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Original Paper

Does Internet of Things Affect on Sustainable Development?

Investigation through Intermediate Applications

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Abstract

Since, the technology of Internet of Things (IoT) is utilized to facilitate new and improve existing applications in a large variety of domains, such as manufacturing, healthcare and energy, the main aim of this research work is to evaluate the role of IoT applications on Sustainable Development (SD). To conduct this research work, a conceptual model has been proposed by considering intermediate applications to connect internet of things attributes to the main aspects of sustainable development. Sustainability is divided into three main components of environment, economy and society as well as IoT has been also divided into information dissemination, communication and information technology and information transmission. The proposed conceptual model has been validated using a purpose designed questionnaire to gather experts' opinions in Likert scale where each application connects IoT attributes to SD components. Analysing filled out questionnaires using the well-known statistical method of T-Test revealed that there are significant relations between IoT attributes and sustainable development component. It can be also concluded that the applications of IoT would improve sustainablity over development process. Therefore, IoT applications would be improved and renewed over the next years because sustainability is getting to be a serious concern all over the world.

Keywords

Internet of Things, conceptual model, sustainable development, technology, statistical t-test

1. Introduction

As global inequality and climate change become mainstream concerns, the main question is how to save environment for next generations (Piramuthu & Zhou, 2016). Sustainable development is the answer to the above concern which can provide a clear definition to the complex relationships between

economy, society and environment. The main concept behind the sustainable development is to apply smart and applicable methods to protect our environment. For example, when smart health is used, it provides care for patients with persistent illnesses without visiting clinic sites. Since, patients going to hospital is reduced, the result is reduction on healthy cost, hospital staying time, traffic and fuel consumption (Boulos & Al-Shorbaji, 2014) known as the basic principles of sustainable development. Therefore, sustanable development looks for methods and techniques which are used to satisfy human needs in a manner of environment pretoctions. Toward more clarifications on internet of things and sustainable development, the next part of this section is comprised of internet of things, sustainable development ended by some figures on their relations and eventually followed by vision statement in the present research work which lies to investigate how IoT affects on sustainable development in detail.

1.1 Internet of Things Technology

Internet of Things, abbreviated as IoT, is composed of two frequant repeated words of "Internet" and "Things". Internet is the most typical application in an intermediary information platform which provides fast and cost efficient way for users and new business opportunities to share information. Another service has been recently developed through promotion of knowledge by using internet together with objects identified as "Internet of Things" as an emerging technology (Xiaopu et al., 2012). The IoT technology was first proposed by Ashton (Ashton, 2009) and Brock (Brock, 2001) at Massachusetts Institute of Technology (MIT). As an information and communication technology, the Internet of Things is expected to offer solutions to trannsform the operation via internet (Da-Xu et al., 2014). In other words, IoT is the connection of objects via internet from physical world those are equipped with sensors, actuators and communication technology to a global network infrastructure and information processing technologies (Da-Xu et al., 2014). The main aim of using or developing Internet of Things (IoT) technology is to identify and remove unnecessary costs in order to optimize both time and cost of production or service stages through playing significant roles on sustainable development (Bojanova et al., 2015) when objects are tracked while moving from one place to another as confirmed in nore details by Meloan (2003).

In terms of structure, IoT leads to make higher-level systems composed of a huge number of machines, devices, sensors, actuators, and other objects interconnected to each other. Within the above mentioned perspective, the term "Internet of Things" is broadly used to refer to the resulting global network interconnecting smart objects by means of extended Internet technologies, the set of supporting technologies necessary to realize vision and ensemble of applications and services leveraging such technologies to open new business and market opportunities (Miorandi et al., 2012). Moreover, in terms of application, business owners have reflected on Internet of Things where they believe that it is a good potential for earning money (Palavalli et al., 2016). In addition to growing interest on using IoT technologies in various industries, a number of industrial IoT projects have been also conducted in other affected areas such as agriculture, food processing industry, environmental monitoring, security surveillance, and, etc. In 2002, National Science Foundation (NSF) published a report on convergent

