The Role of Urban Informatics in Monitoring the Physical Deterioration of Urban Environment

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Abstract. The twenty-first century is witnessing a rapid growth population in urban areas; this growth needs intelligent urban planning and management. The field of urban informatics is one of the new and vital specialties to organize and analyse the urban system at all levels and areas. ICT works with interactive community participation to guide and manage the urban environment to serve, provide the residents with safety and security. The paper presents a new vision in terms of employing the field of urban informatics in mapping and monitoring the urban deterioration of the built environment in general and buildings in particular. The urban informatics system is still taking its first steps to manage and serve the city's facilities (transportation, communication, air pollution, etc.). The built environment and the deterioration through time and other factors are still far from this area. This paper aims to identify the urban information field, the situations, and types of urban deterioration and move to capture urban deterioration indicators (main and secondary), which can be measured in urban informatics. This paper recommends the adoption of such a mechanism in managing and controlling the deterioration that contributes to the reduction of material and human losses, saving time and money away from traditional methods, and the possibility of employing them in times of crisis and disasters in the urban environment.

1. Introduction

The 21st century is characterized by rapid urban growth and expansion worldwide. UN reports indicate that more than 60% of the world's population will live in cities by 2030 and is expected to reach 70% by 2050. In order to counter this expansion urban development and technological development must play an active role in sustainable urban management and planning to provide a safe and dignified life for the urban dwellers. This theme took the lead on 31 October when experts met on the occasion of the International Day of Cities 2017 to attend the event “Cities of the United Nations: Empowering Cities in the Future to Be Smart” [2].

Urban informatics is one of the new fields that operate according to a large information (Big Data) base of the urban system in a holistic manner, to assist the management, control, collect information and analysis of the urban environment at various levels using the means of communication and information technology.

The paper assumes the possibility of benefiting from the technological development in the field of urban informatics, and smart buildings for the purpose of employing this development in the
management, regulation and control of the urban deterioration of buildings in particular and urban areas in general to achieve the sustainable development of smart cities.

As it is known, the physical or/and structure of buildings are changing continuously by time passing, which has a clear effect on the safeties of their dwellers, their functional performance or even affecting the urban scene of the city. This paper aims to identify a set of standard indicators that can be adopted in the urban informatics system for the purpose of monitoring, measuring and analyzing the physical deterioration of any building in a specific city.

The importance of this study shows the applying of this standard indicators which can control the catastrophic and dangerous situations of the buildings that can be exposed to as a result of landslides or any other symptoms threaten the lives of the population, also identifying the degrees of decline and deterioration of historic and heritage buildings, which represent an important human and cultural heritage for each society beside the dimensions of environmental degradation and its impact on climate pollution of the surrounding environment as well as controlling the consequent possibility of expansion of this pollution to other system of information city CIM.

2. Urban informatics

2.1. The definition of Urban Informatics

The Urban Science Center at the University of New York (NYC) defines urban informatics as the data used to know how cities work better. This knowledge can help to address a wide range of issues affecting the daily life of the community and, on the long run, the health and efficiency of the city (such as daily work trips, emergencies and air quality) [8].

There are those who pointed out that the city is an urban system and the urban informatics system works to explore and understand it through the dynamic resource management, knowledge discovery of the urban patterns that engaged in community participation, urban planning and policy analysis. Urban informatics research approaches involve both theoretical and practical data-driven. [7]

The Center for Advanced Spatial Analysis (CASA) of the University of London defines urban informatics through two levels: the narrow and the broader. The narrow level is associated with computer applications on the city, through data obtained from different sources. The other level has a broader perspective, as it is concerned with the use of communication and informatics to provide services through multiple fields and with active community participation. The Center refers to four main ideas on urban informatics [6]:

a) Interest in new types of data that are not yet visible or not exist.
b) Linking to the local prosperity, urban competition and economic development.
c) The possibility of providing integrated services to enhance competition and urban prosperity.
d) Community participation and direct interaction with public services.

Many local administrations have turned to the use of urban informatics for the efficient management of cities, because the adoption of informatics and communication technology helps to better understand of the needs of metropolitan cities, challenges and opportunities. Urban informatics applications have been classified in different parts of the world, to three main groups: using existing data to improve city services, building new data for better planning and operational decisions, and broadening public participation to develop proposals.

