

Design of Smart Urban Lighting by Using Social Sustainability Approach

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Abstract—Creating cities, objects and spaces that are economically, environmentally and socially sustainable and which meet the challenge of social interaction and generation change will be one of the biggest tasks of designers. Social sustainability is about how individuals, communities and societies live with each other and set out to achieve the objectives of development model which they have chosen for themselves. Urban lightning as one of the most important elements of urban furniture that people constantly interact with it in public spaces; can be a significant object for designers. Using intelligence by internet of things for urban lighting makes it more interactive in public environments. It can encourage individuals to carry out appropriate behaviors and provides them the social awareness through new interactions. The greatest strength of this technology is its strong impact on many aspects of everyday life and users' behaviors. The analytical phase of the research is based on a multiple method survey strategy. Smart lighting proposed in this paper is an urban lighting designed on results obtained from a collective point of view about the social sustainability. In this paper, referring to behavioral design methods, the social behaviors of the people has been studied. Data show that people demands for a deeper experience of social participation, safety perception and energy saving with the meaningful use of interactive and colourful lighting effects. By using intelligent technology, some suggestions are provided in the field of future lighting to consider the new forms of social sustainability.

Keywords—Behavior model, internet of things, social sustainability, urban lighting.

I. INTRODUCTION

URBAN lighting is introduced as a link between people, urban environments and technology. On the one hand, the presence of light and its source of energy, and on the other hand the quality of its emitting from of the light, represent another aspect of urban lighting as an urban furniture element. With the exception of the energy issues, some factors such as new technologies and at the top of them the intelligent systems also find a special place for urban lightings. Undoubtedly, these technologies benefit from the Internet for special applications. Therefore, the possibility of using the Internet system of objects in urban lighting can be explored in order to enhance the new identity of urban lighting systems, which resulted in the improvement of the social environment and individual behaviors. The provision of a suitable environment

for increasing its impact on the citizens provides the context for social sustainability by modifying individual behavior, social behavior. Such a process requires the recognition of native textures and requires the metropolitan and national macro-prospects. Providing some facilities where a person can find the right behaviors and motive him/her for doing so and behaving as one of the promoters of this behavior can, in the long term, create the way for healthy competition between individuals and, consequently, the spread of the right behaviors in society. The application of Internet of Things and the intelligence of urban lightning in such a way as to take into account the human resources of the society and to plan for improperly eradicated behaviors can make this element seemingly urban, vibrant, attractive, and productive in the public spaces. In order to know more about the requirements of such a project, some suggestions have been made in this area by focusing on the new technologies and using different attitudes in the field of behavioral design.

II. SMART OBJECTS AND INTERNET OF THINGS

A. Review Stage

Living in a world where everything is smart is a desire that was imagined more than 30 years ago and today it has become evident and predictable with the advent of computers and microprocessors. Comprehensive computing is a new perspective on the promotion of microprocessors and sensors in any devices and it is used intelligently for many products. In fact, this view through the network of communication in the real world will be a great benefit to individuals. The development of computer knowledge, along with the acquisition of microscopic knowledge, makes it possible to make the components in very small sizes. A world away from desktop computers, keyboards, video audio systems, and all of them is possible by replacing them with consumable products such as clothing, watches, pencils, sofas, etc., and the relationship between these devices with each other and with users is a kind of thinking that is based on human research. Weiser in 'The computers for twenty-first century' says that the computer goes all the way, in which computers abandon daily and repetitive tasks [1]. The parents will be informed about their conditions without worrying about their children by placing sensors in their clothes, or informing themselves about the weather and environment in their upcoming days. Similar projects have been implemented in Japan in this regard. Moore believes that the driving force behind the advancement of technology and microcontroller development information is effective [2]. In his view, this development is roughly equal to the power of microprocessors every 18

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months. This process is shown in Fig. 1. In addition to microprocessor technology and object-oriented science, nanotechnology has also come to the front stage. For example, the polymer science gives the flexible polymer sheets to a large number of industries in the world. The electronic chipsets or RFIDs are the electric components which are recently used in intelligent systems with the least amount of energy needed and can work in small dimensions through radio waves. These components are currently used in some stores and intelligent homes. These electric components are capable of reading several hundred characters and respond within a few milliseconds and can operate wirelessly up to a few meters. In fact, they define for each object a binary code that is unique to that object and identified by it and its information can be stored at a specific time on the Internet or at any given data base. So, this small piece approaches all things in the world to intelligent computing. The wireless or GPS positioning system is another technology that, without

the need for a large amount of energy, finds and understands the status of individuals and objects and is now used in mobile object and vehicles. With the help of these technologies (miniaturization, materials science, microcontroller development, etc.), besides the handsets, it can be used in all the objects, and through a bar code and the wireless, the objects send their data and the exchanges between them and also inform about the situation.

