Internet of things in industries: a survey for sustainable development

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Abstract: Nations have developed their plans for sustainable development, including social, environmental, and economic aspects. Internet of things (IoT) has been introduced as the next wave of innovation. However, there is still little evidence of progressing IoT in developing countries. Therefore, making policies for investors and tech-entrepreneurs are much needed. Iran, as a transition economy, follows its 1404 economic outlook and should prioritise industries for using IoT. Thus, the aim of this study is to prioritise these industries. In the Iran Telecommunication Research Center and by using the multiple attribute decision making (MADM), criteria weight and prioritising the industries were obtained and each aspect of ‘sustainable IoT’, obtained and for this aim and to prioritise the industries the analytic hierarchy process (AHP), technique for order of preference by similarity to ideal solution (TOPSIS) and ELimination Et Choix Traduisant la REalité e (ELECTRE) methods applied. The result is, respectively, healthcare, energy, smart home, transportation and retailing. The research sheds light on how policy makers can implement policies to use the IoT for achieving sustainable development.
Keywords: sustainable IoT; sustainable development; internet of things; IoT; policy making; developing countries; grey analytic hierarchy process; GAHP; technique for order of preference by similarity to ideal solution; TOPSIS; ELimination Et Choix Traduisant la REalité e; ELECTRE.


Biographical notes: Mohammad Zarei as a MSc in Corporate Entrepreneurship from the only Entrepreneurship Faculty in the Middle-East has learnt to manipulate his knowledge to solve the real world’s problems. These days, he has been working in a National Research Center – ITRC – on several national projects as a Researcher to explore and develop thoughts in regard to Gartner’s hype cycle start-ups. Also, he has more than five years of experience with Iranian organisations in regard to process, strategy and intrapreneurship.

Ayoub Mohammadian is an Assistant Professor of Information Technology (IT) Management. He earned his BS in Business Administration and his MA and PhD in IT Management from the University of Tehran. In addition to teaching, he is the Director of the ICT Entrepreneurship and Business Development Study Group at Iran Telecommunication Research Centre (ITRC). He was honoured with the award for his contributions to national e-government project in Iran’s ministry of commerce. He is author of more than 40 scholarly papers. His primary fields of research are e-business modelling, IT strategic management, entrepreneurship and business development in new technologies.

Rohollah Ghasemi is a PhD student in Production and Operations Management from the University of Tehran, Iran. He has published more than 20 papers among the top journals. Also he has been invited to be a Reviewer in the several international journals like Total Quality Management and Business Excellence. His current research interests include supply chain management, competitiveness, quality management, sustainable development, strategy, and technology.

1 Introduction

Industrialisation is considered as the engine of development and technological growth in lower-developed countries (Lall, 2000), and the Information Industries as a valuable resource for developing countries that can lead to effectiveness, efficiency and overall competitiveness (Jarvenpaa and Leidner, 1998). Markets play a fundamental role in the economy, and we have witnessed the key role of information and communication technology (ICT) in the markets, and just in the recent decades, the internet revolution proved us that the markets are affected by internet technology in myriad ways (Bakos, 1998). Besides, the internet proves us that a new sort of technologies can affect the different facets of business (Premkumar and Roberts, 1999). Internet of things (IoT) has recently been introduced as the next ICT revolution (Chui et al., 2010; Gubbi et al., 2013;
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(ITU, 2005; WEF, 2015). Therewith, there is a growing interest in using the IoT technology in various industries, as well as the number of cases in which the IoT is applied (Li et al., 2012).

In the realm of research, the number of published papers in web of knowledge has been increased from less than 20 papers in 2009, to more than 80 papers in 2010 and to 100 papers in 2013 (Da Xu et al., 2014). On the other hand, the governments in various countries such as USA (The Smart America Challenge, 2015), China (China Internet of Things, 2015), Japan (Koshizuka, 2009), European Union (IERC, 2015) and India (Deity, 2015) have practically supported IoT technology development with various motivations. Countries have found the high potential of IoT, for example Miorandi et al. (2012) mentioned that a number of large-scale initiatives on IoT are being performed in the USA, Europe, Japan, China and Korea. And Da Xu et al. (2014) discuss the UK government has started a 5-million-pound project for developing IoT.