technology (NSF/DOC, 2002; Yin et al., 2016), which was focused on integrating nano-technology with Information and Communication Technology (ICT) to improve the life quality of people and the productivity of nations in dramatic manner. IoT is combined with technologies in object identifications, wireless networks, sensors, embedded system and nanotechnologies to connect things in the world, so that things could be tagged, sensed, and controlled over Internet (ITU, 2005) which consists of a set of technologies to support the communication and interaction among a broad range of networked devices and appliances (Yin et al., 2016). Today, a commonly accepted definition for IoT is: "a dynamic global network infrastructure with self-configuring capabilities protocols where physical and virtual 'Things' have identities. Physical attributes and virtual 'Things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network" (Da-Xu et al., 2014).

1.2 Sustainable Development

The United Nations defines sustainability as a concept that seeks to provide or supply the current human needs without making dificulties to future generations to meet their needs (Wheeler & Beatley, 2014). In other words, sustainable development is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Adams, 2008). Another definition is that the sustainable development is the organizing principle for meeting human development goals while sustaining the ability of natural systems to provide the natural resources and ecosystem services, simultaneously. The expected result is to meet human needs without undermining the integrity and stability of the natural systems (Dlodlo & Kalezhi, 2015). The UN Commission concern lies on natural resources in which it is considered that human beings have to use natural resources to meet their needs but it can be minimized by methods such as increased resource efficiency and the use of new or clean energy resources. Participation of the citizens in implementing the sustainable development programm is the key of city management and urban development (Allison & Prout, 2015). Looking at from another view, sustainable development was defined basically on environment but as the concept developed, it has shifted to focus more on economic and social development as well as environmental protection for future generations. Therefore, the term "sustainability" refers to humanity's target goal of human-ecosystem equilibrium, while "sustainable development" refers to the holistic approach and temporal processes that lead us to the end point of sustainability (Shaker, 2015). The acceptance of sustainable development ideas is heavily dependent on the recognition of the fact that the past models for economical growth are restricted by limitations and flaws. Economical objectives to sustainablity are economical, social (welfare and equity) and ecological objectives (biodiversity and resources) such as a definition proposed by Renehepset (Economist) who covers three principles of economic, social and environmental sustainability components (Benkhelifa et al., 2014). While population and consumption of natural resources increase, sustainable development aims to make a balance between economic growths, quality of life and environmental preservation in medium and long term programs without increasing consumption of natural resources. Another term of "Green Growth" is mainly used besides to sustainable

development in which the development paradigm shifts from consumption to sustainable development and recognition of new courses of action.

There are many studies in which sustainable development and internet of things are investigated together. One of the main studies in this field has been recently published by World Economic Forum Annual Meeting 2018 (Rodrigo Arias et al., 2018) in which authors elaborated the use of new technology on three important factors for sustainability including CO2 emition, water polution and poor mental health. Jiong Jin et al. (Jin et al., 2014) investigated IoT for smart cities to improve human services over the cities. The study of Muraleedharan (2018) is focused on using IoT in food industry which is investigating the main fields of water management, agriculture, wildlife, marine organisms, buildings and waste management, revealed that new technologies, such as Artificial Intelligence. The main concept is to emerge making IoT more intuitive and user friendly, but largely, manufacturers will have to work harder at securing their connected devices as the risk to data will also increase.

1.3 Vision

According to what mentioned in the previous subsections, it can be concluded that many techniques should be applied to decrease natural consumptions. One of the new techniques is internet connected to sensors named Internet of Things. Following that, the aim of this research work is to evaluate the role of Internet of Things applications on sustainable development procedures. The applications of internet of things are investigated over the sustainable development of economical, social and evironment components. To evaluate the influencing factors over IoT applications and sustainable development components, the well-known method of questionnaire analysis is proposed gathering experts' viewpoints on the relevant questions.