Some examples of such technology can be applied to the payment of insurance, for example, health insurance. For example, anyone can be insured with more cigarettes each time using cigarettes and with health exercises, he/she has the benefits of reducing the cost of health insurance. In a world where each object captures all its surrounding events, the power of human decision making may be diminished, and this intelligent memory that shadows the various parts of human life is often more powerful than human memory and may even threaten their privacy.

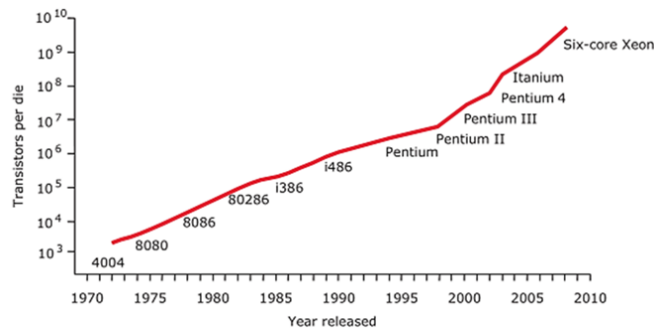


Fig. 1 Moore's law (Based on [2])

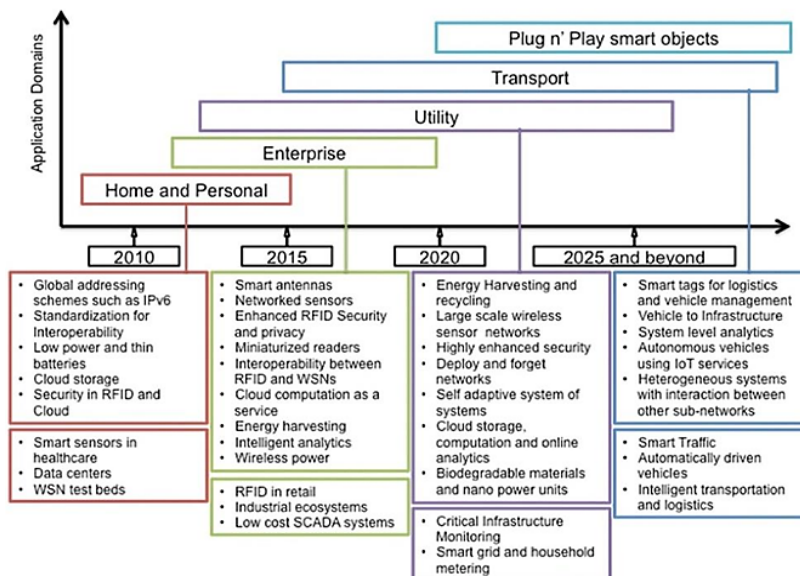


Fig. 2 The evolution of the development of smart technologies in IOT with a variety of applied fields [3]

The hypothesis is whether in the near future these smart devices will have the ability to feel, see, and hear. In line with such hypothesis, the metaphorical concept of objects is

formed. Metaphor means that an object, in addition to its appearance, has a meaning beyond it, or is related to the relationship between two seemingly heterogeneous objects

that fall into one category. In fact, the goal of the creation of a metaphor is the metaphor feedback of a type of phenomenon that has been shaped by the designer. The goal of the metaphor is to present a form beyond the object that is understood at a different level.

Lakoff states that each object is understood by its form [4]. The obvious example of this sentence is evident in the famous phrase of Le Corbusier: ‘...the home is a machine for life. In principle, the house does not look like a car, but it has some similarity in terms of its use’. Another example in this regard is Microsoft, which for the first time used instead of the command line more tangible forms in the Windows version, and was widely welcomed, which is itself a kind of use of metaphor for better user interaction with technology. The evolutionary process of developing smart technologies is shown in Fig. 2.

When the Internet is used to link people, it is called the Internet of People. When things are replaced by humans, we will have the Internet of Things. In fact, the Internet of Things relates to the relationship between objects and the transfer of all its information through the Internet. This connection, in a way, gives us a new sense of control over the surrounding environment. This concept is a definition of the combination of the material world and the digital world. The definition given in WSIS 2005 provides the Internet of Things with a kind of Internet that involves people and is a bridge between people and objects and objects between them.

According to the definition in IOT 2008 [5], the Internet of Things provides a set of technologies through which the Internet penetrates the physical world of objects. Nowadays, the number of objects that are connected through the Internet is more than the population of the planet, and in 2020, 50 billion objects are expected to be connected in this way. This connection is not limited to the objects, but also the human body in its entirety can be considered as a part to send or receive the information. A study of the University of California, Berkeley, showed that the computers can collect the data from the brain and transfer it to the skin. With such an idea, even the human body will be connected to the Internet. Wherever, anytime and any object can provide the Internet with objects and have special functions. Fig. 3 shows this feature.