The Urban Informatics Research Lab at Queensland University of Technology (QUT), Brisbane, Australia, defines, for the first time (Urban informatics) as a disciplinary domain situated at the intersection of notions, trends and consideration for place, technology, and people [1]. The study of (Foth,Choi & Satchell) specifies three domains and consideration in urban environment, firstly, place.
The UN reports indicate that more than 60% of the world's population will live in cities by 2030 and is expected to reach 70% by 2050. Thus planning, managing, controlling and infrastructure of the city, including physical structure and environmental conditions, are becoming increasingly complex. The urban population growth will help to accelerate and increase the physical deterioration of the urban environment, unless there are procedures and mechanisms working to control the urban environment to keep its balance and efficiency with the passage of time. The deterioration of the urban environment has multiple impacts; some affected people's lives and others affect the natural environment, in addition to the physical dimension of historical buildings and archaeological sites of cities.

2.2. Areas of urban informatics

With the rise of environmental degradation and urbanization, there are technological development in the field of informatics and communication. The second domain in the study of (Foth, Choi & Satchell,...) is technology. They explore four trends in technology innovation further:

1. The mobile phone will play a crucial role in expanding the means of participatory culture in an effort to embrace and foster values of sustainability. That means active participation by various group in society.
2. As a consequence of widespread ubicomp deployment in urban environments such as sensor networks, locative media and mobile devices, the accessibility of real-time information enables a major transformation of the way we perceive, understand subsequently conceive and plan city spaces. The use of technology will help control the factor of time and dealing with the rapid changes in the Built Environment quickly and efficiently
3. Lab’s research goal to inform the design of real-time mobile information systems that make the invisible visible holds great potential to have wide-ranging impacts on sustainable urban development. As our study raised the case of the physical deterioration of the Built Environment, which is considered as invisible risk in the first stages, so the urban informatics will allow us to detect the deterioration much earlier, long before to expand and cause humanitarian disasters or material damages.
4. There is a trend towards Geographical Information Systems (GIS) and related tools that can be used by lay persons and non-experts without intensive training. This new trend of GIS has led to the term ‘Neogeography’. This means the involvement of civil society and non-specialists in the field of Urban Planning.

The third domain in the study of (Foth, Choi & Satchell) is people. The core of the urban environment is people occupying this place, because of the various services, whether technological or spatial resolution is to serve the people and their needs, so people are the core of the city.

The summery from the above, the continued urban expansion would be offset by the rapid deterioration of the built environment, in order to control and monitor the various changes in the urban environment, technological development in the field of urban Informatics through community participation should be used.

2.3. Applications of urban informatics

All these three domains that we have discussed could be viewed throughout three general applications [5]: using existing city data to improve service delivery, building new data for better operational and planning decisions, and increasing public engagement to improve problem solving.

Information should be collected through the use of technology for better city management. Nearly half of the applications reviewed by (Bays & Callanan) gave access to existing services via the Web,
SMS, 2 smartphones, or electronic kiosks. These technologies can help a city make its basic transactions faster, develop enhancements to existing services, and improve coordination between city planners and the organizations that deliver services. For better future to the next generation, these data enabling multiple options through creation of new data sets and (novel) model? Ways of using them.

2.4. Instrumenting the city

As this study aims to keeping up with the advent of technology in urban areas, so we are talking about Smart Cities Movement. This will take us into questions of big data, how the city is being instrumented which is set against the idea that computable functions should be integrated, jointed up [6]. Instrumenting the city is providing systems of control, systems to deliver services and big data (Big Data – Thakuriah and Illinois Universities- is the term being used to describe a wide spectrum of observation or naturally occurring data generated through transactional, operational, planning and social activities that are not specifically designed for research) on a second by second, and locational precise basis, theses will shorten the timescales for which we have data and information about the city quite radically.

