HAL
open science

Design methodology for "Smartification" of Cities: Principles and case study

Bertrand T. David, René Chalon, Chuantao Yin

To cite this version:

Bertrand T. David, René Chalon, Chuantao Yin. Design methodology for "Smartification" of Cities: Principles and case study. IEEE 25th International Conference on Computer Supported Cooperative Work in Design, May 2022, Hangzhou, China. pp.1486-1491, 10.1109/CSCWD54268.2022.9776257 . hal-03658035

HAL Id: hal-03658035

https://hal.science/hal-03658035v1

Submitted on 3 May 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Design methodology for "Smartification" of Cities: Principles and case study

Bertrand DAVID, René CHALON
Université de Lyon, CNRS,
Ecole Centrale de Lyon, LIRIS, UMR5205,
F-69134 Ecully Cedex, France
{Bertrand.David, Rene.Chalon}@ec-lyon.fr

Chuantao YIN
Sino-French Engineering School
Beihang University
100191, Beijing, China
chuantao.yin@buaa.edu.cn

***Abstract*—The Smart City is a possible evolution of each City. With the rapid development of information technologies applied everywhere in city life, cities are becoming smarter and smarter. However, this context has multiple orientations, supported by an architecture of the assistive system and the associated implementation process. In this paper, we propose a design methodology with different approaches and illustrate them by a case study that attempts to transform a coastal city into a Smart Coastal City. All the design methodologies and technologies can be referred in other smart city applications.**

Keywords—Smart city, Collaborative design process, Design methodology, Assistive system, Coastal City, Smartification

I. INTRODUCTION

The Smart City is a very ongoing and important application field of ICT (Information and Communication Technologies), which is able to receive a wide variety of contributions, using multiple declinations of ICT aspects (data management, data processing, Human Computer Interaction, information accessibility in mobility, automated or on demand information access, etc.). This area is so large that it is not easy or possible to find a commonly accepted definition. However, to clarify our view we decided to consider the following definition: "The Concept of <<Smart Cities>> describes how investments in human and social capital and modern Information and Communication Technologies (ICT) infrastructure and e-services fuel sustainable growth and quality of life, enabled by a wise management of natural resources and through participative government" [1]. Another definition is: "a Smart City should use smart computing technologies and infrastructures to make city services more intelligent, interconnected, and efficient, including city administration, education, healthcare, public safety, real estate, transportation, and utilities [2].

The next view is technology-oriented. We identified 7 main techniques needed in order to implement a Smart City approach, namely: context-aware middleware for ambient intelligence; appropriate user interface in relation with the users' situations (mobile, nomadic or static), and the relationship with an appropriate set of rules related to the privacy of information exchanged between smart city applications by their users: Web 2.0 use i.e. collaborative (wiki-based) surfing, Internet of Things (IoT), allowing object to object communication without human implication, Location-Based Services (LBS) with multiple exchange configurations related to environment context; Open Data use in order to share available data collected by other applications in ours, thus avoiding installation of new devices in the field; and Machine and Deep Learning in order to benefit from available data and confront them with new ones and obtain an automated adaptation to new working or living conditions and behaviors.

To establish the context of a "Smartification" of a city, two basic questions must be answered:

- Smart City to whom: there are many answers, from a generic one "to all", to more specialized and precise ones (by age: kids, teenagers, adults, seniors), by city status, by implication in the city (citizen, neighbor, student, worker, administrator, governor); and also, "to all" from the deficiencies' point of view.
- Smart City for what: better common well-being and neighborhood, energy, transportation of goods and passengers, information dissemination on culture, sports, social services, etc.

The Smart City is an area of use for all ICT possibilities: data accessibility, data processing, information access exchange and manipulation in static and mobility situations, using wired or wireless networks, in appropriate applications considering contextual situations.

The remaining sections are organized as follows. The next very short Section two is devoted to a brief state-of-the-art presentation. Section three discusses the conceptual view of a smart city management system from three viewpoints: assistive system role and functions, intermediation platform, and its architecture. The fourth section describes the design methodology of city "smartification". The fifth section gives an example applied to the Coastal City. The last section proposes main conclusions and future work.

II. STATE-OF-THE-ART

To carry out a complete state-of-the-art for the Smart City seems to be a totally impossible goal as the amount of work is large and diversified. Just to establish a common definition and classification is hard and not yet successful, while to list all approaches and contributions seems very difficult [2]. We can split it into two viewpoints: the users' one and the technological one.