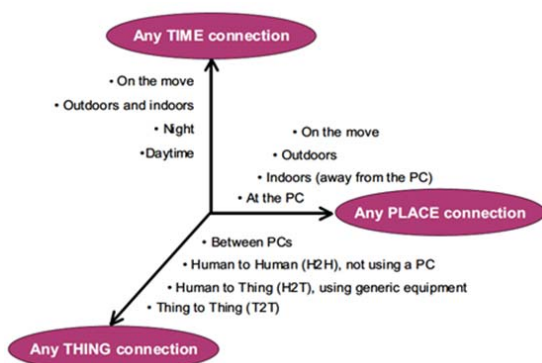


Fig. 3 Aspects of the Internet of Things [5]

The overall characters of Internet of Things can be summarized in five points:

- Ambient Intelligence, or AI, which means that the system must respond to any subject matter and environmental characteristic of the information it obtains and can organize this information.
- Flexible Structure or FS, which means there are hundreds and thousands of microprocessors that should be deactivated or activated at the right time.
- Semantic Sharing or SS, which means that devices should be able to analyze and send information alone and should not require human presence.
- Complex Access Technology, or CAT, which means that there are different types of media that require a variety of technologies for use by users.
- Event Driven or ED, which means that it requires proportional design and it is a specific type of design which is required for each subject area.

Any system that has some kind of Internet of Things has these features and it is imperative to include them in the design (Fig. 4). Fig. 5 shows a schematic diagram of the architecture of the Internet-equipped systems.

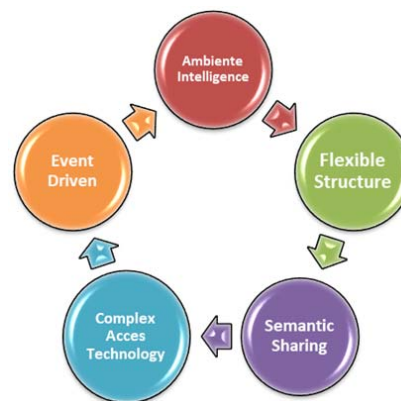


Fig. 4 The cycle of properties and requirements of the Internet of Things

III. BEHAVIORAL DESIGN

One of the issues that preoccupy designers today is designing to influence people and change the wrong behaviors and establish social norms. This kind of design is a multi-stage process, and various theories have been proposed for its formation. One of them is the Fogg model. In this pattern, Fogg believes that changing behavior is influenced by three factors without which there will be no change. The ability to do that behavior is considered as the first factor. Having a motive for changing that behavior is a second factor, and the third most important factor, whose condition is necessary, is the discussion of time; that is, changing the behavior and ability to do it at its proper time. He even divides each of the factors into smaller ones. For example, regarding the attribute of ability, it is attributed to factors such as financial, physical, intellectual, social and temporal ability, and focuses on its motivating factor into three sections of sadness, happiness,

fear and hope, and rejection or acceptance by the public. He also divides the position and time into three sections: Awesome, Warning and Spark. In terms of Fogg, one of these three factors, which is subordinate to smaller attributes, is not

affected by the change in behavior. The Fogg model has helped designers to consider their psychology in their designs and consider the need to consider these three factors in design [6]. This model is presented in Fig. 6.