In the last about 10 years, digital sensors have been embedded into the physical infrastructure which provide data for the means to control urban systems, like traffic, services, air pollution...etc. Sensors in the physical built environment and those associated with people through portable devices are complementing one another. These sensors or any other means can be used to monitor the physical deterioration as it will be discussed in the following paragraphs. It will be a short time before everything will be connected to everything else in (an internet of things) [5]. Several commentators and inventors are now suggesting such things as (operating systems for cities), but connectivity based on access to services anytime, anywhere is clearly one of the main driving forces in cities.

The research can define the urban informatics according into four main dimensions

1. The structural dimension: main pillars of urban informatics include: (society, place, and technology): The community includes; the people and the citizens of different levels and categories, the place includes; the different levels of the urban environment of the neighborhood unit, urban space, suburbs and the region. Technology includes and refers to different types of ICT, software, communication, and computer science
2. Theoretical dimension: It refers to the processes of understanding data obtained from various means, data analysis and information building, exploration and construction of new data, study and research of existing data and information.
3. Applied dimension: These structural and theoretical aspects of urban informatics produce a range of practical and applied aspects that serve the community and the urban environment, such as improving and providing better services to the city, community participation in planning and decision-making, facing the challenges (Emergency or future), identify opportunities to promote competition and urban prosperity.
4. The time dimension: All of the above dimensions are governed temporally by the time dimension. The variables and the different conditions that the city undergoes through time are considered the main guide to all the components of the urban environment of society, place and technology, all the updating of theoretical and applied sciences developed in the field of Urban Informatics.

The uprising of urban informatics is a product of urban expanding at the city level, which has become difficult to manage and operate efficiently and effectively according to traditional methods, in addition
to the rapid change in the urban areas and in emergency situations that the city can face. The means and advanced techniques have come to help people manage and direct their settlements to the right direction.

3. Transition from building information modeling (BIM) to city information modeling (CIM)

The technological and digital development in the field of informatics and communication has been reflected in the field of architecture and construction as a first stage. The computer programs that help designer to create models for all the building information to make it accessible to all participants in the project and from various specialties during the life cycle of the building, so-called Building Information Modeling –BIM-. On the other hand, in the field of planning and urban design, a computer-based system appeared working on collecting, maintaining, storing, analyzing, distributing output data and spatial information. These systems collect, input, process, analyze, display and produce spatial and descriptive information for specific objectives, and assist in planning and decision-making in relation to agriculture, urban planning and housing expansion, so-called Geographic Information System –GIS-. [10]

From the collection of the BIM database with the spatial and geographic database of the site (GIS), we obtain the total data of the city with different levels, which is called CIM [10] City Information Modeling (CIM) is a useful way to organize urban information of the city with its size and diversity. The urban system is divided into a set of secondary models (road and traffic network, infrastructure, buildings, etc.). The BIM system is used for the purpose of building, a database for these parts, then using GIS to determine the spatial location of those secondary parts [10].

The modeling of the city's information at all levels and fields will be the specialized field in urban informatics for everything related to the built environment, which includes the field of urban deterioration that affects buildings in particular and urban areas in general, which is the subject of this paper.

4. The use of urban informatics to monitor the urban deterioration of buildings

The previous sections introduce the system of urban informatics and its role in improving efficiency the urban environment. This system depends mainly on the City Information Modelling System (CIM) and the Building Information Modelling System (BIM). But what enters into this system within the building sector is the structural components in terms of the quality of walls, floors, doors, windows, etc., during the design and implementation phase, using software such as CAD, REVIT, and does not enter the depth of the structure and building materials and doesn’t follow the stages of decline and change that affect these materials due to time factor and other factors.

For that this paper has been conducted to examine the possibility of employing urban informatics in monitoring the aspects of urban deterioration of the buildings, specifically the structure of the buildings, because of its importance in terms of providing the safety of the dwellers over the time as a result of the deterioration and erosion that affect the buildings under the influence of multiple factors; Preservation of historical and heritage buildings and controlling of the environment from pollution caused by the erosion of old buildings to achieve sustainable development of the urban environment.

Therefore, in the next paragraph, the study will identify urban deterioration, its types and measurements, and then determine the indicators of urban deterioration that can be measured by adopting the urban informatics system.

