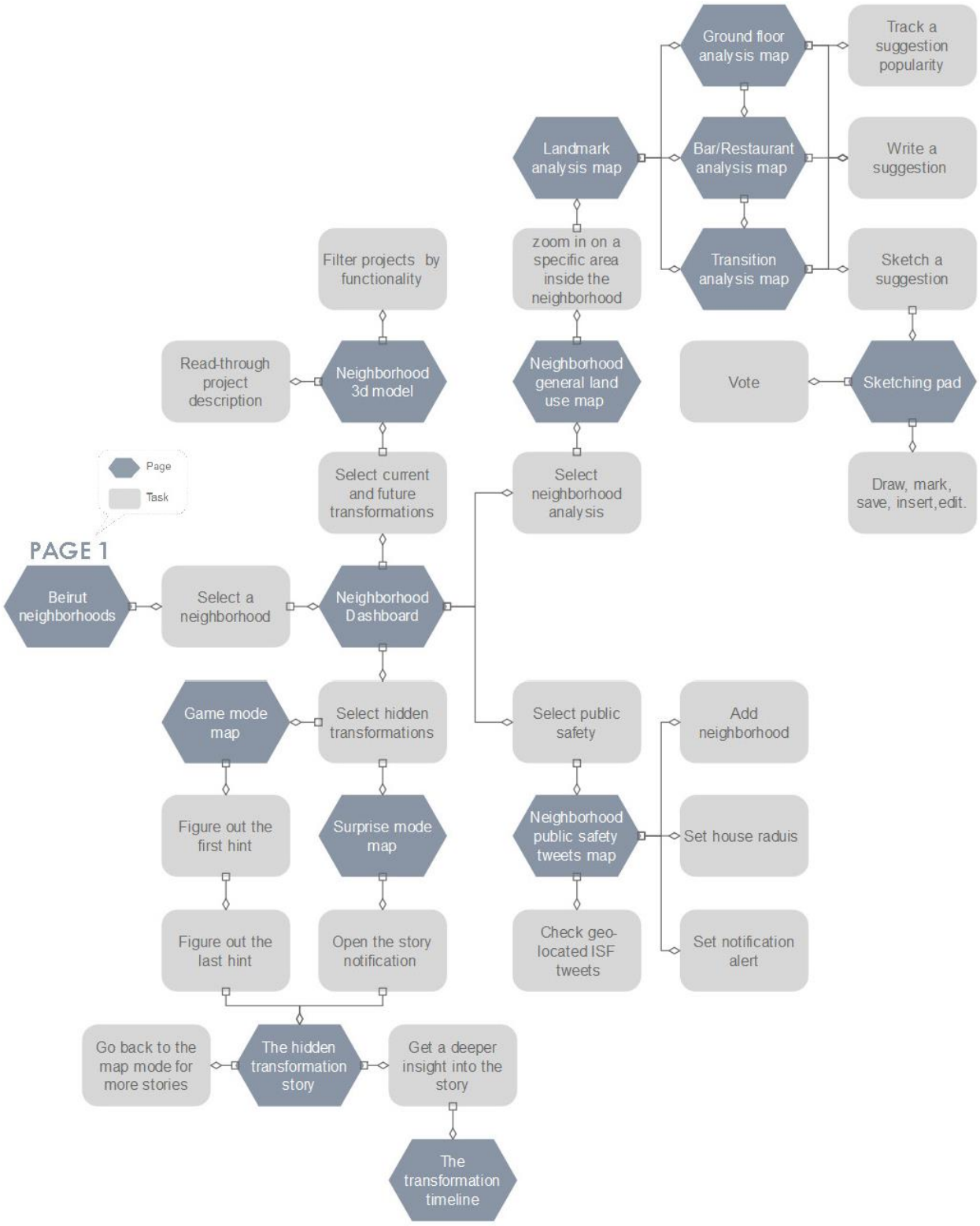


Figure 42: The structure of the app consisting of app pages and tasks

6.4 Welcoming screen and home page

As soon as the user first opens the app, a splash screen appears for a few seconds. The splash screen consists of a satellite image of Beirut on top of which the term “Beirut” is written in Arabic calligraphy (Figure 42). Then comes the search page where the user can either click on the map to select a neighborhood or he can type in the neighborhood name using the search bar.

Selecting a neighborhood leads the user to the dashboard home page, which consists of four features: current and future transformations, neighborhood analysis, hidden transformations and public safety (Figure 42). The dashboard home page provides the user an up-to-date overview of each feature. It raises the awareness of his own neighborhood transformations. It fulfills his interest in local scale data. The user can alter the update setting of each feature individually. If the user is interested in monitoring an additional neighborhood, he can.

Figure 43: Welcoming screen and home page

6.5 Current and future transformations

Selecting the first feature brings the user to the current and future transformations taking place in his neighborhood (Figure 43). The user dives into a three-dimensional model imported from a 3D software. The model is extruded on 3D max using a 2D cadastral map of Beirut. Only current and future projects are rendered in a realistic mode. Based on a suggestion made by a participant in the user evaluation survey, the feature provides the chance to filter the projects according to their functionality. After applying a certain filter, popups corresponding to his selection appear. These popups define briefly the project name, due date and functionality. For further details, the user could click on the info button which will provide him with the project description.

Figure 44: Current and future transformations

6.6 Neighborhood analysis

Switching to the neighborhood analysis feature, by default a general land use map is displayed (Figure 44). The map highlights the selected neighborhood. The user can slide up the legend to identify the different zones of Ras Beirut. If the user is interested in checking the zoning of an adjacent neighborhood because he lives on the border of “Ras

Beirut", it is possible for him to highlight an adjacent neighborhood. Whenever the user moves into a higher zoom level, the map would suggest additional classification options. These classifications consist of superimposed layers of analysis: landmark analysis, bar/restaurant analysis, ground floor analysis and transition analysis. The outcome of the user evaluation survey confirms the user interest regarding the participation feature. The user is able to express his ideas of change by adding a suggestion on any of these layers. He can choose either to enter a text or to sketch his idea. He can check all pinned suggestions within his neighborhood dashboard, he can keep track of their popularity and he can edit a previously made suggestion.

Selecting a landmark analysis allows the user to locate religious buildings, hospitals, theaters, hotels, schools and residential buildings. When choosing the ground floor analysis tool, he will be able to locate commercial activities at street level. The fourth button makes it possible to locate bars, restaurants and take-away shops around his place. The last layer highlights transition such as empty buildings, buildings to be demolished, buildings to be renovated, buildings under construction and empty lots used as parking space. Zooming out brings back the user to the general land use analysis. Altogether maps share a redundant color-coded legend.