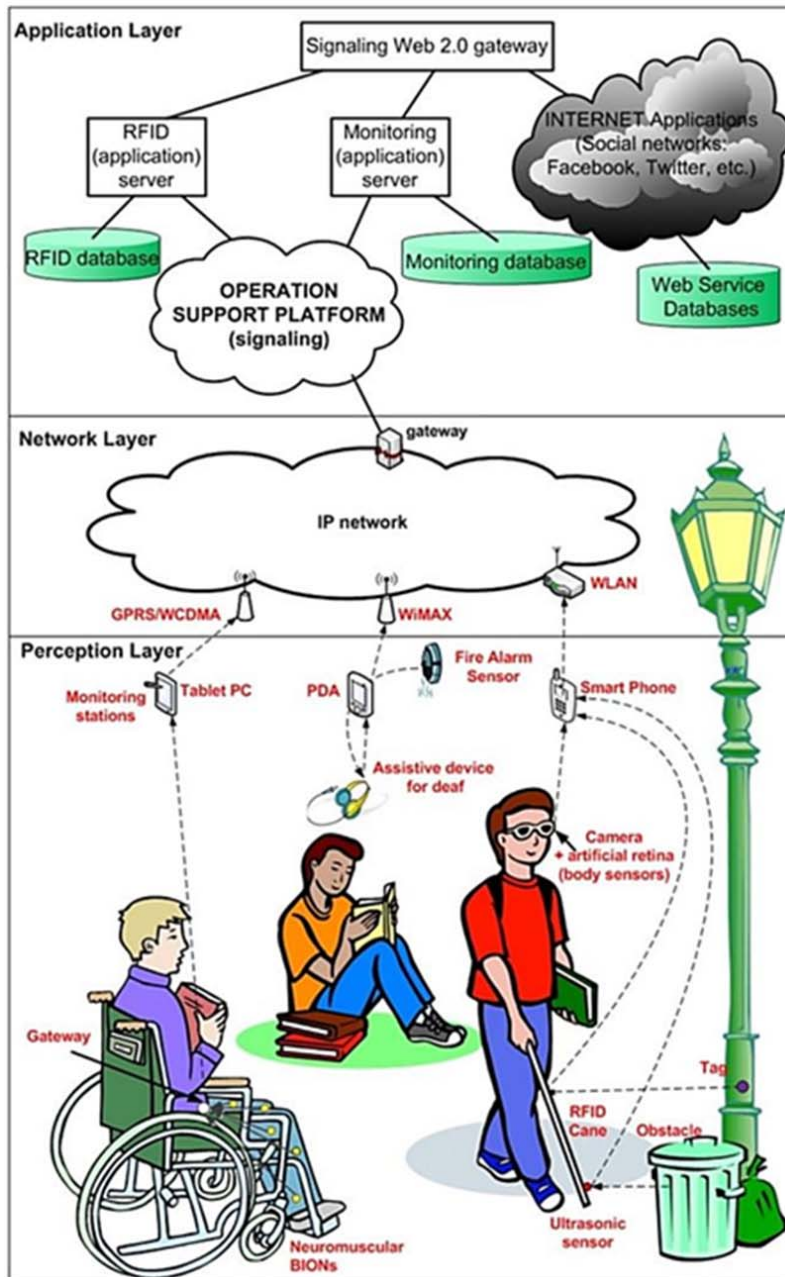


Fig. 5 The architecture of the Internet of Things [7]

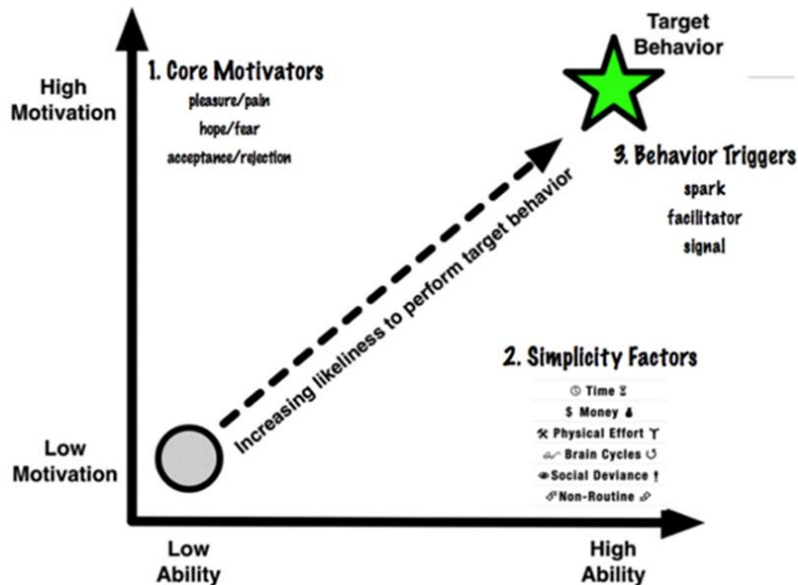


Fig. 6 Fogg behavioral model [6]

Tromp who uses another critic believes that understanding the role of a designer should take into account the interaction between the consumer and the product [8]. He has put forward a framework in this regard. From Tromp's point of view, there are many ways to change a particular behavior, and each product can create these behavioral changes by creating different effects. He divides the effects into four sections of coercive, persuasive, seductive and decisive. He believes that each person may have a different effect on a product, or that the individual will, over time, experience different effects on a product. Therefore, the review of user experience in using the product is an essential principle, and the main purpose is to influence the user more about changing behavior. Tromp, considering these four sections, defines 11 subcategories for each of them. Punitive rule is strong and effective, but temporarily, he recommends reinforcement instead and introduces speed control cameras in this section for example. Another type of design effect is the fear of accusing the community. In this regard, he refers to a company whose staff must disinfect their hands after using hands-free equipment and, if they do not make so, they will be emitted from them when they leave, which distinguishes them from others.