In fact, IoT will be grown out of its infancy, and the evolution towards the ubiquitous data and communication networks has been already happened and the technologies like cloud computing (CC) (Gubbi et al., 2013), content delivery networks (CDN), data science, autonomous vehicles, wearable user interfaces, complex-event processing, and content analytics play the chief role in this evolution. This revolution affords to enable the interconnection between the things, and IoT has opened up a new exciting way for both the scholars and the businesses (Miorandi et al., 2012). The active companies in an economy can improve their competitive advantage by making strategies on the emerging threats and opportunities from the IoT (Li et al., 2012).

On the basis of the European Research Cluster on the IoT (IERC) report, the three drivers for development of IoT are: increasing the economic prosperity, quality of life and environmental protection (Smith, 2012, p.232) which are also discussed in the literature of the sustainable development (Carter and Easton, 2011; Lehtonen, 2004; Pearce and Atkinson, 1993). Along the same line, there has been Economic Prosperity index in the field of economics (Bansal, 2005), Quality of Life in social field (Baud et al., 2001) and Environmental Protection index in the environmental field (Zhang and Wen, 2008). Moreover, the United Nations (1987) defined sustainability as the concept of following the current needs of human, without endangering the next generations’ capability for satisfying their needs.

On the other hand, Porter and Kramer (2011) have expressed that in the recent years, businesses are considered as the main cause of social, environmental and economic problems. Because of the reduced trust on the businesses, the political leaders should set policies which undermine the competitiveness and sap economic growth; such decisions in the recent decades have created the belief that there is a trade-off between the economic efficiency and the social progress. Governments must learn how to legalise the ways that enable socially and economically shared values, rather than work against it. Simultaneously, the shared value idea focuses on the social progress and economy, and this will drive the next wave of innovation and productive growth in global economy. Furthermore, the authors express that, the concept of shared value is used similarly in both developed economies and developing economies. By searching for the best practices in various countries, they have found that, there are plenty of ways which can lead to the economic growth by tackling the social concerns. The three ways that the companies
can create shared value opportunities are: by reconceiving products and markets, by redefining productivity in the value chain and finally by enabling local cluster development.

Iran as a transition economy from factor-driven to efficiency-driven economy (Schwab, 2014), and based on its 1404 outlook, plans to be one of the most developed countries comparing with the other nations in the region – the Middle-East (Iran Outlook 1404, 2015). To achieve this goal, leaders should make decisive decisions and encourage, sustain and increase economic growth to enhance their countries’ competitiveness and next economic outlook (Schwab, 2014).

Many of the researchers such as Miorandi et al. (2012) have discussed huge market opportunities exist for the IoT, but they do not suggest identification and/or prioritisation of the industries for entrée to IoT. Besides, these authors have merely stated that some sectors/industries – six areas – can provide the competitive advantages and play a productive role in the adoption of the IoT technology. However, for making the IoT more real, more significant researches need to be conducted (Zheng et al., 2011). Investment on IoT and choosing the appropriate industries to develop IoT have been challenging, and each country must make policies in the particular parts of IoT based on its state of affairs and their economic driver, and here is the gap which this paper is going to bridge. In this way, the first step is to identify and prioritise industries for developing Sustainable IoT. On the basis of what was discussed and according to the government’s restricted resources, the main aim of this study is to identify the industry that plays the chief role for achieving sustainable development of Iran’s government by using IoT. Therefore, Iranian policy makers are required to answer the following questions so that they could employ IoT:

- What is the value of **Economic Prosperity**, **Quality of Life** and **Environmental Protection** indicators for Sustainable IoT development in Iran?

- Which industry is the most important for developing Sustainable IoT?

Hence, this research project was defined for developing IoT in Iran Telecommunication Research Center (ITRC), the subgroup of Ministry of ICT by title of The “Internet of Things (IoT) Research, Market and Industries”, and the tasks which are addressed and the methods that are used for achieving the research aims are as follows: understanding the concept of sustainable development and IoT, a related literature in the form has been studied in Section 2. Emphasising the importance of IoT in various industries a table – Table 1 – has been conducted for presenting the examples of studies that are pointed out the IoT applications in various industries. In Section 3, the selected – five – industries should be prioritised for using IoT in sustainable development of Iran and for this aim the multiple attribute decision making (MADM) methodology was chosen and explained. In Section 4, the weights of each criterion (economic prosperity, quality of life and environmental protection) of sustainable development based on our national experts’ opinions were discussed. Section 5 has been dedicated to discuss the results, conclusions, implication, limitations and recommendations for future researches, besides, in this section it will be demonstrated that how IoT will help Iranian sustainable development in the context of country’s real challenges.
### Table 1  IoT sectors/industries which recognised by the literature review