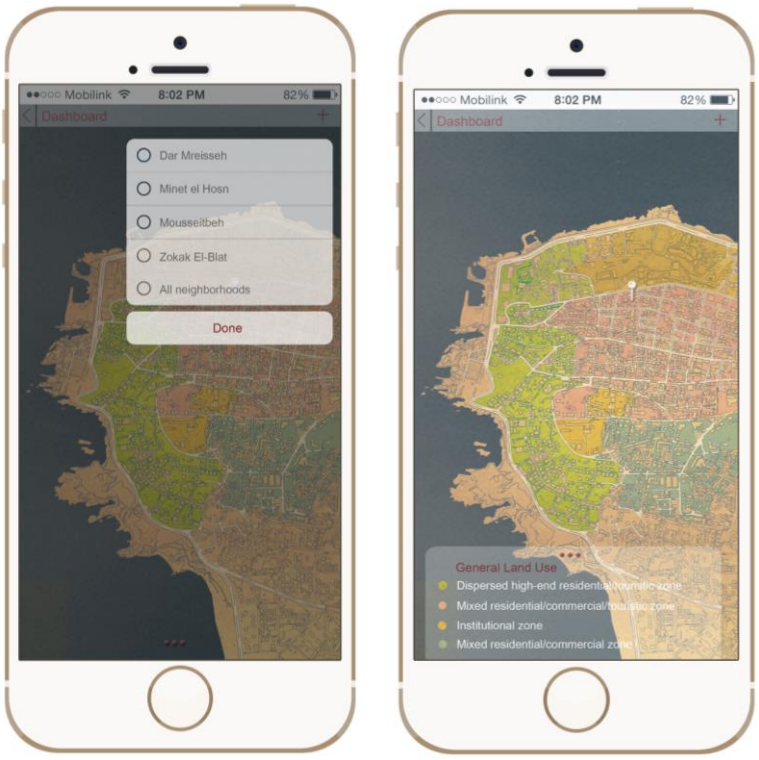


Figure 45: General land use map

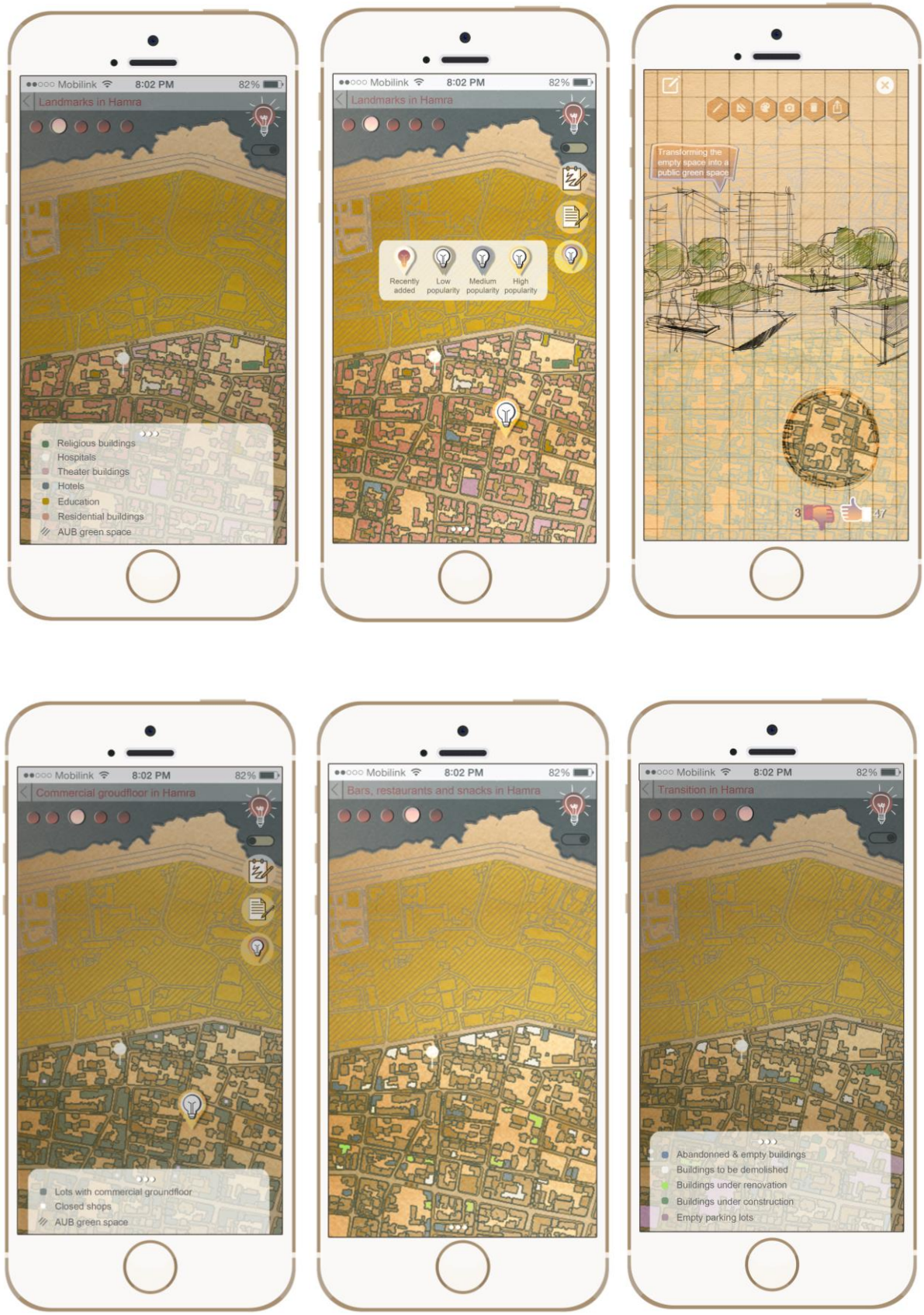


Figure 46: Neighborhood analysis

6.7 The hidden transformations

Once the user moves back to the dashboard home page and chooses the hidden transformations feature, he can switch between a surprise mode and a game mode (Figure 46). Based on the user evaluation, there has been a tie on how users would prefer to discover some exciting hidden locations in their city. Accordingly, the dashboard gives the user two options: either to play a game or to get a surprise notification when they are close to the hidden location. When choosing the game mode, the user switches to the map where he can see his location within a radius of 250 meters. The radius resembles a sonar detection screen, which indicates the direction of the upcoming transformation location. When the user clicks on the info popup, he will start to collect his hints. The first hint should lead him to the right region. He will receive the second hint as soon as he is within the 250-meter radius of the hidden spot. The last hint leads him to be a few meters away from the right place. From this distance he can spot the transformation. More hints could be added depending on the desired complexity level. Always at the last hint, the user should provide something in return to be able to position his hidden discovery. The hints content is always related to the transformation story. While the user is trying to solve the hints, this feature will allow him to discover new relations, such as connecting places to events that took place at a certain time in history. He will understand the project's contextual impact, the reason behind its existence and what are the layers of transformations that shape the project in a given way. Every hidden spot reveals a layer of history of a specific neighborhood. Succeeding to uncover the story, gives him a choice to look at the transformation drawings as well as the transformation timeline or to return to his game mode looking for one more story. If the user selects the surprise mode, he will receive the location of hidden transformation in a radius of 250 meters around his location.