He also points out that by adding elements to the product, individuals can be subjected to subjective behavior [8]. Another mode can be a dialogue that encourages or encourages them to do something. Among other things, creating an instinctive instinct in individuals is to create favorable conditions for achieving a particular behavior and to create conditions that the user has no other solution other than doing the particular behavior. Stimulating feelings, creating feelings of gaining points and encouraging are some of the ways in which Tromp has the potential of many studies in the field of behavioral change.

Designing products with a view to changing behavior is, in many cases, temporary and it is good to give a place to the

design with long-term effects. It is advisable to look at the change in behavior rather than the correct and incorrect look at one's behavior and its complete elimination, with a gradual and gradual view, so that it is misconduct and may be desirable in some way and without defects. Designers, through their strong role in creating new behaviors in the community, prior to designing creative relationships and prioritize user experience.

According to Tromp, design concepts need to be redefined by the designer as the creator of a product. Although designers can never fully predict the future social consequences, this does not mean that they avoid the consideration of the specific social consequences created by the use of their proposed product. According to Tromp, the user-centered approach should gradually shift to a social-oriented approach and focus on it with its expertise and with the help of needs and social concerns [8]. This model is shown in Fig. 7.

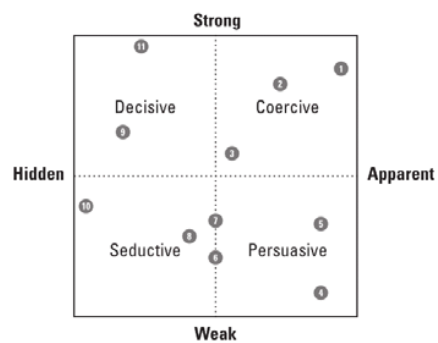


Fig. 7 Tromp's behavioral classification [8]

Another theory proposed in this regard is the Lockton's theory [9]. He believes that the behavior of individuals should not only be investigated in the wrong situations and he/she seeks to discover a strategy for changing those behaviors. He

does not recognize the reason for failing to change behavior by laziness, but he/she does not have enough time to ignore the problem.

With the goal of formulating the relationship between the product and the user and understanding by designers, he designed the web toolkit to help designers to create the right products that change behavior in the community. His focus is on nature and its effects on human behavior. By creating cards and dividing them into different colors, he created 101 templates to change designer behavior. In this way, the designer can understand how users decide on the problems and thus create more impressive product creation [9].

In 2002, Katyal proposed the theory of control and reduction of crime statistics with the help of architecture [10]. He considers the impact of specific buildings, neighborhoods, and urban issues effective in changing crime statistics, and believes that, the Internet carries architectural spaces to influence the users in the real world. For example, to avoid breaking the window, instead of looking for a legal solution, it is best to deal with the architecture and design approach. In this regard, he puts forward four strategies to prevent crime through the design of the Crime Prevention Through Environmental Design (CPTED).

1. Increase natural surveillance in a region by neighbors, residents or spectators, e.g. by widening narrow alleys and using more windows that have a public view.
2. Create a sense of belonging and ownership to the region and motivation for the locals. For example, statistics show that houses with numbers and identities are less likely to be stolen than other homes.
3. Reduce social isolation with the help of natural environment architecture. For example, taking a public lobby together with a seat in that location can make people more cohesive.
4. The approach to protecting against crime, such as placing shrubby bushes near the windows.

He considers light and color very effective in this regard. The light helps to illuminate the space and raises the public's view. Even light colors are important in this regard. As with the statistics taken, in streets with light-yellow lights, the crime rates are higher than white-light streets; or the use of blue light in the public restroom prevents injections by addicts. He considers all of these indicators to be the architectural links with the community and people, and even believes that architecture is not only effective in reducing crime rates, but also has a significant impact on behaviors and helping to change behavior [10].

IV. SOCIAL SUSTAINABILITY

Sustainability can be looked at in three areas of economy, environment and society. Based on an illustrative model of O'Riordan, sustainable development is primarily concerned with economic development [11], and social sustainability also combines social and principle laws such as economy, environment, social equality, health, needs and, most recently, joyous concepts [12]. These three areas of sustainability are not separate from each other and are shared with each other as

shown in Fig. 8.

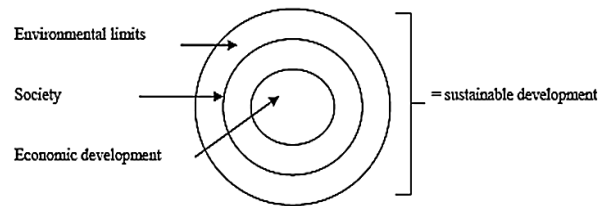


Fig. 8 Social development layers [11]

Social sustainability deals with how people interact with each other and strive to achieve their goals. In this way, it is important to achieve these goals because different societies have different behaviors to pursue their goals [13]. Hence, modifying the behavioral patterns of the community based on social sustainability and applying behavioral patterns consistent with the target community, in which positive cultural aspects are valued [14], is become one of the greatest challenges for active social sustainability planners. In fact, achieving a sustainable planet without taking behavioral patterns into account is not possible [15].