From the users' viewpoint, the list of applications is unbounded, as we mentioned earlier. From the technological

one, i.e. from the implementation one, the list is also over abounded, but shorter to explain: software architecture, Internet, Cloud computing, Internet of Things (IoT), Location-Based Services (LBS), Open Data (OD), and Machine and Deep Learning (ML & DL).

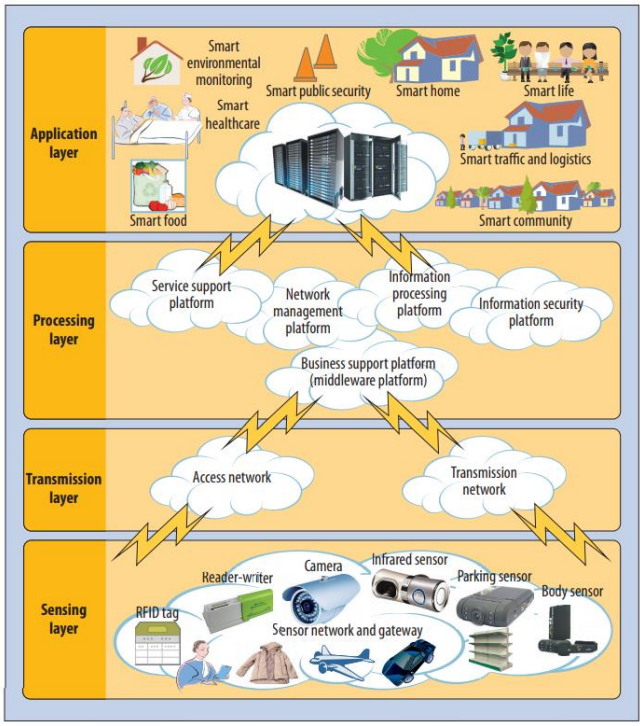

Fig. 1. Smart city architecture summarized by Liu and Peng [3].

III. Conceptual view

A. Assistive system role and functions

To provide appropriate services organized in an assistive system, it is important to identify the main aspects of this system. Globally, ITS (Information & Communication Systems) are responsible for considering data collection, storage and management, appropriate manipulations in different working situations, providing communication over short and large distances by wireless and wired networks, in mobility, and interacting with the environment in which active and passive things are organized in IoT (Internet of Things). Two important aspects are HCI (Human-Computer Interaction), and new services based on AI (Artificial Intelligence). The main HCI objectives are related to multimodal and multi-channel communication with various devices and interaction styles such as touch-based and speech-based interactions, as well as AR (Augmented Reality) approaches. These interactions can occur either on a desktop computer or with mobile devices (smartphones, connected watches, tablets), allowing individual and collaborative situations, and large, in-the-field, screens or in infrastructure integrated HCI devices, as in the vehicle dashboard.

From the AI point of view, Big Data, Open Data, and Machine and Deep Learning are mainly used to procure appropriate information from the huge amount of data available and to synthetize observed behaviors issued from typical data. An interesting summarization is proposed in Fig. 1 [3].

B. Intermediation platforms

To organize all these aspects, it is appropriate to create an Intermediation platform, the aim of which is to connect people, services and even things in ways that have been unthinkable until now. Search engines provide relevant references for people searching for information. Social networks connect users in their environment.

Users' activities on the platform collect the data coming from the field either from specific sensors or from Open Data, and generate secondary data. The latter mainly consist of traces that the platform is able to use and transform for specifically created secondary services.

C. Intermediation architecture

A generic intermediation platform needs to be adapted to different working situations (as for our case study described later on). The objective is to provide appropriate collection of data, services, and acquisition sensors and valuators, which are able to work together in a vitalization approach and create adapted User Interfaces allowing appropriate interactions. The Mashup approach is an interesting way to support these adaptations. Mashups are defined as "the software engineering approach, which is able to construct by assembling and combination of several existing functions new applications" [4].

The Mashup architecture is made up of three elements according to Merrill cited by [6]: Data, Services, and User Interface. Mashup aims at the composition of a three-tier application: (1) Data (data integration), (2) Application logic (process integration), and (3) User Interface (presentation integration). Integration of heterogeneous data sources uses two main technologies: web services and Mashup.