<table>
<thead>
<tr>
<th>The IoT sectors/Industries</th>
<th>Sources for reviewing the literature</th>
</tr>
</thead>
</table>
| **Energy industry**        | Ad Hoc Networks (Miorandi et al., 2012)  
                          | Future Generation Computer Systems (Gubbi et al., 2013)  
                          | IEEE Communications Surveys & Tutorials (Perera et al., 2014; Tsai et al., 2014)  
                          | McKinsey Quarterly (Chui et al., 2010)  
                          | River Publishers (Vermesan et al., 2011, 2013) |
| **Transportation industry**| Computer Communications (Al-Turjman et al., 2013)  
                          | Computer Networks (Atzori et al., 2010)  
                          | Future Generation Computer Systems (Gubbi et al., 2013)  
                          | IEEE Communications Magazine (Atzori et al., 2014; Xu, 2002; Zheng et al., 2011)  
                          | IEEE Communications Surveys & Tutorials (Tsai et al., 2014)  
                          | IEEE Internet Computing (Broll et al., 2009; Kortuem et al., 2010)  
                          | IEEE Transactions on Industrial Informatics (Da Xu et al., 2014; He et al., 2014)  
                          | McKinsey Quarterly (Chui et al., 2010)  
                          | Personal and Ubiquitous Computing (Konomi and Roussos, 2007)  
                          | River Publishers (Vermesan et al., 2011, 2013) |
| **Healthcare industry**    | Ad Hoc Networks (Miorandi et al., 2012)  
                          | Computer networks (Atzori et al., 2010)  
                          | Future Generation Computer Systems (Gubbi et al., 2013)  
                          | IEEE Communications Magazine (Akyildiz et al., 2002; Atzori et al., 2014; Gluhak et al., 2014; Li et al., 2011; Xu, 2002; Zheng et al., 2011)  
                          | IEEE Communications Surveys & Tutorials (Perera et al., 2014; Tsai et al., 2014)  
                          | IEEE Journal on Selected Areas in Communications (Lin et al., 2009)  
                          | IEEE Transactions on Industrial Informatics (Da Xu et al., 2014; He et al., 2014)  
                          | IEEE Wireless Communications (Luo et al., 2010)  
                          | McKinsey Quarterly (Chui et al., 2010)  
                          | New England Journal of Medicine (Barbash and Glied, 2010)  
                          | Personal and Ubiquitous Computing (Jara et al., 2011)  
                          | River Publishers (Vermesan et al., 2011, 2013) |
| **Retailing industry**     | Ad Hoc Networks (Miorandi et al., 2012)  
                          | Electronic Markets (Thießen and Köhler, 2008)  
                          | Future Generation Computer Systems (Gubbi et al., 2013)  
                          | IEEE Communications Magazine (Zheng et al., 2011)  
                          | IEEE Transactions on Industrial Informatics (Da Xu et al., 2014)  
                          | McKinsey Quarterly (Chui et al., 2010)  
                          | Personal and Ubiquitous Computing (Konomi and Roussos, 2007)  
                          | River Publishers (Vermesan et al., 2013) |
Table 1  IoT sectors/industries which recognised by the literature review (continued)

<table>
<thead>
<tr>
<th>The IoT sectors/Industries</th>
<th>Sources for reviewing the literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart home industry</td>
<td><em>Ad Hoc Networks</em> (Miorandi et al., 2012)</td>
</tr>
<tr>
<td></td>
<td><em>Computer networks</em> (Atzori et al., 2010)</td>
</tr>
<tr>
<td></td>
<td><em>Future Generation Computer Systems</em> (Akyildiz et al., 2002; Gubbi et al., 2013)</td>
</tr>
<tr>
<td></td>
<td><em>IEEE Communications Magazine</em> (Atzori et al., 2014; Li et al., 2011; Xu, 2002)</td>
</tr>
<tr>
<td></td>
<td><em>IEEE Communications Surveys &amp; Tutorials</em> (Perera et al., 2014; Tsai et al., 2014)</td>
</tr>
<tr>
<td></td>
<td><em>IEEE Internet Computing</em> (Kortuem et al., 2010)</td>
</tr>
<tr>
<td></td>
<td><em>IEEE Transactions on Industrial Informatics</em> (Da Xu et al., 2014)</td>
</tr>
<tr>
<td></td>
<td><em>River Publishers</em> (Vermesan et al., 2011, 2013)</td>
</tr>
</tbody>
</table>