To date, most programs have been developed to promote sustainable information-based behaviors. For this purpose, media advertising and dissemination of printed materials, including brochures, catalogues, etc., have been used to promote and accelerate sustained behaviors. The method of giving information based on two perspectives changes behavior: firstly, planners are trying to raise awareness of individuals about a particular subject, such as global warming, and by providing information, inform people about a particular subject. Secondly, they encourage individuals to take supportive activities such as using public transportation to address this problem and thus change their behavior.

Nowadays, new methods have been developed to change the behavior of individuals, which can be considered as one of these new methods.

A recent trend in computer science is to develop advocacy technology to help the daily change of behavior of individuals to achieve the desired lifestyle [16]. Persuasion is considered as part of human interactions. From past traditional societies to today's modern media society, persuasive activities have been continually trying to influence attitudes and behaviors. For example, if we are convinced to pay money for a specific product or pay no money for a particular product, we will vote for a particular party or not, quit smoking, more or less exercise, to fight for the environment, etc. In fact, technology is considered as a powerful tool for interacting more intrusive techniques, and it adjusts interactive patterns based on the characteristics, needs, environments and context of the user, and data related to the user. The realization of this issue allows the advocacy technology to be defined as a class of technology deliberately designed to change the attitude of individuals and their behaviors. The crucial point is that persuasion leads to a voluntary change in attitude or both [17].

Constructive technology designers often use behavioral theories such as target setting or the theoretical model to

change behavior. These two theories are often used in constitutive technology. Targeting theory addresses the various responses of individuals to different goals, which should be set by individuals or members themselves and with the help of relevant specialists. In this case, a challenge will arise for the individual, which will lead the person to believe that he/she can achieve this goal.

Feedback and incentives should also be provided as an enhancement and motivation enhancer, and the individual is not limited to achieving the goal, and only the quality is achieved. People nowadays are interested in using technology in their everyday lives and this method helps us, by using social psychology, to manage the daily behaviors of individuals as part of a larger social context [16]. Landy believes that cities should be sustained emotionally and psychologically, including the quality and design of built spaces, the quality of public communication and the organizational capacity of the citizen.

When lack of motivation prevents the person from engaging in sustainable behavior, incentives (and feedback) can enhance and strengthen it [13], and if these incentives are in line with a person's goal by being in the framework of the theory of target setting, they can motivate more people in the community to behave appropriately and sustainably. If the incentive system can be linked to popular communication, it can greatly enhance its impact, since humans are the most powerful motivators [17].

The use of position-based incentives is one of the most up-to-date and effective methods to motivate individuals to behave appropriately. In fact, the position reflects the position of the individual compared to other people, especially in social networks. As stated above, in the theory of target setting, in addition to incentives, feedback also plays a major role in motivating individuals to achieve goals and thus persuading them to behave appropriately.

Feedback means feedback to the individual and informs him of where he/she is currently. For example, in the Ford Fusion, a hybrid vehicle, the virtual image of a plant represents a person's performance. If the driver uses clean energy, the plant's image begins to grow and grows, and this can be done using fossil fuels [18].

The development of technology in computer science and intelligence has provided new opportunities for this, in particular, the use of sensor technology and new algorithms that lead to the creation of knowledgeable systems. These systems can provide persuasive messages to the person in the form of appropriate behavior in the person's field and activities [17].

Urban spaces can also play an important role in encouraging individuals and motivating them to behave appropriately because of having a suitable communication platform if they are intelligent. Meanwhile, urban lightings, due to their nature, can be considered both as incentives and as appropriate advocates for achieving the goals and appropriate behaviors. For example, if we want to use the position award, the lights can reflect the position and rank of individuals, so that people of different degrees are categorized to use the

desired sustainable behaviors and for different degrees of light that they can be considered.

Digital media cover the pace, urban spaces and architectural spaces. This has created a new form of communication relations in the cities. Often, these communications appear to be dominated by light, which are implemented by screens and smart lighting devices. Although urban communication through light is often left one-dimensional and for public and private affairs, interactive technology is now acquiring urban spaces as a dialogue space for citizens, which has been installed in many art projects. Therefore, urban lightning design is also seen as a form of interactive design [19]. In recent years, the amount of information displayed in digital form has been steadily growing by environmental displays, which are part of urban lightning. Although the most used displays are advertising, with the least amount of conflict and interaction with passersby, they provide only a large amount of information, but these urban displays also provide the infinite capacity for the physical development of the public spaces.