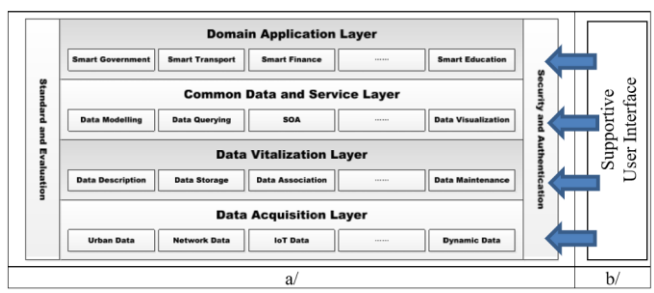

Fig. 2. a/ Architecture of an Intermediation platform with Data Vitalization [5], b/ Supportive User Interface [6].

Application mashuping in the context of intermediation platforms is a much-appreciated approach for creating appropriate applications based on reuse of existing ones. It is based on a four-layer architecture (Fig. 2a). To update or adapt data and services, a particular User Interface is used called "Supportive UI", the aim of which is to introduce appropriate adaptations concerning data, services, IoT exchanges, and HCI. This supportive User Interface, which is

also Mashup application creation- or evolution-oriented, proposes a programming interface for experienced developers, and a visual programming-oriented approach for experienced users (Fig. 2b).

D. Open data

One of the possible sources of information is the access to open data published by different operators, such as municipalities, road operators, etc. These data can be either historical data synthetized and giving general tendencies or real-time data, indicating what is happening now or a few minutes ago.

Open Data [7] is the idea that some data should be freely available to everyone to use and republish as they wish, without restrictions from copyright, patents or other mechanisms of control [8]. The goals of the open-source data movement are similar to those of other "open(-source)" movements such as open-source software, hardware, open content, open specifications, open education, open educational resources, open government, open knowledge, open access, open science, and the open web. Paradoxically, the growth of the open data movement is paralleled by a rise in intellectual property rights [9]. INSPIRE (Infrastructure for Spatial Information in the European Community) is an EU initiative to establish an infrastructure for spatial information in Europe, which is geared to help make spatial or geographical information more accessible and interoperable for a wide range of purposes supporting sustainable development.

E. Machine Learning and Deep Learning

Deep Learning is hugely popular today. The past few decades have witnessed its tremendous success in many applications. Academia and industry alike have competed to apply deep learning to a wider range of applications due to its capability to solve many complex tasks while providing state-of-the-art results [10]. In some situations, Deep Learning can be used to analyze existing data, leading to interesting solutions. We can take intelligent navigation and travel planning as examples. For intelligent navigation, the intermediation platform considers the starting position and the destination position, combines the time information, meteorological information and other interfering factors, before providing the most appropriate one or more recommended paths. As for travel planning, the focus is to intelligently analyze the user's intention of their behavior and finally make travel recommendations based on the tags they are interested in and their browsing history.

In practice, we can use the RNN structure in path planning, including intelligent navigation, travel for the disabled, Parcel post and so on, while the CNN model can be used for vehicle recognition to assist smart parking. For some scenarios with recommendation tasks, such as goods transportation and travel planning, we can use multi-layer perceptron, LSTM, and other models [11].

IV. Design methodology

To design a Smart City, it is possible to proceed in several ways. The easiest is to create from scratch an application and deploy it. When several applications are proposed, a more system-oriented approach is suggested, which either can be proposed or must be elaborated.

Several design methods can be used, depending on the context in which they evolve (Fig. 3). In the case of Smart City system design from scratch, the **top- down approach (1)** seems appropriate. In this case, the study starts with identification of potential users and corresponding services by a discussion with them in order to identify their wishes and expectations. Naturally, the next steps are identification of data on which these selected services can work and, finally, the sensors and actuators needed to obtain an appropriate relationship with the field. These different aspects are implemented progressively place in the Assistive System Platform described earlier (§ III.A).

Conversely, the **bottom-up approach (2)**, could be appropriate if the objective or main question is which services can be provided to potential users on the bases of available data. In this case, the working process starts with identification of in-the-field devices and corresponding data provided by them. Also, services and potential users are determined later. This environment-based approach is appropriate if the starting point is composed of a large scope of problems, and if the set of potential users (and services) is open-ended.