2 Literature review

2.1 Sustainable development

Before 1960s, the efforts that focused on increasing the economic outputs and national wealth in countries were developed. In the next decades, the topic of development has considered universally and the non-economic considerations were initiated. In this way, sustainable development topics were formed by focusing on *Economic, Social* and *Environmental* (UNCED, 1992). Social sustainability, in turn, is defined as the institutions, policies and factors which enable all members of society to experience the best feasible health, taking part and security; and maximise their potential to put up and benefit from the economic success/prosperity of the country in which they live. The World Economic Forum (WEF) defines environmental sustainability as the institutions, policies and the issues that should be considered to achieve an efficient management of the resources to enable success prosperity for present and next generations. Even though, the gain of a certain level of economic prosperity is crucial for obtaining high standards of living, within this exercise, countries are also assessed by their ability to generate this long-lasting prosperity for their citizens in a sustainable way. The notion of sustainable competitiveness places more emphasis on the importance of productivity as a driver of prosperity and long-duration growth. Nevertheless, the sustainable competitiveness is defined as the set of institutions, policies and factors which make a nation productive over the longer duration while ensuring the social and environmental sustainability (Schwab, 2014, pp.55–64).

2.2 Examining the concept of internet of things (IoT)

IoT may represent the next big leap ahead into the ICT zone (Miorandi et al., 2012; Zarei et al., 2015). The Institute of Electrical and Electronics Engineers (IEEE) states that IoT is not a second internet, but rather, it is a network of things – items – which are embedded with sensors and are connected to the ‘internet’ and IoT’s true value lies within the data of interconnected items (IEEE, 2015). It has been reported that,
at the present time, there are ‘9’ billion interconnected devices and it is expected to reach the ‘24’ billion devices by 2020 (Gubbi et al., 2013).

IoT is a multidisciplinary field that covers a large variety of areas (Gluhak et al., 2014). As identified by Atzori et al. (2010) the three significant paradigms of IoT are:

• internet oriented
• things oriented
• semantic oriented, which Gubbi et al. (2013) discuss them under the names of: middleware, sensors and knowledge, respectively.

From another point of view, the ITU (2005) states that a new dimension has been added to the world of ICTs: From anytime, anyplace connectivity for anyone, now we will have connectivity for everything and the IoT will enable the forms of cooperation and communication between people and things, and between things themselves. On the other hand, IERC states: anything, anytime, anyone, anyplace, any service and any network (IERC, 2015).

In other words, IoT has been primarily about thing-to-thing interaction (Atzori et al., 2010; Caceres and Friday, 2011; Gubbi et al., 2013) and IoT attempts to grow and increase intelligence (Atzori et al., 2010).

2.3 The internet of things in industries

The project is defined by ITRC to develop IoT in Iran. Therefore, after holding the meetings with the national experts, as well as reviewing the Iran Outlook 1404 and the literature and international reports, the following sectors/industries were extracted: energy, transportation, healthcare, retailing and smart home. The results of these evidences are briefly shown in Table 1.

The evidences of the high potential of using IoT in the selected industries have been observed, as shown in Table 1.