Pihlajaniemi et al. [19] argue that urban displays use all physical environments as digital information interfaces. In fact, the architectural environment in which we live is a new interface between the human being and digital online information. As a result, information will be transmitted through changes in form, motion, sound, color, smell, temperature or light.

The Light Story is a sample of urban displays that utilize urban infrastructure to display information in urban spaces, and has achieved this through color, light intensity and light motion to change citizens' attitudes. The web-based project allows citizens to narrate the narrative and tailor-made a central dynamic lighting system in the northern city for one hour. Lighting systems consist of RGB bulbs that allow designers to change colors. Light intensity and optical movement can also be adjusted.

This project allows people to design light according to the chapters and occasions they want; for example, an optical light with a warm color theme for the autumn season and a happy light for the holiday season. Usman Haque is one of the designers who has a critical look at the issue of the pollution of the waves in the environment, and has created a special type of lighting in the sky through the project "Listening to the Sky 20" by connecting optical cells with cell phones. He considers his goal of these lighting to make society aware of his behaviors.

V. CONCLUSION

Given the recent trend in intelligence and capacity provided by Internet of Things, there has been a good platform for making objects more interactive. Urban lighting systems have also been exempted from this due to the appropriate communication feature in urban space. However, today they are used more as a means of lighting and advertising, but if they are intelligent, they will have a huge capacity due to their dynamic characteristics and will lead to more interaction between citizens.

Intelligence has also made it possible for urban lighting to provide citizens with information and messages in addition to the field of awareness, and the technology of the Internet of Things, by expanding this field to all the living environments of individuals, provides a platform for creating messages. In this case, optical systems can intelligently receive information adapted to each person, and in accordance with this information, disseminate interactive messages. Messages are not only published by screens and can even be defined in terms of the color change of light, intensity, or movement of light, and these messages can contain information to change the behavior and attitudes of citizens.

Intelligent technology and the Internet of Things in urban lighting can be defined as a tool for advocating technology to change the behavior of users. This technology of encouragement and feedback to reach a particular purpose, gives individuals an optional choice without being forced to change their behavior. Urban lighting because of their dynamic and flexible characteristics can contain encouraging messages and feedback tailored to different people to encourage individuals to apply new form of attitudes or behaviors. These messages become more effective when urban lighting is introduced as a communication tool between humans, because, as explained above, humans are the strongest encouragers of each other. For example, if the problem of water scarcity is defined as a problem because of abusive behaviors as an inappropriate behavior, and the target is to correct it for combating water scarcity, first, there is a technology for identifying individual behaviors and saving their needs to be the unique information for Internet of Things to be perfectly analyzed. In fact, the person who uses optimal water is identified and his/her data are stored on RFID tags. This tag can be embedded anywhere, including a smartphone (smartphone), that contains person's identity information. Now, technology is needed to retrieve this information into appropriate conversational messages for the individual, and intelligent lighting systems are responsible for this. By giving them proper feedback, they point to the position of the individual among others, who are called in the position to be corrected, thereby persuading the person to continue their activity. In this case, urban lighting systems can, by intelligent technology, lead to the modification of the behavioral patterns

of individuals as a small part of the community and thus create social sustainability in the community. Social sustainability will still be affected by the person, the environment, urban lighting systems and the Internet of Things. Organizing these factors can create a cultural, environmental, and metaphorical context, so that luminous metaphorical messages can influence the modification of individual's behaviors.

This pyramid is shown in Fig. 9. Based on this pyramid, each of the funds directly or indirectly affects the process of modifying the behavior, and the existing commons can create the overall structure of the pyramid. Undoubtedly, the quality of reaching the goals in any given subject is a necessary condition for the efficient knowledge of the system.

According to the principles of intelligence and capacity provided by internet of things technology, a suitable condition for having more interaction in urban lighting systems is proposed in this research (Fig. 10).

The context awareness of intelligent system in urban lighting proposes the mutual information and messages for citizens and creates target statements. So lighting systems are capable of receiving required information related to individuals and publish the mutual messages related to received information. Such communications are not published through display, but through changing light, its intensity or its moving. These communications could conduct citizens' behavior and manner.