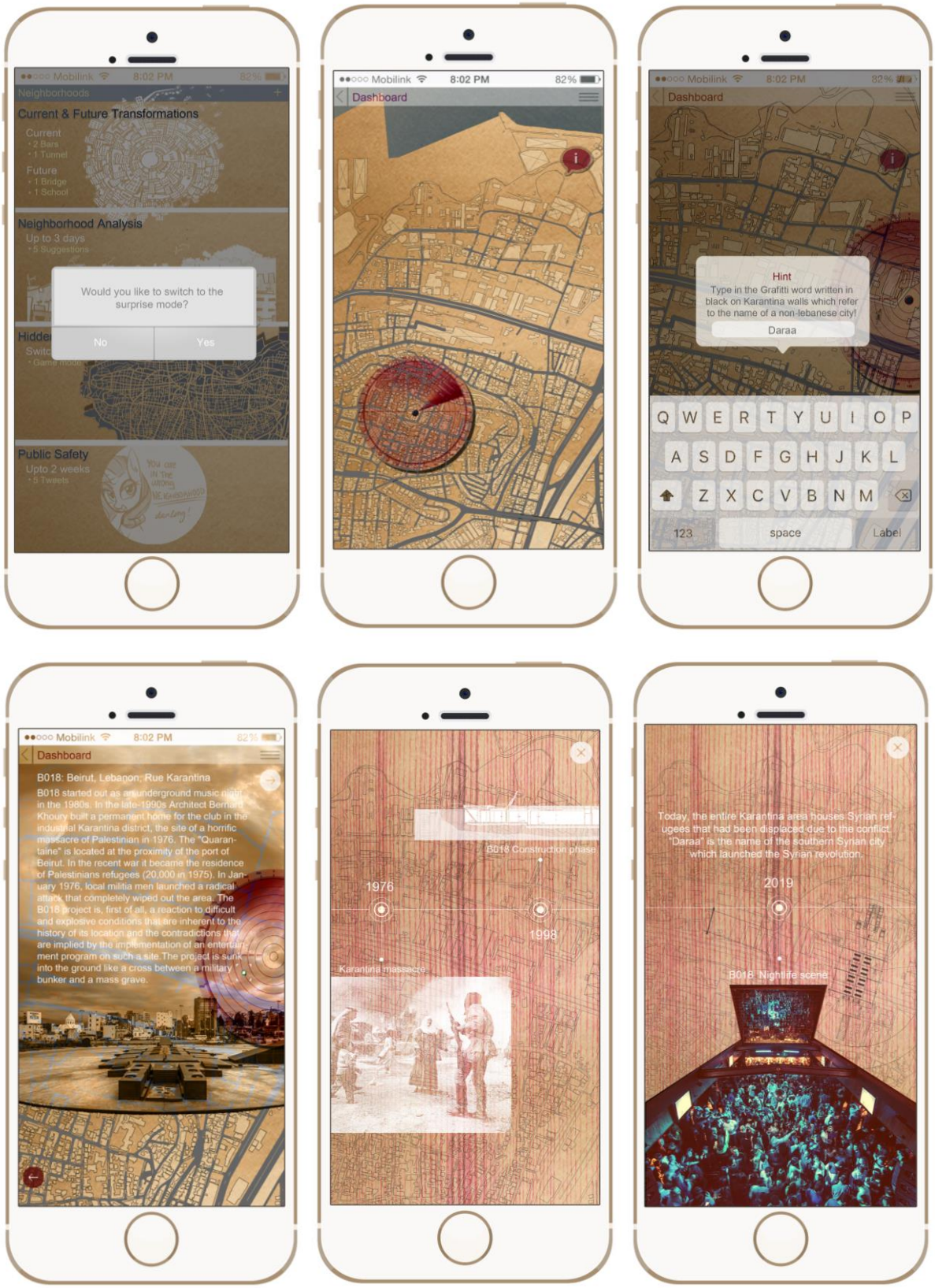


Figure 47: Hidden transformations

6.8 The safety feature

As a final feature and due to the user's full consent on integrating a feature which informs Beirut residents about troubling events taking place in their neighborhood, the dashboard suggests the public safety feature. This feature visualizes the geo-located ISF tweets on the user's neighborhood map (Figure 47). The user is able to select a smaller radius around his house where the map is locked on a certain zoom level. The user is also able to control his notification settings.