Naturally, between these “extreme” approaches an **extension-oriented approach** is also possible, and may probably be most commonly used. Its characteristic is its adaptation to extension-oriented situations, i.e. to consider **new users, new services, and/or new data integration to an existing Smart City Assistive System (3).**

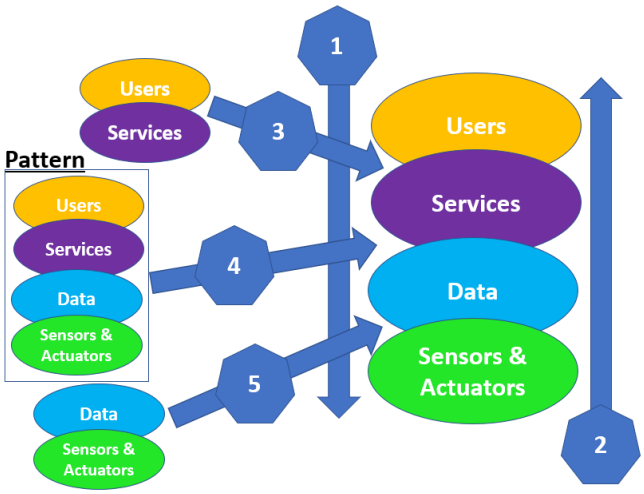

Fig. 3. Design and deployment approaches

In this case, two sub-approaches can be distinguished, in the same way as for the “from scratch” approach: top-down or bottom-up with integration of different starting points: either from users and services or from data, sensors, and

actuators needed. In these two cases, the objective of this integration process is to identify the new set of actors and homogenize services, data, sensors, and actuators to avoid redundancy and incoherence that are difficult to manage during platform life.

Another approach is based on integration and reuse of **on-the-shelf applications**, constituting **patterns (4)**, which have been created earlier and proposed as pattern solutions. In this case, the integration process could also contain homogenization considering all the pattern characteristics: User + Services + Data + Sensors & Actuators to reach a homogeneous system.

The last t approach but not the least is based on **Open Data as starting point (5),** and integration or elaboration of appropriate services using them.

V. Case Study: Transformation of a Coastal City into a Smart City

In order to propose the evolution of a city to a Smart City, and specifically for the Coastal City, we need first to characterize what the Coastal City is, before applying the approaches presented above to the "smartification" of a Coastal City. We limit it to the dimension of management of mobility, and its integration into the corresponding assistive system.

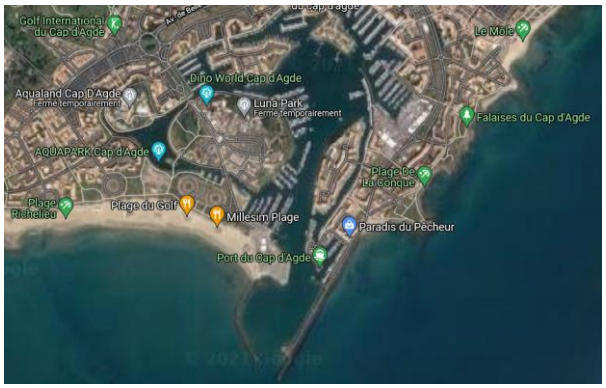

Fig. 4. Coastal city with downtown, harbor, beaches, and boating industrial zone.

We characterize a Coastal City as a city which is located by the sea or the ocean (Fig. 4). Its activities are related to the sea, i.e. fishing, boat transportation, boat and ship repairing, and also possibly boat and ship construction. A large majority of coastal cities also have major tourist activities related to the proximity of more or less large beaches with swimming, diving, snorkeling, yachting, kitesurfing, fishing as current practices.

This tourist reception aspect dominates the organization of City life. It introduces the notion of high and low season, mainly by the number of its inhabitants, which can vary considerably between these two seasons (multiply their number by 10 or more in summer). This means that the demand of life organization is totally different. In the low season, few inhabitants can live quietly without stress, noise or traffic jams. However, economically speaking, this period is a waiting period for a large majority of inhabitants oriented towards business, excluding retired people, in different forms (restaurants, shops, accommodation, and recreation activities).

It seems natural to study the evolution of this kind of city to a Smart City in the context of high season city life, and only later ensure that in the low season it is possible to propose appropriate limited behaviors and the city services adapted to the low season and its inhabitants.