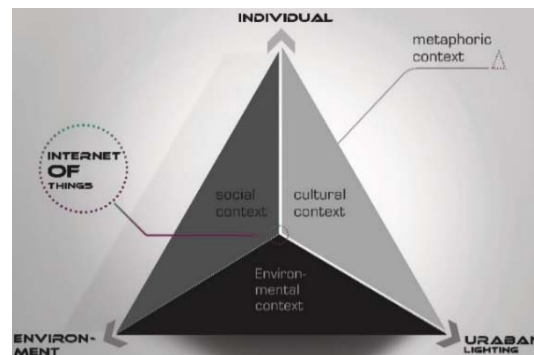


Fig. 9 Pyramide of Behavioral Social Sustainability



Fig. 10 Smart urban lighting connected to individual devices to inform them about their personal behavior

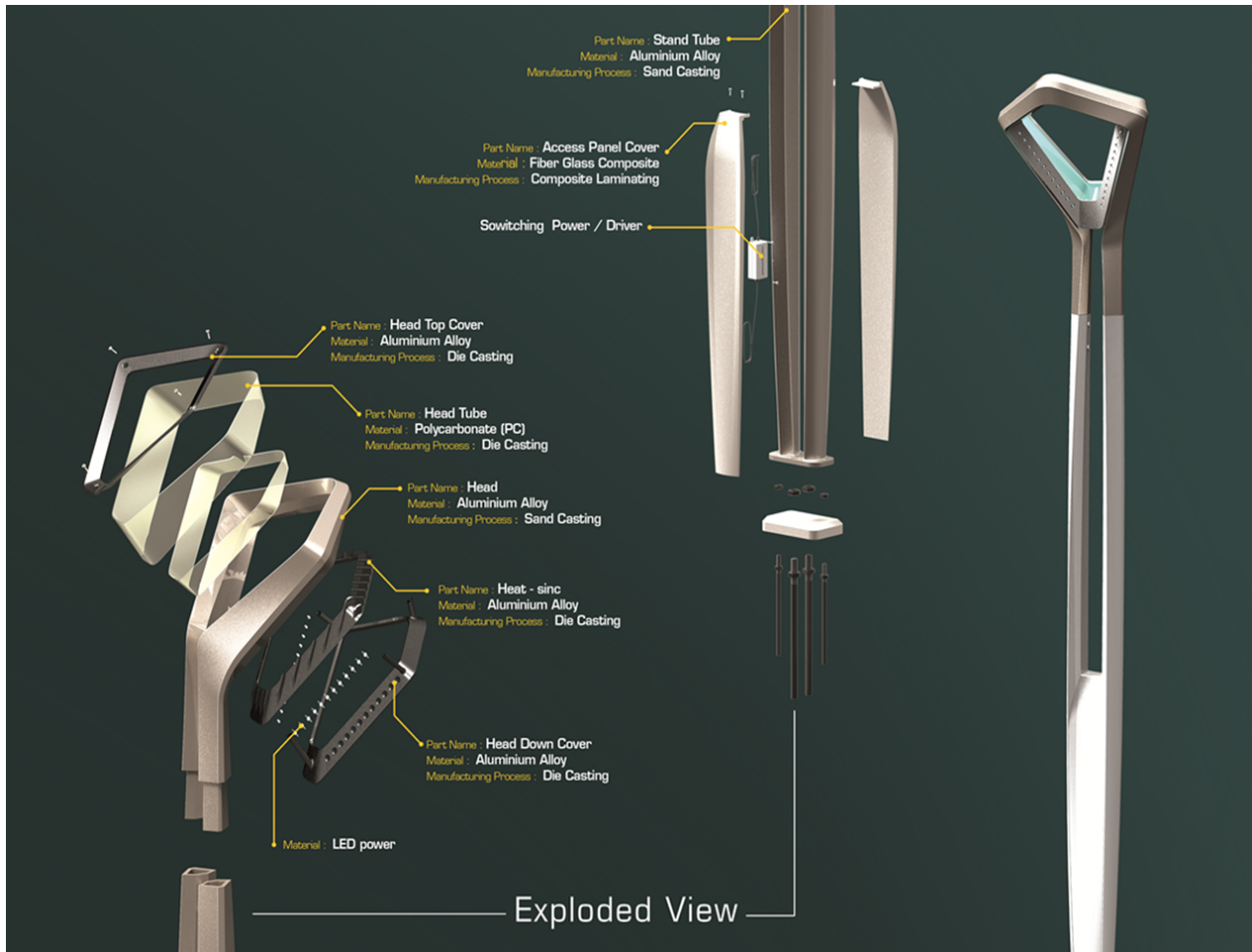


Fig. 11 Exploded view of smart urban lighting

In fact, intelligent technology and internet of thing could lead to introduce as a persuasive tool whereas provoking technology used from incentive and feedbacks for reaching particular aim. Urban lighting concept which is proposed in this paper due to its dynamic and flexible features makes the stimulating messages and suitable feedbacks from the variety of people who interact with it (Fig. 11).

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