This paper is organized as follows. After introduction composed of scientific background and review the relevant literature, the research metodology is proposed in the second section followed by evaluationg process in the third section. Numerical analysis is done in the forth section followed by discussion on conclusion and recommendation for furthur researches in the fifth section.

2. Research Metodology

Research methodology is composed of two main parts. The first is to make coceptual connections between the features of internet of things and Sustainable Development (SD) components. The second part is to evaluate the proposed coceptual connections for approving the proposed relations. Three main features of information transmission, communication and information development, and information dissemination are defined for being connected to the other components. The main components of sustainable development, including environment, community (human resources) and economics (cost, energy consumption and employment), are assumed to be connected with IoT applications. Following the above, a conceptual model is proposed based on the concept in which IoT features are influencing on sustainable development. For each IoT feature (information transmission, communication and information development, and information dissemination) defined applications are supposed to be

connected on SD components. Following the above, the relationship between IoT and SD is defined indirectly, in a conceptual model, means that intermediate relations are investigated on this research methodology. The second part is to evaluate the proposed conceptual model which defines the relationship between IoT features and SD components. In order to evaluate the relationships, a questionnaire has been developed based on five point Likert scale to gather experts' viewpoints. Since, experts' viewpoints usually follow normal distribution, the average scale of answers is statistically checked using T-student distribution function using the null hypothesis of H_0: $\mu = 3$ and one hypothesis of H_1: $\mu > 3$ also applied at (Babaei & Mahmoudabadi, 2018). More detail on scientific bachground on how to make a a hypothesis test is available at (Myers & Walpole, 2012). Figure 1 shows an overall framework for steps conducted in this resesrch work.

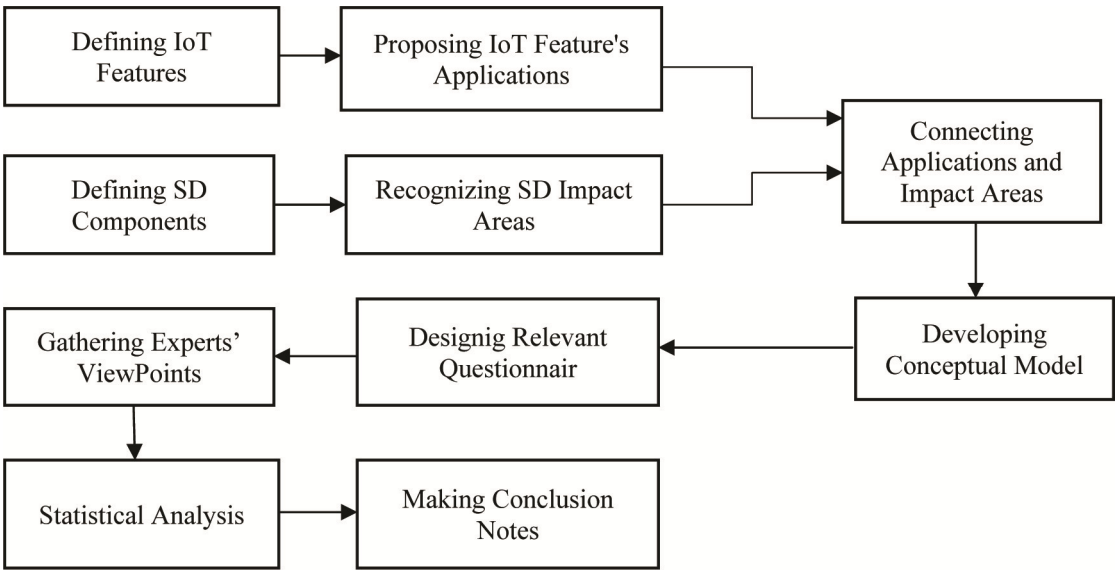

Figure 1. Overall Framework of Research Methodology

3. Developing Conceptual Model

A conceptual model, which is developed to represent a real system, is made of composition of concepts to help people or experts to easily know, understand, or simulate a subject the model represents. Designing a conceptual model is one of the most effective methods to analyze relationships between variables, concepts or parameters. In order to understand how IoT applications affect on sustainable development components, a conceptual model has been designed. The model is designed in three levels as below:

1) The first level is high ranked measures of Internet of Things as dependent factors and sustainable development as independent.