A. *Top-down approach*

An example of the Top-down approach in the Coastal City is the objective to work with all concerned persons and determine main orientations of "smartification" from their viewpoints in the context of mobility. To respond to this, we identified the objective of creating park-and-ride systems outside the city with automatic public transportation to the town and the beaches, to optimize traffic organization on the ground, in the harbor and the sea, as well as management of beach activities. Special solutions such as traffic lane management [12] or delivery parking reservation [13] can constitute concrete examples.

B. *Bottom-up approach*

Concerning the Bottom-up approach, an interesting example is to provide an efficient warning system based on in–the-field devices (sea, water, air, lighthouse, stormy and howling wind, etc.), propagating emergency and rescue information at all levels (global, individual, visual, sound, digital, etc.).

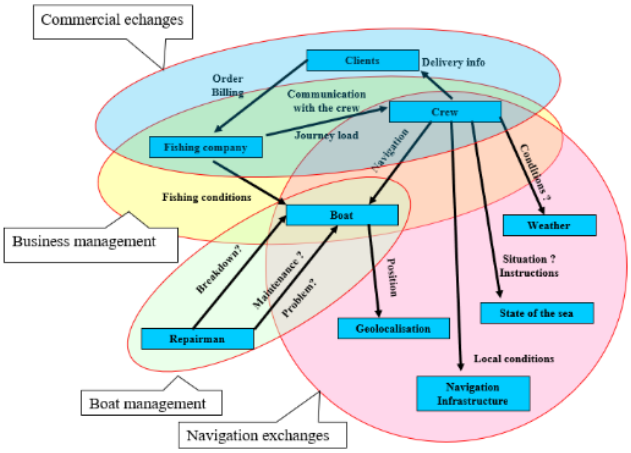

Fig. 5. Fishing Boat information ecosystem.

C. *Add extension: boat management*

The list of possible extensions is open-ended. We can mention the management of circulation in the harbor, which can be either limited to the local area, or generalized to the overall management and supervision of boats in the harbor and on the sea. The ecosystems for fishing and cruising boats are schematized in Fig. 5 & Fig. 6. The principle is to identify all concerned actors and situations and indicate their behaviors, their interrelations, and contributions to appropriate trip and work conditions. In the past, we studied

this kind of ecosystem for buses (e-bus) and trucks (e-truck) [14] and adapted them to these situations.

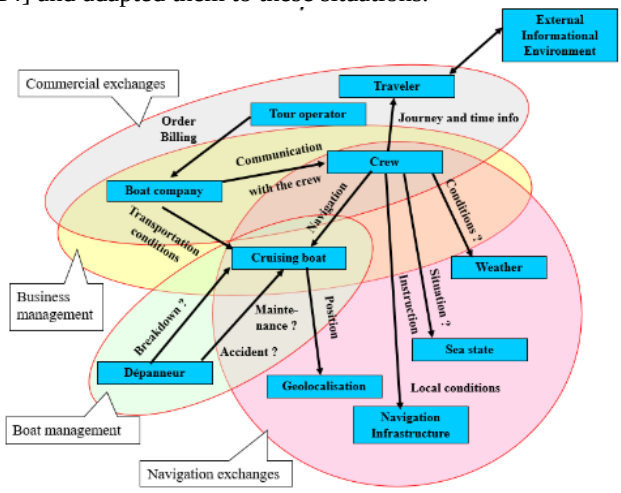

Fig. 6. Cruising Boat information ecosystem.

D. Add extension: beach and sea mobilities

A very important "smartification" is related to beach and sea mobilities. This can be either the main aspect of the overall study or added separately.

Fig. 7. COVID location beach management, sea zone supervision and rescue organization.

On the beach several activities can take place, more or less active in nature: from sunbathing, walking along the seashore, practicing different sports or family activities. In all cases, it is important to take into account other beach users, in order to avoid accidents and disturbing them. During the recent COVID period, for many French beaches, city mayors at local level or, more globally, government authorities decided on several levels of rules: prohibit access to the beaches, authorize only "dynamic use of the beach" (no sitting or sunbathing, only walking and running). This also included respect of distances between groups of users, either natural or physically materialized zones with possibility of reserving them (Fig. 7).

On the sea, the development of activity zones is the usual approach leading to creation of specific zones with supervised swimming, diving, snorkeling activities, as well as sailing, yachting, surfing, kitesurfing, with either visual supervision or more instrumented electronic monitoring. In this case, each actor (swimmer, sailor, kite surfer has at their disposal a connected watch or more sophisticated device able to communicate their position and related situation (OK, emergency call, etc.). On the beach, lifeguards are equipped with a receiver capturing the observed situation and able to trigger rescue actions.