3 The methodology of the research

3.1 Research methodology

To obtain the prioritising of various industries to apply the IoT in Iran to achieve sustainable development, the MADM method was used. At first, the weights of each economic prosperity, quality of life and environmental protection were identified by analytic hierarchy process (AHP) method. Then, separately, the comparison of each industry based on indices was considered in form of three pair-wise comparison questionnaires, and finally the decision matrix was obtained. Then after, by using three methods: grey analytic hierarchy process (GAHP), technique for order of preference by similarity to ideal solution (TOPSIS) and ELimination Et Choix Traduisant la REalité (ELECTRE), the prioritisation of industries to achieve sustainable development of IoT was obtained. Hence, this research is an applied research and its methodology is kind of a descriptive survey. The research steps are shown in Figure 1 briefly.
Tzeng and Huang (2011) discussed AHP is proposed by Saaty between years of 1977 and 1980 to model the subjective decision-making procedures on the basis of multiple features on a hierarchical system. From that time on, it has been extensively used to corporate scheming, choosing the portfolio and even for the cost/benefit analysing by the government agents to optimally allocate resource (Tzeng and Huang, 2011, p.15). The four main steps of the AHP can be summarised as follows:
**Internet of things in industries**

Step 1: To fix the hierarchical system by dispersing and decomposing the problem into a hierarchy of interconnected elements; in the current research the hierarchical structure of the AHP as it follows (Figure 2).

Step 2: To compare the comparative weight between the features/attributes of the decision elements to form the reciprocal matrix.

Step 3: To synthesise the individual subjective judgement and assessment/estimate the relative weight.

Step 4: To aggregate the relative weights of the elements to specify the best alternatives (Tzeng and Huang, 2011, pp.16, 17). Dyer and Forman (1992) describe the benefits of AHP in a group collection as follows:

- the discussion emphasised on both tangibles and intangibles, individual and shared values
- the discussion can be emphasised on objectives instead of alternatives
- the discussion can be structured then each attribute can be considered in turn
- the discussion continues until all the related data has been reviewed and a consensus choice of the decision alternative is obtained.

In the current research for weighting criteria and provide the decision matrix, GAHP method, TOPSIS and ELECTRE methods were used.

**Figure 2** Hierarchical structure of AHP

To form the decision matrix, three days of meetings were held in ITRC with the presence of the 10 Iranian IoT national experts. Our experts’ population was all holding Master of Science (MSc) or PhD and at least have been participating for three years in IoT and ICT projects in the Iranian ICT industries. They are members of ITRC and they have brilliant insights in the new technologies so they are known as our national experts. For the sampling, the Snowball sampling method was used and based on the method, 10 of the national experts were identified. This method in sociology and statistics
researches is so common (Biernacki and Waldorf, 1981). The pair-wise comparison questionnaire was distributed between the experts and finally the four filled questionnaires were compiled and used to conform experts’ comments by using geometric mean. The responses were processed by the Expert Choice (2000) and those with inconsistency ratios greater than 0.10 were asked to reconsider their judgements as suggested by Saaty (Tavana and Hatami-Marbini, 2011).

3.2 The technique for order of preference by similarity to ideal solution (TOPSIS)

TOPSIS was proposed by Hwang and Yoon in 1981 (Chen and Tsao, 2008) to determine the best alternative, based on the compromise solution ideas, and therefore the compromised result can be regarded as choosing the solution with the shortest Euclidean distance from the ideal solution and the farthest Euclidean distance from the negative ideal solution (NIS) and in this way ‘M’ choice by ‘N’ index is examined (Tzeng and Huang, 2011, p.69). The principle of agreement – of TOPSIS – for the multiple criteria decision making is that the chosen solutions must have the shortest distance from the positive ideal solution (PIS) as perfect as the longest distance from the NIS (Lai et al., 1994).

In this survey, after the decision matrix evaluation, prioritising the industries will be done to use the TOPSIS method. The TOPSIS method steps are as follows:

1. To calculate normalised matrix.
2. To calculate weights of the normalised matrix, the multiplying criteria weights in the decision matrix.
3. The positive ideal solution; a possible solution composed of all best accessible criterion values.
4. The negative ideal solution; a potential solution composed of all the worst accessible criterion values.
5. To determine the separation of each ‘i’ option from the PIS option \( D_i^+ \): Euclidean distance for each option to PIS option is calculated.
6. To determine the distance of each ‘i’ option from the NIS option \( D_i^- \): Euclidean distance for each option to NIS option is calculated.
7. To calculate the degree of proximity to the positive ideal option \( C_i^+ \).

Eventually, the preferred orders can be obtained through the similarities to the PIS \( C_i^+ \) in order to narrow down the choice of the best alternatives (Tzeng and Huang, 2011, pp.69, 70).