2) The second level is defining attributes. Information dissemination, communication and information technology and information transmission are IoT attributes on the one hand as well as community, economy and environment are SD components on the other hand.

3) The third level is defining applications including promoting life style, internet advertisement, and education and learning, social justice, public knowledge and traffic reduction are intermediate application.

For each application, there are at least two arrows linking SD components to IoT features as shown in Figure 2. It is not necessarily that each feature should be connected to all components, so the possible links are depicted and investigated by questionnaire analysis. Statistical methods are being utilized on each pre-defined link over the conceptual model. For example, information dissemination helps life level quality promotion which is followed by connection on community. No more relation is being defined for impact study to connect information dissemination on community. Communication and technology together with information dissemination can affect on education and learning which cause impacts on all SD components. Details and more defined indirect connections are depicted in Figure 1.

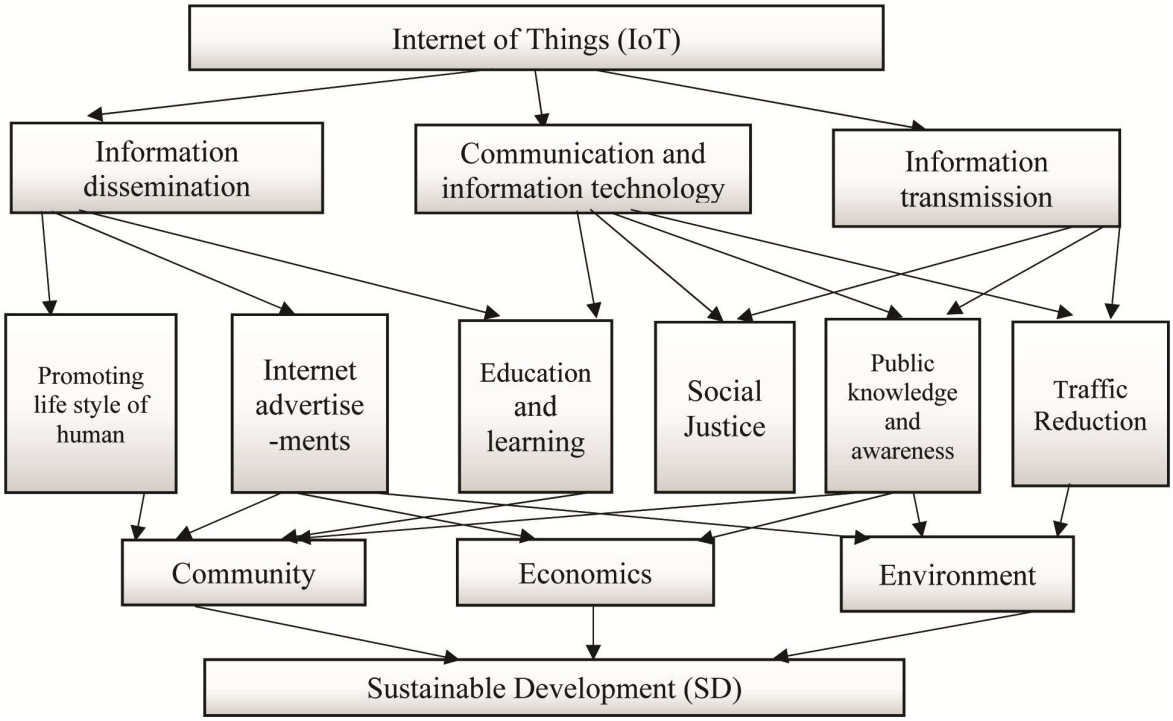

Figure 2. Proposed Conceptual Model of Relationships between IoT Features and SD Components

4. Model Validation

Validation is a necessary step in research work conducted by conceptual models (Pintrich et al., 1993). There are many techniques to validate conceptual models such as focusing on essential elements (Brink-Huis et al., 2008; Campbell, 2000) and natural language discourse generation (Dalianis, 2005). One of the well-known and easiest method to assess the validity of conceptual models is to conduct a survey by designing and filling out the relevant questionnaire (Wilson & Cleary, 1995).