E. Based on open data: shelter

As an example of the service based on open data, we choose a shelter. We initially proposed a bus shelter [15], but its adaptation to other situations, such as beach shelter, harbor shelter, public market shelter is not difficult.

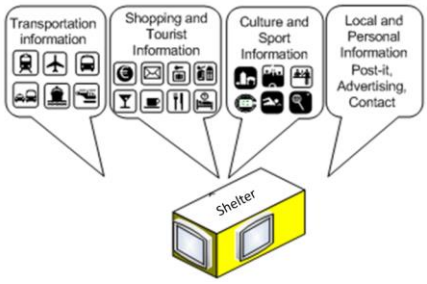

Fig. 8. Bus or Boat shelter

The shelter can be located downtown, near the carpark, on the harbor and near the beaches. Its objective is to provide potential passengers and visitors with appropriate information on transportation lines and their schedules, using appropriate screens, as well as providing local, cultural and sports programs, commercial advertising, etc., together with, if needed, physical services (shower or changing cabin). The information part is mainly based on presentation of generally available information issued from open data (Fig. 8).

F. Pattern-based approach: Pedestrian Drive

As an example of a pattern-based approach, we can present what we call the Pedestrian Drive, the aim of which is to provide fresh food distribution based on box-lockers [16]. The idea is to convey fresh food on the beach instead of asking clients to go to a supermarket. The Pedestrian Drive is a variant of the concept of the supermarket drive, specially designed for pedestrians. Located as near as possible to the client locations (beaches, sports arenas, etc.) and accessible 24 hours a day, it allows ordered goods to be collected at any time. Equally, it is able to store not only ambient temperature products but also fresh and frozen goods (Fig. 9). This fresh product box-locker can be either owned by a supermarket firm and totally integrated into the ordering, management and logistic process of the firm, or can be managed independently. This case is an interesting support system for the shared economy, as the role of the pedestrian drive manager is to manage such use for multiple providers. His/her role is to ensure Internet access for all provider offers and to organize the global supply chain with consumer information on availability of ordered goods in the box-locker. In this way, the circular economy as a short circuit of agricultural goods can be supported. Its characteristic, in

which we are interested, is its independence from the implementation location. That is why we present it as a pattern of autonomous equipment completely characterized by what we call Pattern: User + Services + Data + Sensors & Actuators, which are easy to position at the chosen location.

Fig. 9. Box-Lockers for fresh and frozen foods [16].

G. Machine and Deep Learning use

We would also like to briefly present a possible use of Machine and Deep Learning technics. Our case study is sea behavior-oriented. Its objective is to study evolution in sea behavior over the season and, in particular, weather conditions as the wing and tide coefficient changes to inform swimmers and/or kiters of the organization of the supervised zone. By accumulating the data of different periods, it would seem possible to indicate foreseeable sea behavior (Fig. 10).

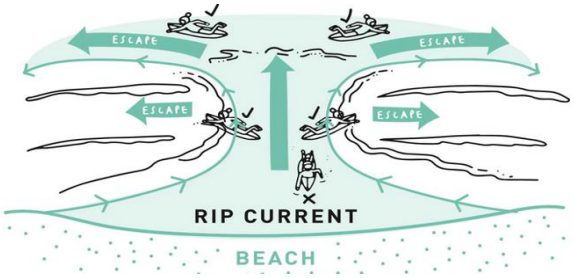

Fig. 10. Surf safety panel issued from history observation [18].

VI. Conclusions

Of course, this case study is not complete. Its objective is only to illustrate proposed approaches of the design methodology of "smartification" of cities in a particular context of the Coastal City. We voluntarily limited our study to mobility aspects and avoided two very important problems, namely adaptation of cities during "smartification" to the elderly and, in particular, to disabled people. We partially studied this last aspect in the following publications [18], [19]. We did not have room to present an important aspect, namely dynamicity in all presented (re)organizations, which can be permanent (available all the time) or evolving according to the time scale (each month, week, day, weekdays, weekend, morning, afternoon, evening, night, per hour or in unpredictable exceptions). Naturally, signaling must be appropriate (static or with appropriate dynamicity), with propagation of applicable rules to different users using suitable HCI devices. In the future, other aspects of "smartification" of mobility will be studied, as well as refinement of proposed support aspects.