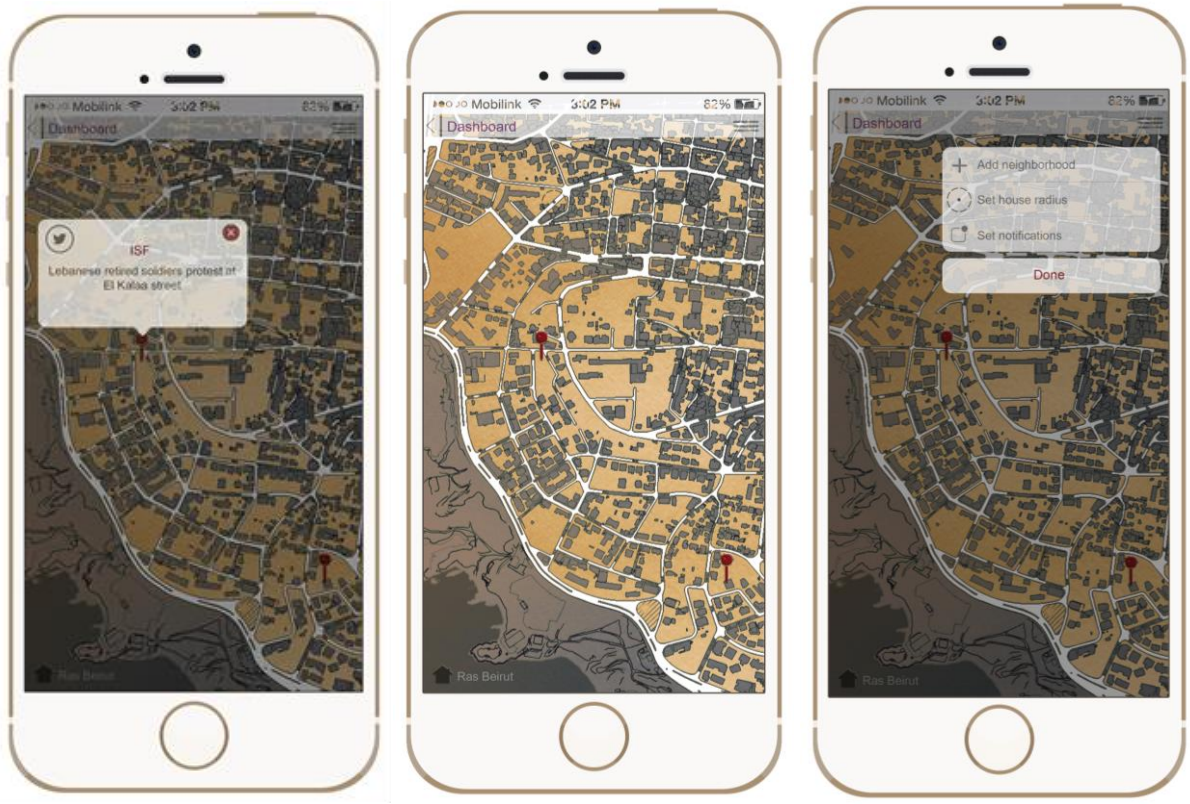


Figure 48: The safety feature

6.9 Animations and transitions between the frames

The last step of this implementation consists of uploading all the final frames in Marvel App in order to create an app demo. Marvel App is a collaborative design platform for prototyping. No coding knowledge is required to create a high-fidelity mockup. Creating a flow in Marvel App is based on clicking and dragging on a specific spot inside a frame. This creates an interactive design hotspot, that enables the user switching to another

frame whenever clicked. Bringing the prototype to life is possible with realistic screen transitions. These transitions are adjustable, and the selection of the transition mode varies from sliding, flipping to fading. Additionally, the designer has the option to decide on the way how the transition is triggered – whether through hover, swipe or a click. The ability for the user to navigate inside the 3D neighborhood model, to zoom in and out, to pan and to play with the hidden transformation timeline is not possible within Marvel App platform. These interactions have not been implemented, but they have been described in detail in the respective sections.

7. Discussion

The performed research study investigated the role of existing urban dashboards and developed a new approach, where urban dashboards inform the citizen about past, present and future scenarios transforming the city. The proposed dashboard design offers the citizen the opportunity to be actively engaged in the planning of the city.

The aim of this work was to gain a comprehensive understanding of the existing dashboards as a base for developing a more reasonable framework of content functionality and design principles. The exploration of dashboards happened on two levels: a perspective focused on the visual design and other focused on indicators selection. This exploration addresses tension between dashboards as a visual domain and dashboards as a functional tool.

The conducted work is subject to some limitations. The conducted comparative study is based on a selection of a limited number of existing urban dashboards. The diversity of the examined dashboards is valuable, but cannot be considered a representative sample in the statistical sense. Despite of that, the study was able to provide a semantic and semiotic meaning for existing dashboards. Further collecting and investigating a larger number of dashboards will bring additional meanings and insights.

Moreover, the selection of urban transformations as a smart city indicator is only one choice out of an infinite set of city indicators. The selection of indicators must be carried out in respect to the individual needs of each city. One indicator might be useful for one city more than the other. For example, integrating public safety feature was particularly important for the case study of Beirut. This feature directly responds to the crucial needs

of Beirut resident's, but it might not be a first degree requirement for residents in other cities around the world.

Additionally, the selection of the visualization type depends on the designated indicator. In order to achieve the intended functionality, a set of design guidelines is established. Based on the case study, the term "city dashboard" covers a wide range of design methods and there is no one unique way of visualizing data. Thus, there is no guarantee that design guidelines from one category of indicators could be efficient for another. The accomplished work did not cover experimenting with design separately for different purposes and context.

The main implication of this work is that there is the need to explore alternative ways for building dashboards. Firstly, there is a need to stop stereotyping dashboards as a single entity. Dashboard designers must therefore become aware of storytelling and narrative visualization. Secondly, dashboard indicators should avoid becoming a goal in themselves. They must help fulfilling the individual needs of citizens, thus the selection of any indicator set should be considered as a starting point of any dashboard creation.

8. Conclusions and future work recommendations

The main objective of this thesis was to propose an alternative to existing urban dashboards which gives a deeper insight into the evolution of the city and implements a bottom-up approach for informal exploration of the city according to the needs of people. To achieve an informal exploration, the proposed urban dashboard takes into consideration both ends. From a top-down perspective, urban planners and architects need to understand the individual needs of people. From a bottom-up perspective, people need tools to express their needs, so that urban planners can take those into account when shaping the city. Somewhere in the middle between bottom-up and top-down collective needs emerge, which refer to an intermediate between the needs of individuals and the overall needs of the society.

"Cities have the capability of providing something for everybody, only because, and only when, they are created by everybody." *The Death and Life of Great American Cities* (1961). The proposed city dashboard supports the idea of a city which is open to change, which is hackable by its own residents, thus, making data accessible in the possibility of intervening. This purpose is fulfilled by providing an inner understanding of the city, by engaging people with ongoing developments, and by establishing collectives around shared issues of concern (de Lange & de Waal, 2013).

The framework and literature review suggest a research direction which supports dashboard design and use. Rejecting the idea of a single authoritative definition of dashboards, a greater flexibility should be considered. Otherwise, dashboards are subject to failure. Dashboard designers struggle with the ability to reflect the diversity of the user needs with one fits-all layout arrangement.

An interesting future study might consist of consulting dashboard designers for further understanding of design challenges and considerations. These can also investigate mismatches between intended use and actual use. It would be useful to observe how major design principles switch from being primary to tertiary depending on the function of the dashboard. A designer working supposedly on dashboard (x) may wish to keep a logical order of views to communicate an idea, while a designer working on dashboard (y) may wish to order views differently so that the most crucial information is the most outstanding one.

Another interesting research possibility consists of analyzing the relations between dashboard indicators, for instance, questioning if there is any kind of relationship between the displayed indicators. They might be totally independent, or they might have an impact on each other in a certain way. The question is how to qualify this impact and how it affects the indicator's distribution.

Finally, it would of great significance to transform the proposed urban dashboard prototype into a real functioning application. However, this outcome depends on several prerequisites such as: an access to various databases of Beirut municipality; willingness of urban planning offices, architects and real estate companies to share their data, as well as the readiness of government structures to response to citizens reports and promote further public engagement.