4.1. Definition of urban deterioration

The decline in the housing is one of the most noticeable manifestations in different residential environments. This deterioration affects not only the formal or aesthetic aspect of the city, but also the safety and health of the inhabitants.
Urban deterioration appears in different aspects of the residential environment, exceeding acceptable or permissible appropriate limits and standards which include the following criteria:

- Health and psychological criteria.
- Security and safety criteria.
- Planning criteria.

At this stage the study will focus and discusses the security and safety criteria that affect occupants’ life and the users of the building.

4.2. Types of physical deterioration of buildings

Physical deterioration affects the building components by: Packages\(^1\) and connections\(^2\). Both cases can be expressed through [4].

- Changes of materials characteristics.
- Changes of shape characteristics.
- Changes of location characteristics.

4.3. Indicators of physical deterioration

Deterioration is one of the types of change that one or more components of a building are exposed to. This physical change can be traced based on the following standards:

1. The location of the deterioration
2. The speed of the deterioration
3. Factors Affecting the deterioration
4. The direction of the deterioration.
5. The characteristics of the physical deterioration.

4.3.1. The location of the deterioration

An important and fundamental stage for monitoring the state of physical deterioration in the urban informatics system is to locate the situation. The identification of the location and place of degradation is important for the purpose of constructing the initial perception of the seriousness or importance of the situation based on its location. As in the case of locating traffic congestion or environmental pollution zone, and also helps to estimate the speed of intervention to control the area of physical deterioration. The location of the deterioration is at two main levels:

a) Urban level: Determinate the area of deterioration within a residential area, commercial area, city center, industrial zones and also in important historical and heritage areas. And also determine the dimension of the deterioration area.

b) Architectural level: Determine the state of deterioration in the building itself (main components or connections between them), or in surrounding buildings. The main components of the building are:

- Floor(s)

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\(^1\) A package is defined as every coherent distinguishable part of a building with a distinguishable set of performance characteristics related to a set of requirements. (Hermans, 1995)

\(^2\) The word connection is used for every location where packages meet or end, counting from the place where the composition of the package changes for the benefit of the connection to other packages. (Hermans, 1995)
• Roof(s)
• Internal walls
• External walls (facades)
• The main structure
• Foundations
• Services

Structural connections that connect one of the components with the rest of the components, for example:
• Connection façade- floor(s)
• Connection façade- roof(s)
• Connection façade- inner walls [4].

4.3.2. The Speed of the deterioration

The second indicator of the deterioration is its speed. Measuring the speed of a building's deterioration is important to be the leader in decision-making and execution. Certainly, the rabid deterioration situations require faster intervention to control them than other slow-moving cases.

The speed of deterioration can be illustrated by the location of the deterioration situation and the factors influencing it. The physical deterioration of buildings is caused by two types of factors; external and internal:

• Internal deterioration: the deterioration of building materials and structure are under the influence of internal factors of the structural component itself. According to the science of physical movement, this deterioration represents one of the types of movement of the body itself, without any external factors. This movement (degradation) may be of a (Regular speed), when a body is changing with uniform speed in equal intervals of time, or the speed is (Irregular), when a body is changing with variable speed in equal intervals of time.
• External deterioration: The deterioration of building components is influenced by external factors, biased on (Engineering Dynamics). The change in the characteristics of the components of the building or form and location will remain at rest or in uniform motion unless compelled to change its state by the action of an external force (Newton's first law). This type of deterioration speed we can called (Variable speed).

4.3.3. Factors Affecting deterioration

After identifying the location of the deterioration and determining its speed we come to identify and clarify the factors and forces that affect the state of deterioration. Identifying these factors and the proportion of its impact on the building for controlling and treatment is necessary to stop the continuity of the deterioration, otherwise the process has become useless because this case is possible to go back again and infect the building and its structural components.

Four measurable major factors affecting the state of the building can be identified in the Urban Informatics System [4]:

• Chemical factors: material incompatibility, pollutants, air pollution, pollutants from other building components, pollutants resulting from mis-use and cleaning.
• Biological factors: insects, fungi, algae, vegetation, bacteria and excrement.
• Physical factors: light and radiation, temperature, moisture/rain.
• Mechanical factors: loads, use, movement.
4.3.4. The direction of deterioration

The indication and measurement of the direction of the physical deterioration of the building and its proximity are important for the purpose of identifying the future impacts of this condition. The location or the size of the deterioration may be not important, but its effect over time on the components of the building may be important and influential.