3.3 The ELimination Et Choix Traduisant la REALité (ELECTRE)

The ELECTRE model was first presented by Roy (1968) to find the kernel solution under a circumstance which the true criteria and restricted outranking relations are available. In ELECTRE, two indices named the concordance index and the discordance index are used to measure the relations between objects. As to the concordance index, \( C(a, b) \)
calculates how much \((a)\) is at least as well as \((b)\). On the other side, the discordance index, \(D(a, b)\) measures the degree to which ‘\(b\)’ is strictly preferred to ‘\(a\)’ and the concordance index and the discordance index in ELECTRE can be defined by:

\[
C(a, b) = \frac{\sum_{i=1}^{n} w_i}{\sum_{i=1}^{n} w_i} \quad (1)
\]

and

\[
D(a, b) = \frac{\max_{c,\alpha,b} w_i (g_i(b) - g_i(a))}{\max_{c,\alpha,b} w_i (g_i(c) - g_i(d))} \quad (2)
\]

\(C(a, b)\) and \(D(a, b)\) ∈ \([0, 1]\), \(g(k)\) indicate the ideal scores of the \(j\)th attribute for the \(k\)th alternative; \(Q(a, b)\) indicate the set of criteria for which ‘\(a\)’ is equal or preferred to ‘\(b\)’; \(R(a, b)\) is the set of criteria for which ‘\(b\)’ is strictly preferred to ‘\(a\)’; ‘\(a\)’ denotes the set of all alternatives. For comparing the alternatives ‘\(a\)’ and ‘\(b\)’, we can determine the relation between ‘\(a\)’ and ‘\(b\)’ using the following procedures:

If \(C(a, b) > C^*\) and \(D(a, b) < D^*\) then ‘\(a\)’ outranks ‘\(b\)’, otherwise ‘\(a\)’ does not outrank ‘\(b\)’.

If \(C(b, a) > C^*\) and \(D(b, a) > D^*\) then ‘\(b\)’ outranks ‘\(a\)’, otherwise ‘\(b\)’ does not outrank ‘\(a\)’.

Then, the outrank relation among ‘\(a\)’ and ‘\(b\)’ can be derived by referring to Table 2. Outrank relation between ‘\(a\)’ and ‘\(b\)’ (Tzeng and Huang, 2011, pp.81, 82).

<table>
<thead>
<tr>
<th>Outrank relation</th>
<th>(a) does not outrank (b)</th>
<th>(a) outranks (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b) does not outrank (a)</td>
<td>Incomparable</td>
<td>(a) outranks (b) ((a &gt; b))</td>
</tr>
<tr>
<td>(b) outranks (a)</td>
<td>(b) outranks (a) ((b &gt; a))</td>
<td>Indifference ((a - b))</td>
</tr>
</tbody>
</table>

### 4 Data analysis

#### 4.1 Weighting criteria by GAHP method

On the basis of the result of pair-wise comparison questionnaires for criteria, the experts’ comments in form of a synthesised matrix according to Table 3 were obtained. The elements of the matrix were calculated based on the geometric mean of the individuals’ comments.

<table>
<thead>
<tr>
<th>Synthesised matrix for the criteria</th>
<th>Economic prosperity</th>
<th>Quality of life</th>
<th>Environmental protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic prosperity</td>
<td>1</td>
<td>2.3403</td>
<td>6.9640</td>
</tr>
<tr>
<td>Quality of life</td>
<td>0.4273</td>
<td>1</td>
<td>5.3836</td>
</tr>
<tr>
<td>Environmental protection</td>
<td>0.1436</td>
<td>0.1858</td>
<td>1</td>
</tr>
</tbody>
</table>
Also, for examining the reliability of questionnaire and for pair-wise comparison synthesised matrix, consistency ratio (CR) was estimated equal to 0.0226, which is less than 0.1 and is less than the accepted upper limitation for CR, so it shows a good compatibility in comparisons (Wang and Yang, 2007). Sustainable IoT criteria weighting was done with GAHP method by Expert Choice 11 software and its results are shown in Figure 3.

**Figure 3** Sustainable IoT criteria weighting in Iran (see online version for colours)

![Figure 3](image)

### 4.2 Providing the decision matrix with pair-wise comparison method

Then, based on the result of pair-wise comparison questionnaire for each industry in each criterion, the pair-wise comparison synthesised matrix was calculated and in this matrix the score of each industry in each criteria, has been determined. Pair-wise comparison synthesised matrix was obtained as to the economic prosperity criteria in accordance with Table 4.