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Appendix A

Table A: Results of the selection process

	City	Source	Status
1	Cork	http://www.corkdashboard.ie/pages/CorkMapped	Valid
2	Dublin	http://www.dublindashboard.ie/pages/index	Valid
3	Brussels	https://opendata.brussels.be/explore/?sort=modified&refine.features=analyze	Valid
4	London	http://citydashboard.org/london/	Valid
5	Birmingham	http://citydashboard.org/birmingham/	Valid
6	Brighton	http://citydashboard.org/brighton/	Valid
7	Cardiff	http://citydashboard.org/cardiff/	Valid
8	Edinburgh	http://citydashboard.org/edinburgh/	Valid
9	Glasgow	http://citydashboard.org/glasgow/	Valid
10	Leeds	http://citydashboard.org/leeds/	Valid
11	Manchester	http://citydashboard.org/manchester/	Valid
12	Glasgow	http://dashboard.glasgow.gov.uk/	Under construction
13	Boston	https://boston.opendatasoft.com/page/smart-city-2/	Valid
14	Munich	http://transparency.smartdataplatform.info/	Under construction
15	Sydney	http://citydashboard.be.unsw.edu.au/	Valid
16	Amsterdam	http://citydashboard.waag.org/	Under construction
17	Toronto	https://www.toronto.ca/city-government/data-research-maps/toronto-progress-portal/	Valid
18	Venice	https://dashboard.veniceprojectcenter.org/#!/home	Site error
19	Adelaide	http://www.citydashboard.com.au/adelaide.php	Valid
20	Dallas	http://dallas365.dallascityhall.com/	Valid
21	Melbourne	https://insight.livestories.com/s/v2/trees-planted/0bc2663d-f32e-4df7-9bb9-d26cd742978c/	Valid
22	Calgary	http://www.transforminggov.ca/2015/11/citizen-dashboard.html	Site error
23	Guelph	https://guelph.ca/city-hall/city-administrators-office/public-reporting/performance-dashboard/	Valid
24	Syracuse	http://dashboards.syrgov.net/	Valid
25	Berkley	http://www.berkleymich.org/departments/finance_treasury/citydashboard.php	Valid
26	Boulder	https://bouldercolorado.gov/boulder-measures	Valid
27	San Diego	http://performance.sandiego.gov/	Valid
28	Lake Oswego	https://www.ci.oswego.or.us/budget/#/	Valid
29	Muskegon	https://secure.munetrix.com/page/module/dashboard/79	Valid
30	Columbia	http://www.como.gov/Maps/Dashboard/	Valid
31	Canberra	http://www.citydashboard.com.au/canberra.php	Valid
32	Tulsa	https://www.cityoftulsa.org/government/performance-strategy-and-innovation/dashboards/	So-called dashborad
33	Niles	https://bsaonline.com/MunicipalDashboard/Performance?uid=134	Valid
34	Bristol	https://opendata.bristol.gov.uk/pages/homepage/	Valid
35	Hamilton	https://www.hamilton.ca/city-initiatives/citizen-dashboard	Valid
36	Galway	http://galwaydashboard.ie/	Valid
37	Gladstone	http://cyclonedashboard.com/gladstone.php	Valid
38	Raleigh	https://openmaps.raleighnc.gov/development-dashboard/	Valid
39	New York	https://vizzuality.com/project/nyc-data-dashboard/	Under construction
40	Townsville	http://disaster.townsville.qld.gov.au/	Valid
41	New York	https://www.cityhealthdashboard.com/	Valid
42	Pisa	https://dashboard.km4city.org/dashboardSmartCity/view/index.php?iddasboard=MjMx	Valid
43	Florence	http://dashboard.km4city.org/view/?iddasboard=MzA=&nome_dashboard=Firenze2	Valid
44	Los Angeles	http://geohub.lacity.org/	So-called dashborad
45	Osaka	http://cyclonedashboard.com/osaka.php	Valid
46	Tokyo	http://cyclonedashboard.com/tokyo.php	Valid
47	Hong kong	https://www.arcgis.com/apps/opsdashboard/index.html#/e8ae3f3ab03e44ada342d95c957d406b	Valid
48	Buenos Aires	http://rpubs.com/HAVB/dashboard_saneamiento	Not up-to-date
49	Paris	http://serveur.arcorama.fr/CityDashboard	Valid
50	Taipei	http://www.citydashboard.com.au/taipei.php	Valid

Appendix B

Table B: Topics and dashboard types

		Cities	Topics							
			Transportation and mobility	Environment	Public safety	Economy and finance	Livability	Housing	Education	Urban transformations
Type 1	1	London	x	x			x		x	
	2	Birmingham	x	x			x		x	
	3	Brighton	x	x			x		x	
	4	Cardiff	x	x			x		x	
	5	Edinburgh	x	x			x		x	
	6	Glasgow	x	x			x		x	
	7	Leeds	x	x			x		x	
	8	Manchester	x	x			x		x	
	9	Sydney	x	x			x		x	
Type 2	10	Florence	x	x			x			
	11	Pisa	x	x						
	12	Hong kong	x	x						
	13	Boston	x	x						
Type 3	14	Cork	x	x	x	x	x	x	x	x
	15	Dublin	x	x	x	x	x	x	x	x
Type 4	16	Brussels	x			x	x	x		
	17	Bristol	x	x	x	x	x	x	x	
Type 5	18	Adelaide	x	x	x		x			
	19	Canberra	x	x	x		x			
	20	Gladstone	x	x	x		x			
	21	Osaka	x	x	x		x			
	22	Tokyo	x	x	x		x			
	23	Taipei	x	x	x		x			
Type 6	24	Dallas	x	x	x	x	x	x		
	25	Guelph	x	x	x	x	x			
	26	Syracuse		x		x	x			
	27	Berkley			x	x	x			
	28	Boulder		x	x	x	x	x		
	29	San Diego	x	x	x	x	x			
	30	Muskegon			x	x			x	
	31	Niles			x	x	x			
	32	Hamilton		x	x	x	x	x		
	33	Melbourne		x						
	34	Toronto			x	x	x			
Type 7	35	Lake Oswego				x				
Type 8	36	Townsville	x	x	x					
	37	Paris	x	x			x			x
Type 9	38	Galway		x		x	x			
	39	New York	x	x	x	x	x	x	x	
Type 10	40	Columbia								x
	41	Raleigh								x

Appendix C

User questionnaire

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oFb - der onlineFragebogen

0% completed

WELCOME!

What's this about?

Urban dashboards have developed in the last few years as a visual language through which the smart city is represented. These city dashboards display real-time and historical data visualizations together with interactive maps which is intended to help citizens with their own decision-making.

Your answers will be valuable to investigate the role of existing urban dashboards.

This questionnaire will not take more than 12 minutes of your time. Your data is going to stay 100% anonymous and encrypted.

Thank you very much for participating in this survey.

1. Please enter you age.

[Please choose]

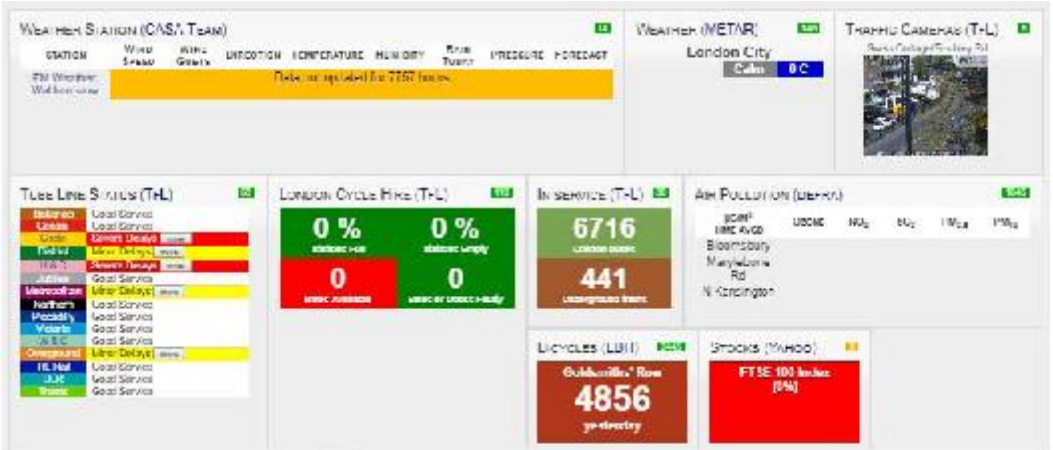
2. Please indicate your gender.