Acknowledgment

This work is a collaboration between one French team located in Lyon and one Chinese team located in Beijing. We thank our partners and their students and researchers for their contributions. This work is partially supported for the Chinese part by the National Key R&D Program of China (No. 2019YFB2102200) and the National Natural Science Foundation of China (No. 61977003).

References

[1] A. Caragliu, C. Del Bo, P. Nijkamp, "Smart cities in Europe." J. Urban Technol. 18(2), 65–82 (2011)

[2] C. Yin., Z. Xiong, H. Chen, J. Wang, D. Cooper, B. David, "A literature survey on smart cities". Sci. China Inf. Sci. 58, 100102:1–100102:18 (2015). https://doi.org/10.1007/s11432-015-5397-4

[3] P. Liu, Z. Peng, « China's smart city pilots: a progress report." Computer 10, 72–81 (2014)

[4] B. David, R. Chalon, "Orchestration modeling of interactive systems". In: Jacko, J.A. (ed.) HCI 2009. LNCS, vol. 5610, pp. 796–805. Springer, Heidelberg (2009). https://doi.org/10.1007/978-3-642-02574-7_89

[5] Z. Xiong, "Smart city and data vitalisation". In: The 5th Beihang Centrale Workshop, 7 January 2012

[6] A. Atrouche, D. Idoughi, B. David, "A mashup-based application for the smart city problematic". In: Kurosu, M. (ed.) HCI 2015. LNCS, vol. 9170, pp. 683–694. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-20916-6_63

[7] S. R. Auer, C. Bizer, G. Kobilarov, J. Lehmann, R. Cyganiak, Z. Ives, "DBpedia: A Nucleus for a Web of Open Data". The Semantic Web. Lecture Notes in Computer Science. 4825. p. 722. (2007). doi:10.1007/978-3-540-76298-0_52. ISBN 978-3-540-76297-3

[8] R. Kitchin, "The Data Revolution". London: Sage. p. 49. (2014). ISBN 978-1-4462-8748-4.

[9] https://en.wikipedia.org/wiki/Open_data

[10] C. Paul, A. Jay, S. Emre: Deep neural networks for youtube recommendations. In Recsys. 191– 198 (2016).

[11] P.-S. Huang, X. He, J. Gao, L. Deng, A. Acero, L. Heck, "Learning deep structured semantic models for web search using click through data". In: CIKM 2013: Proceedings of the 22nd ACM international conference on Information & Knowledge Management, pp. 2333–2338 (2013)

[12] C. Wang, B. David, R. Chalon, C. Yin, "Dynamic Road Lane Management Study: A Smart City Application", Journal Elsevier Transportation Research, Part E: Logistics and Transportation Review vol. 89, pp. 272-287 (2015). doi: 10.1016/j.tre.2015.06.003

[13] D. Patier, B. David, V. Deslandres, R. Chalon "A new concept for urban logistics: Delivery area Booking". The Eigth International Conference on City Logistics, Bali, Indonesia. pp. 99-110. Procedia Social and Behavioral Sciences 125. Elsevier ISSN 1877-0428 (2014).

[14] B. David, T. Xu, H. Jin, Y. Zhou, R. Chalon, B. Zhang, C. Yin, C. Wang, "User-oriented System for Smart City approaches". The 12th IFAC/IFIP/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Human-Machine Systems, 2013, Las Vegas, Nevada, USA. pp. 333-340. IFAC / Elsevier. ISSN 1474-6670.

[15] B. David, R. Chalon, "Hotspot based mobile web communication and cooperation: ABRI+ Bus Shelter as a hotspot for mobile contextual transportation and social collaboration", SWWS'10, Las Vegas, July 2010.

[16] http://www.surf4all.net/article29.html

[17] https://barefootsurftravel.com/fr/livemore-magazine/aspects-de-securite-en-surf

[18] C. Yin, B. David, R. Chalon, H. Sheng, "Assistive systems for special needs in mobility in the Smart City". HCI International 2020, Copenhagen (Danemark). HAL hal-02487688.

[19] Y. Li, C. Yin, Z. Xiong, B. David, R. Chalon, H. Sheng "Assistive Systems for Mobility in Smart City: Humans and Goods". HCI in Mobility, Transport, and Automotive Systems, Springer International Publishing, pp. 89-104. 2021. doi : 10.1007/978-3-030-78358-7_6.