4.1 Questionnaire

The main purpose of the research based questionnaire is to evaluate and validate each proposed solution to improve sustainability through IoT applications and features. The proposed questionnaire includes 15 questions related to each link between the features of the IoT technology on the one hand and sustainable development components on the other hand. The average scale of answers identified by experts is compared to the mean scale of Likert scores. The designed questionnaire is shown in Appendix in which each question is related to each link on the conceptual model. For example, one question has been designed as "Reducing city traffic with cars and reducing CO2 emissions from cars will be effective in protecting the environment". It means that there is a relationship between the features of information transmission and environmental component. Experts presented their opinions using Likert scale followed by gathering data from all experts' opinions to make a clear vote on proposing the above suggestion links on conceptual model to check if it is suitable to apply or not. Other questions, designed for all connections relevant to conceptual model in the questionnaire, are shown in Appendix.

After distributing questionnaire to experts, 48 filled out questionnaires have been returned. The well-known coefficient of Cronbach's alpha (Cronbach, 1949) is used for questionnaire validation calculated by equation (1), where, k is the number of questions, S_i^2 is the variance of answers to the question i and S_T^2 is the total variance of the questionnaire response for each expert. Since, a reliability coefficient of 0.70 or higher is considered "acceptable" in most social science research situations (Bruin, 2006). Since, the calculated alpha coefficient is 0.756 (more than 0.7), it means that all answers are reliable and hypothesis testing can be done.

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum s_i^2}{s_T^2}\right) \quad (1)$$

4.2 Checking Model Validation (Hypothesis Testing)

Scores are ranked as "1" for totally disagree, "2" for disagree, "3" for somewhat, "4" for agree and eventually "5" for quite agree votes. Since, single-sample T test is utilized to compare the mean of answer scores to $\mu = 3$ for 5-point Likert scale. T-stat is obtained by equation (2) where, X is the mean value of experts' answers, μ is the basis of the survey (= 3) and δ is the standard deviation of all samples. This stat should be compared to distribution function stat of $T_{\alpha,n-1}$ can be derived from T-table (Meyer & Walpole, 2012).

$$t = \frac{\bar{x} - \mu}{\delta/\sqrt{n}} \quad (2)$$

For example; 48 experts filled out the first question which asks about traffic reduction and impacts on environment. The average score has been calculated 4.652 with standard deviation of 0.47. Therefore, t-stat is calculated as 23.524 which should be compared to $T_{\alpha,n-1} = T_{0.95,\ 47} = 1.677$ means that null hypothesis is rejected, so there is strong relation between IoT feature and SD component via the first question. Results are obtained for all questions and tabulated in Table 1. As shown, results revealed that

the proposed model can be accepted in confidence interval 95%. In other words, results revealed that the proposed conceptual model approved the concept of increasing sustainability through IoT technology.

Table 1. Statistical Analysis for Each Link of the Conceptual Model

Question Designed to Investigate the Relationship Between IoT Feature and SD Component	Mean	Standard deviation	(T-stat)
Reducing traffic congestion and similarly (reducing) their CO2 protects the environment.	4.652	0.476	23.524
Reducing traffic congestion affects on human life cost reduction.	4.391	0.674	13.980
Reducing traffic congestion is useful to reduce fossil fuel consumption (such as fuel consumption).	4.391	0.617	15.372
Reducing traffic congestion is useful to reduce traffic casualties.	4.333	0.557	16.053
Improving education and learning skills is an effective way protect human resources.	4.239	0.697	12.056
Promoting educational strategies through electronic programs affect on employment creation.	3.933	0.646	9.6880
Reducing paper consumption affects on protecting the environment.	4.711	0.542	21.176
Reducing paper (use) leads to reduce tree cutting down (deforestation).	4.622	0.606	17.954
Increasing the public knowledge and awareness affects on improving human resources status.	4.285	0.764	10.900
Promoting public knowledge and awareness is effective in the environment('s) protection awareness.	4.340	0.600	14.814
Achieving social justice through communication affects on improving the human resources situation.	4.000	0.738	8.9880
Advertising through internet affects on environmental protection.	4.222	0.662	12.382
Advertising through internet reduces advertising cost(s).	4.431	0.617	15.384
Advertising through internet based on business models affects on creating new job opportunities.	4.431	0.705	10.904
Information dissemination and easy access to information improve human life style.	4.400	0.679	13.831