- Male
- Female

3. In which city do you live?

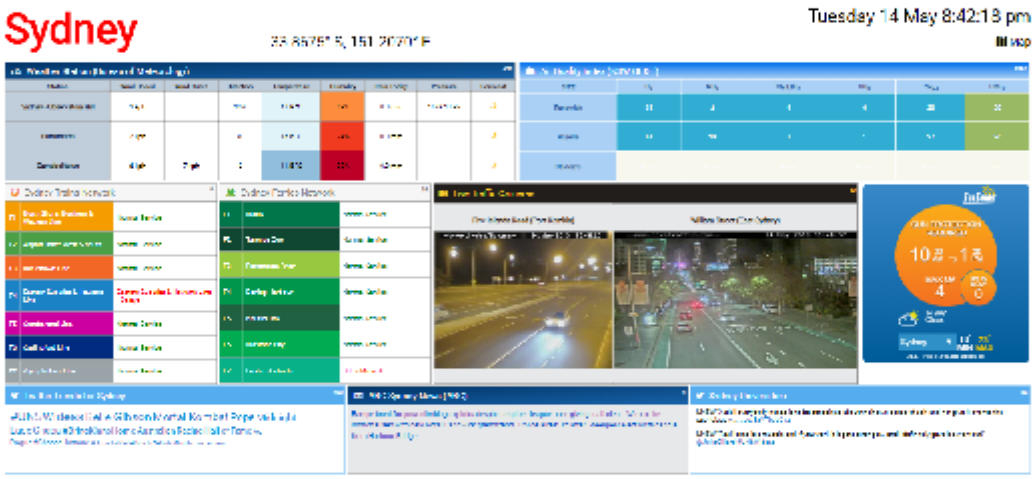
4. Please have a look on the urban dashboard for London. Pick up to 3 most relevant topics from this city dashboard that you would like to have access to in your city dashboard.

- Weather
- Traffic Cameras
- Tube line status
- London Cycle Hire
- Number of buses and trains in Service
- Number of bicycles
- Air pollution
- Stocks
- BBC London news
- Open street map updates
- Electricity
- Mood
- Twitter trends for London
- None



5. The image below presents the urban dashboard for Sydney. Pick the topics that you consider insignificant to be displayed in a city dashboard.

- ☐ Weather station
- ☐ Air quality index
- ☐ Sydney trains network
- ☐ Sydney ferries network
- ☐ Live traffic cameras
- ☐ Twitter trends for Sydney
- ☐ ABC Sydney news
- ☐ Sydney universities
- ☐ All
- ☐ None



6. How useful are these displayed numbers, percentage values and arrows in giving an overview of the performance of a city?