The physical degradation of structural units or structural connection leads to a series of negative changes from the following aspects:

• Building efficiency.
• The aesthetic shape of the building and its impact on the visual aspects of the urban environment.
• To ensure the safety of the occupants of the building.

Physical deterioration tends to be harmful in two directions:
• The direction towards the buildings, and its impact on the structure weakness and durability of the materials.
• The direction of deterioration leading out of the building and subsequent negative effects on the surroundings of the buildings [4].

4.3.5. Characteristics of the physical deterioration

After determining the physical deterioration of the building in terms of; location, speed, influencing factors and direction, the study will present in this paragraph the characteristics of the deterioration. For the purpose of identifying in detail the status of the building and the deterioration, so it is essential to measure a number of the main characteristics of the situation, as follows:

• The architectural and aesthetic quality of the building: It is possible to monitor changes in the properties of structural units and joints by changing the dimensions, color, texture, or any other apparent details.
• The material characteristics: These variables can be measured in terms of the proportions of the materials involved in their composition, durability, strength and efficiency.
• Characteristics of the performance and efficiency of the building operational: The possibility of identifying the extent to which the building provides the basic requirements of occupants (e.g. thermal insulation, services, functional efficiency ... etc.).
• The quantity of deterioration: the measurement of the size and amount of the deterioration is important (small, medium or large) to help the specialists to develop appropriate plans to intervene according to the size of the deterioration as well as other considerations

5. Conclusions and recommendations

This study presents a new vision in terms of the use of urban informatics in monitoring and measuring the physical deterioration of buildings over time. These indicators can be distributed at the level of buildings or urban areas on a given scale.

• Urban Informatics was addressed as a new area in information and communications technology. This field could be employed to achieve smart and sustainable cities, which was of the United Nations goals.
• For the activation of the Urban Informatics to improve the conditions of the built environment, the paper suggested to use this technology in mapping and monitoring the urban deterioration.
• The importance of the study comes in terms of management, control, and analysis of urban changes in the city at various levels, these changes may have an impact on the safety and security of citizens or may have an aesthetic and architectural influence on the townscape. The adoption of such a mechanism
would help save human efforts and overhead costs economically if used traditional methods. It will control the time and place.

- A set of five leading indicators have been developed to measure and monitor urban deterioration. The first one is the location of the deterioration in the level of the urban area and at the level of an individual building. Then measure the speed of decline during a specific period. To control and treat the situation, we should indicate the forces acting on the continuity of deterioration. The fourth indicator is the directional deterioration to know the future impact of this situation. Finally, the paper determined number of characteristics that can be measured by urban informatics. Table (1) summarized all primary and secondary indicators.

This study should be developed and expanded to play a pivotal role in the scope of urban informatics in its early stages. The prospect of this subject could be seen in the following fields:

- Technical field: the use of such a system will assist in studying and analyzing different kinds of urban deterioration comparable, comprehensive, and accurate. It would be helpful in academic and research institutions.
- Practical field: the paper recommends the participation of various disciplines (e.g., civil engineer, ICT, decision-maker, government institutions and local communities...) that would help to save many lives, with the use of smart construction system possible to face risks and disaster of the built environment (such as the devastation of war and earthquakes).

Table 1. Primary and secondary indicators that can be measured by Urban Informatics

| Primary indicators of deterioration | Secondary indicators                                      |
|-------------------------------------|----------------------------------------------------------|
| Location                            | • Urban level/land use                                    |
|                                     | • Architectural level/building components                  |
| Speed                               | • Regular speed                                          |
|                                     | • Irregular speed                                         |
|                                     | • Variable change                                         |
| Direction                           | • Inside the building                                     |
|                                     | • Outside the building                                    |
| Affecting Factors                   | • Chemical                                               |
|                                     | • Biological                                             |
|                                     | • Physical                                               |
|                                     | • Mechanical                                             |
| The characteristics                 | • The architectural and aesthetic quality of the building  |
|                                     | • The material characteristics                           |
|                                     | • the performance and efficiency of the building operational |
|                                     | • The quantity of deterioration                          |

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