5. Summary and Conclusion

In this research work, the affects of Internet of Things (IoT) applications (IoT) have been investigated on Sustainable Development (SD). Both IoT and SD identified by three main attributes and components for each as well as a conceptual model has been proposed to make relations using intermediate applications. Since, IoT is composed of three main attributes of information transmission, communication and information development and information dissemination and SD is related to economy, society and environment, all possible relations have been identified and one question has been designed to check relations. In order to check the validity of conceptual model, a research based

questionnaire has been designed in which each link related to developing sustainability through Internet of Thing is connected to a specific question. Conceptual model has been validated after gathering data from questionnaires filled out by experts and managers those are working in the field of IoT technology. Each relation between IoT attributes and sustainable development components is investigated by a specific question in queastionnaire in which experts' viewpoints have been gathered using linguistic measures. Statistical analysis has also been performed utilizing T-test in which for each of the corresponding sustaiability-related suggestion, the T-stat has been calculated, and corresponding suggestion is approved if calculated T-stat is grater than critical value. Results revealed that there is a positive attitude toward the proposed sustainability strategies, means that sustaiability can be more managed over the Internet of Things technology. In other words, statistical hypotesises showed that sustainable development is affected by applications of internet of things. Since, sustainability is getiing more and more concern over the world, IoT applications will be improved and wide spread over the next few years. Internet and its applications will more include in the human life while time waste reduction is a critical viewpoint for all people all over the world.

Further studies in this field are recommended to focus on the pathology of the Internet of Things as an issue of interest and evaluate the Internet of Things technology in other sectors such as smart health.

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Appendix

Questionnaire

This questionnaire is designed to assess the sustainability development through Internet of Things technology. Employing the IoT technology as a new tool to achieve flexible and fare management in urban environments and transforming it into sustainability is investigated. Various types of connectable devices and data provide information on creating services, features and new functionality. This information is being collected for planning and decision making for who are dealing with sustainability strategies.

For each of application of IoT, sustainability is presented in the following questionnaire. Filling out the questionnaire is highly appreciated and will help us to conduct the above study which may be useful for decision makers who are dealing with sustainability.

Questionnaire Designed to Validate Conceptual Model Based on Five-Point Likert Scale

Question Designed to Investigate the Relationship Between IoT Feature and SD Component	Quite agree	Agree	Some what	Disagree	Totally disagree
Reducing traffic congestion and similarly (reducing) their CO2 protects the environment.					
Reducing traffic congestion affects on human life cost reduction.					
Reducing traffic congestion is useful to reduce fossil fuel consumption (such as fuel consumption).					
Reducing traffic congestion is useful to reduce traffic casualties.					
Improving education and learning skills is an effective way protect human resources.					
Promoting educational strategies through electronic programs affect on					

employment creation.	
Reducing paper consumption affects on protecting the environment.	
Reducing paper (use) leads to reduce tree cutting down (deforestation).	
Increasing the public knowledge and awareness affects on improving human resources status.	
Promoting public knowledge and awareness is effective in the environment(’s) protection awareness.	
Achieving social justice through communication affects on improving the human resources situation.	
Advertising through internet affects on environmental protection.	
Advertising through internet reduces advertising cost(s).	
Advertising through internet based on business models affects on creating new job opportunities.	
Information dissemination and easy access to information improve human life style.	