Numbers

Not useful ——— Very usefu

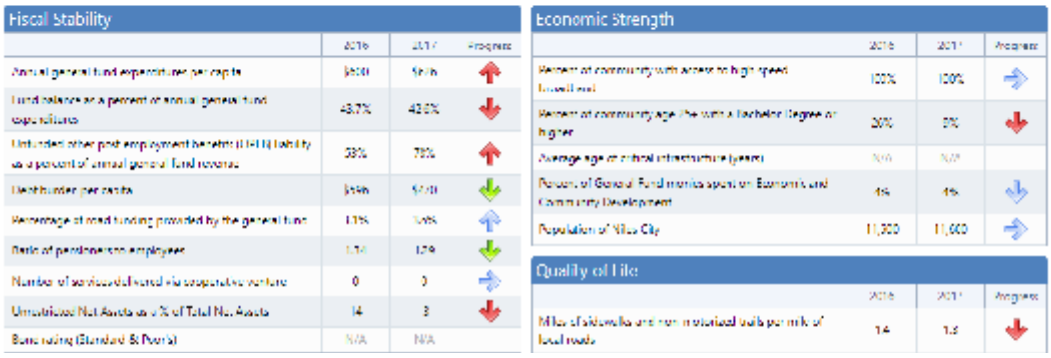
Percentage values

Not useful ——— Very usefu

Arrows

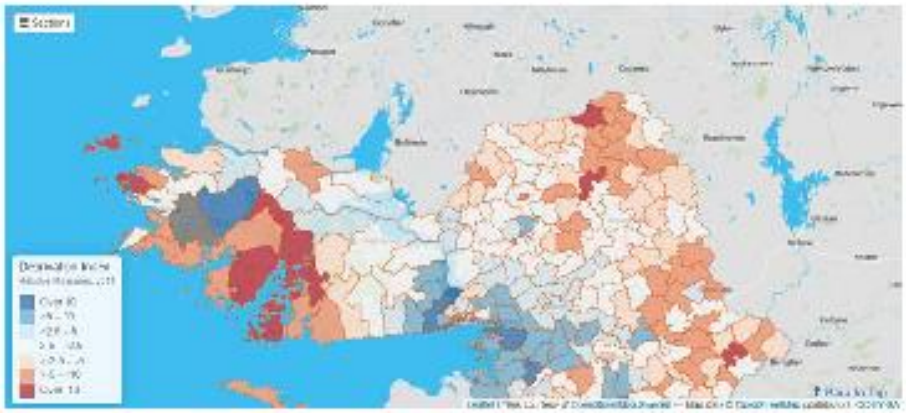
Not useful ——— Very usefu

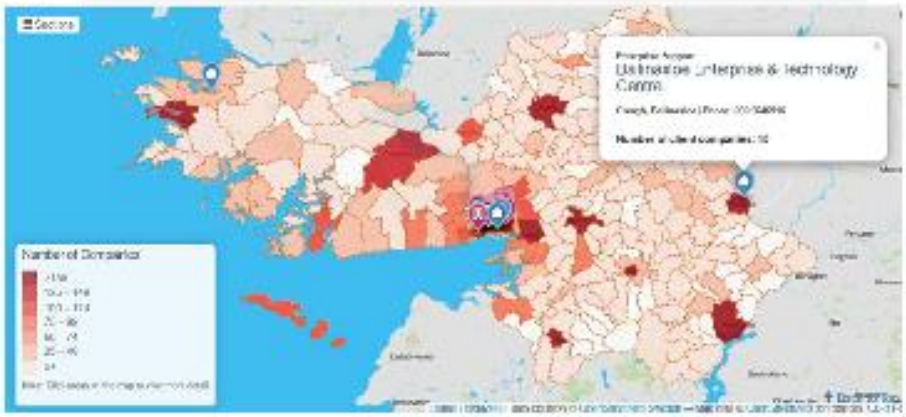
Municipal Performance Dashboard



7. How frequently would you check the content of this urban dashboard ?

Everyday | Once a week | Once a month | Every 6 month | Once a year | Not at all

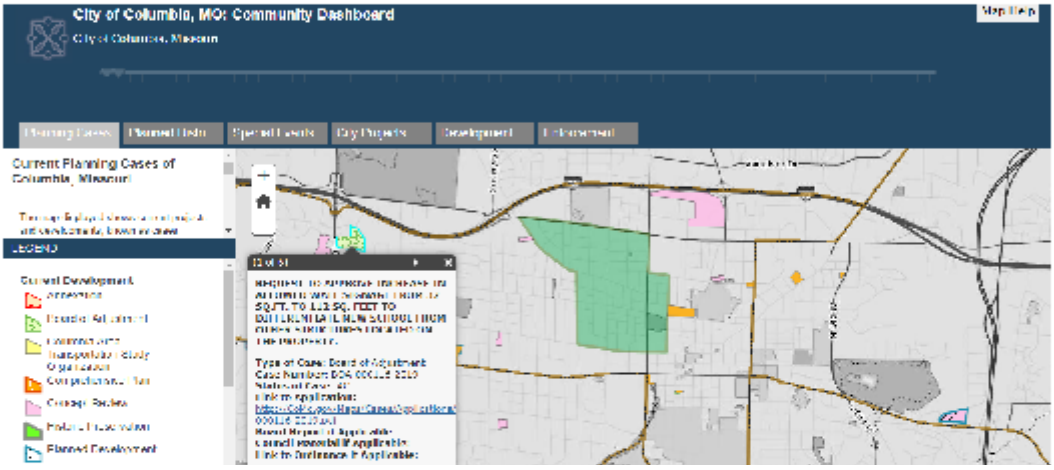




8. Please rank the following aspects according to their necessity/importance to track the changes of the city.

Recreation and culture	Public safety	1
Infrastructure	Sustainability	2
Transportation and mobility	Economy and finance	3
Civic engagement	Communication	4
Customer satisfaction		5
		6
		7
		8
		9

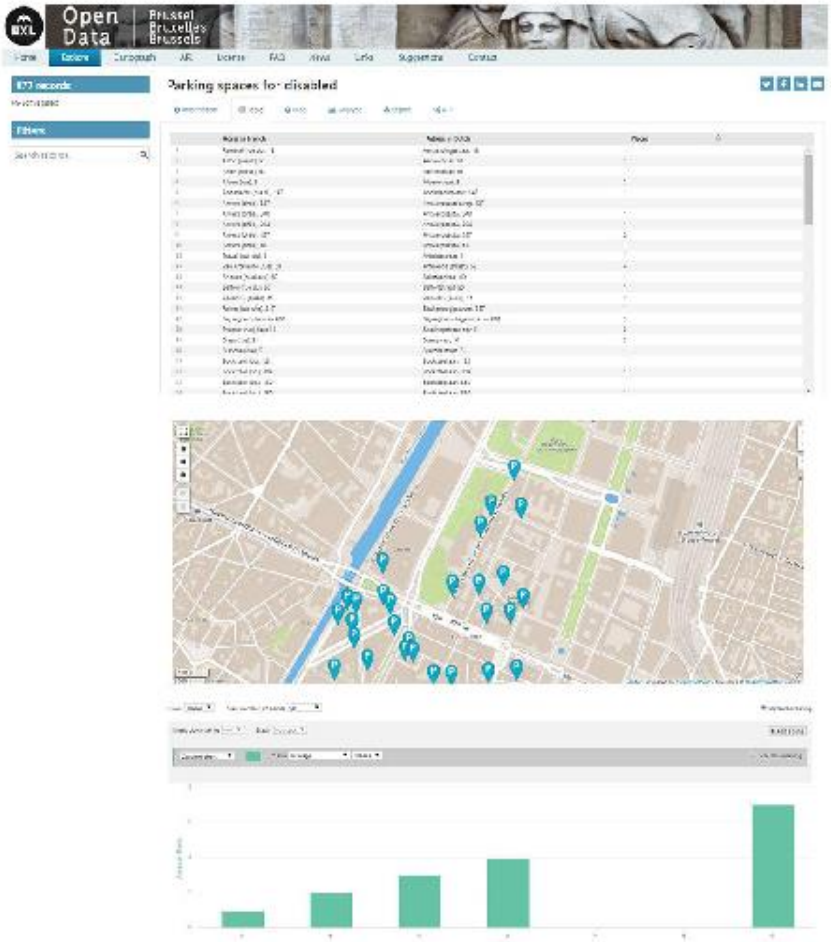
9. How important to you would be a dashboard displaying the current transformations and future projects taking place in the city?



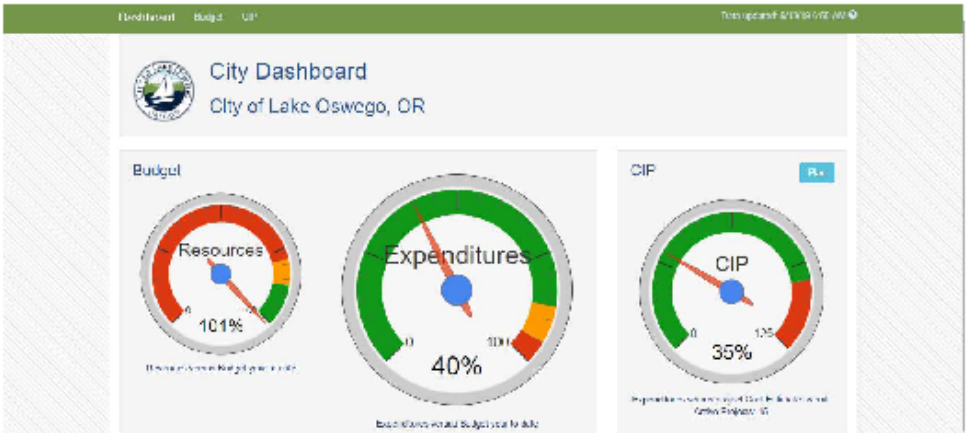
10. Which type of data visualization you prefer most?

Tables	Maps	Charts

Other



11. What do you think about of this visual representation?



12. Do you see benefits in using a map-based visualization for urban dashboards? If yes, please indicate them.

13. Dashboard Navigation Test: Try to find a free parking space for your car using the Dublin dashboard! Afterwards please rate your experience (close the tab after your task and return to this questionnaire).

Please click on the link below:
Dublin Dashboard

Very simple	_____	Very complex
Very clear	_____	Very confusing
Very smooth	_____	Very disruptive

14. Do you think the previous shown urban dashboards offer the citizens the opportunity to participate in making decisions regarding their cities?

- ○ Yes
- ○ Partly
- ○ No

15. Have you ever used a city dashboard?

- ○ Yes
- ○ No

16. Please elaborate on what kind of information would you like to see on your city dashboard.

Thank you for completing this questionnaire! :)

I would like to thank you very much for helping me.

Appendix D

User evaluation

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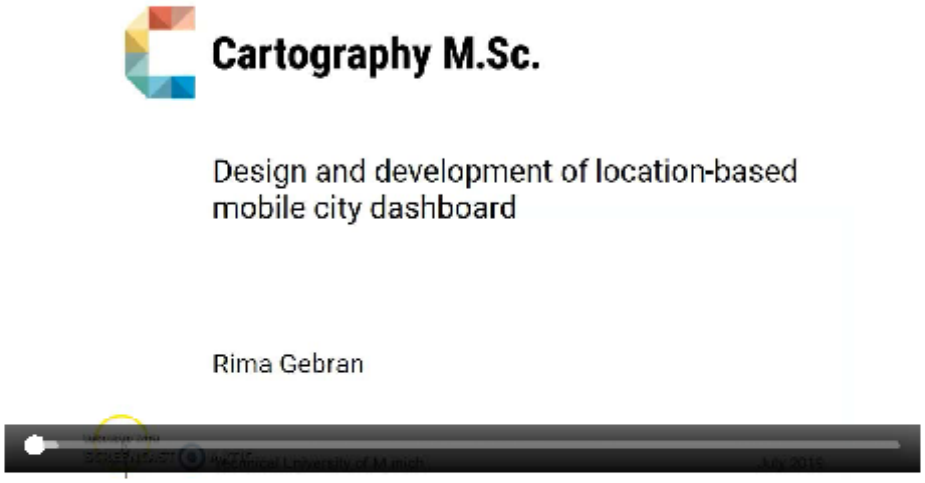
0% completed

Welcome!

Thank you very much for participating in this survey.

The survey consists of a short video followed by a series of eight questions.

Start watching...



Next

1. If you imagine yourself using this app, what would be your preferred way of making city-related suggestions?

- [ ] Sketch your suggestion
- [ ] Write your suggestion
- [ ] Alter a land use classification
- [ ] Something else:

2. If it would be possible to rate in the app these urbanistic solutions suggested by citizens, could you see yourself wanting to:

	YES	NO
Rate them (at least the ones you think are very good or bad for the city)	☐	☐
Check or keep track of their popularity	☐	☐

3. Which way(s) is the best for you to understand statistical information, for example about the land use of your neighborhood:

- [ ] Percentages: 5% green spaces, 10% parking areas, etc.
- [ ] Counts: 3 parks, 6 parking areas, etc.
- [ ] Graphically: bar chart, line graph, etc.
- [ ] Something else:

4. What would you like to know about a new project popping up in your neighborhood?

- [ ] The project functionality (e.g. offices)
- [ ] The project due date
- [ ] The impact of the construction phase on your daily life (e.g. less parking space, noise hours)
- [ ] Description on available spaces to buy/to rent spaces (e.g. price per square meter)
- [ ] Something else:

5. If you imagine you want to discover some possibly exciting locations in your city which you don't know yet because they are, let's say, 'hidden', how would you prefer to do it?

- [ ] By playing a game, like treasure hunt.
- [ ] By receiving informative notification once a day, like an animated feed or story of maximally 60 seconds.
- [ ] By receiving automatic notification when I am close to the 'hidden' location, like in a radius of 200 meters.
- [ ] Something else:

6. Would you check the public safety feature for consistently updated geo-located events before visiting a certain neighborhood in Beirut?

- ( ) Yes
- ( ) No

7. Will you enable the push notification to receive messages from ISF (Internal Security Force)?

- ( ) Yes
- ( ) No

8. Do you think it would be meaningful to add some more options to the app, or do something in a different way? Please, explain if yes

Thank you for completing this questionnaire!

Your answers were transmitted, you may close the browser window or tab now.

Appendix E

Prototype references

B018 images and drawings

Source 1: *Atlas of places*
Link: https://atlasofplaces.com/architecture/b018/
License: Fair Use. This site is for educational purposes only.
Source 2: *Bernard Khoury*
Link: https://www.bernardkhoury.com/project.php?id=127

Beirut map (DWG file)

Source: *Notre Dame University*
License: free access for studio design lectures as a previous architecture student at NDU.

Beirut Neighborhood analysis data

Source 1: *American University of Beirut Neighborhood Initiative, 2015*
Link: https://www.aub.edu.lb/Neighborhood/Pages/analyticalmaps.aspx
License: Students and researchers are welcome to use them. Please use this source citation: AUB Neighborhood Initiative, 2015.
Source 2: *American University of Beirut Libraries*
Link: https://scholarworks.aub.edu.lb/handle/10938/10279
License: All digitized texts and images in the AUB Libraries collections are for the personal, not-for-profit use of students, scholars, and the public. Any such use must name The American University of Beirut Libraries as the original source for the material.

Beirut satellite image

Source: *Atlas of places*
Link: https://atlasofplaces.com/architecture/b018/
License: Fair Use. This site is for educational purposes only.

Icons

Source 1: *Icons made by Hobby from www.Flaticon.com*
License: Free License (with attribution). This license allows you to use for free any of Flat icon contents for your projects as long as they are attributed to their author in the definitive project.
Source 2: *lit light bulb doodle | Designed by Vexels.com*
Link: https://www.vexels.com/png-svg/preview/151089/lit-light-bulb-doodle
License: Free Use can only be done if you credit us when publishing the graphic.
Source 3: *Get Drawings*
Link: http://getdrawings.com/license
License: Creative Commons Attribution-Noncommercial 4.0 International Public License.
Source 4: *Blog Baladi Posted By Najib, Jan 31, 2015 11:17*
Link: https://blogbaladi.com/a-short-animated-movie-that-depicts-living-in-beirut/comment-page-1/
Source 5: *Location Pin Icon #45185 | www.icon-library.net*
License: CC0 Public Domain License - Free for personal use only - Attribution required.

Source 6: *files design*
Link: https://files.design/free
License: Free resources.
Source 7: *Wall stickers by Jana Traboulsi*
Link: https://www.plan-bey.com/other/wall-stickers/vinyls-by-jana-traboulsi/
Source 8: *dreams time*
License: Royalty-Free. Public Domain Images Licensed Under the Creative Commons Zero (CC0) License.

Karantina massacre image

Source: *Françoise De mulder , Quartier de la Quarantaine, Beyrouth , 1976*
Link: http://www.artnet.com/artists/fran%C3%A7oise-demulder/quartier-de-la-quarantaine-beyrouth-KwYcw2hidE5AEBU149CZSg2

Textures

Source: *Wild textures*
Link: https://www.wildtextures.com/category/free-textures/
License: All textures at wildtextures.com are completely free for both, personal and commercial use.