**Table 4** Industries pair-wise comparison synthesised matrix (in terms of) to economic prosperity criteria

<table>
<thead>
<tr>
<th>Pair-wise comparison synthesised matrix</th>
<th>Healthcare industry</th>
<th>Transportation industry</th>
<th>Smart home</th>
<th>Energy industry</th>
<th>Retailing industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthcare industry</td>
<td>1</td>
<td>3.4641</td>
<td>5.5951</td>
<td>1.4142</td>
<td>7.4156</td>
</tr>
<tr>
<td>Transportation industry</td>
<td>0.2887</td>
<td>1</td>
<td>0.8944</td>
<td>0.2445</td>
<td>1.0000</td>
</tr>
<tr>
<td>Smart home</td>
<td>0.1787</td>
<td>1.1180</td>
<td>1</td>
<td>0.1996</td>
<td>3.0274</td>
</tr>
<tr>
<td>Energy industry</td>
<td>0.7071</td>
<td>4.0906</td>
<td>5.0100</td>
<td>1</td>
<td>2.6458</td>
</tr>
<tr>
<td>Retailing industry</td>
<td>0.1349</td>
<td>1.0000</td>
<td>0.3303</td>
<td>0.3780</td>
<td>1</td>
</tr>
</tbody>
</table>

CR for this pair-wise comparison synthesised matrix was estimated equal to 0.0509 and since the number 0.1 is accepted as the upper limitation for CR, it shows a good
compatibility in comparisons (Wang and Yang, 2007). Therefore, the score of each industry in the economic prosperity criteria was obtained, respectively, in Figure 4.

Pair-wise comparison synthesised matrix was obtained in terms of quality of life criteria in accordance with Table 5.

**Figure 4**  The score of each industry in economic prosperity criteria (see online version for colours)

![Figure 4](image)

**Table 5**  Industries pair-wise comparison synthesised matrix (in terms of) to quality of life criteria

<table>
<thead>
<tr>
<th>Pair-wise comparison synthesised matrix</th>
<th>Healthcare industry</th>
<th>Transportation industry</th>
<th>Smart home</th>
<th>Energy industry</th>
<th>Retailing industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthcare industry</td>
<td>1</td>
<td>5.4772</td>
<td>3.6628</td>
<td>6.7354</td>
<td>7.4833</td>
</tr>
<tr>
<td>Transportation industry</td>
<td>0.1826</td>
<td>1</td>
<td>0.2515</td>
<td>3.3098</td>
<td>5.0915</td>
</tr>
<tr>
<td>Smart home</td>
<td>0.2730</td>
<td>3.9764</td>
<td>1</td>
<td>5.1800</td>
<td>6.9010</td>
</tr>
<tr>
<td>Energy industry</td>
<td>0.1485</td>
<td>0.3021</td>
<td>0.1930</td>
<td>1</td>
<td>2.2134</td>
</tr>
<tr>
<td>Retailing industry</td>
<td>0.1336</td>
<td>0.1964</td>
<td>0.1449</td>
<td>0.4518</td>
<td>1</td>
</tr>
</tbody>
</table>

**Figure 5**  The score of each industry in quality of life (see online version for colours)

![Figure 5](image)
CR for this pair-wise comparison synthesised matrix was estimated equal to 0.0687 and since the number 0.1 is accepted as the upper limitation for CR. It shows a good compatibility in comparisons (Wang and Yang, 2007). Therefore, the score of each industry in quality of life criteria was, respectively, obtained in Figure 5.

Pair-wise comparison synthesised matrix was obtained in accordance with environmental protection criteria and is shown in Table 6.

**Table 6**  Industries pair wise comparison synthesised matrix accordance with environmental protection

<table>
<thead>
<tr>
<th>Pair-wise comparison synthesised matrix</th>
<th>Healthcare industry</th>
<th>Transportation industry</th>
<th>Smart home</th>
<th>Energy industry</th>
<th>Retailing industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthcare Industry</td>
<td>1</td>
<td>0.1492</td>
<td>0.2427</td>
<td>0.1292</td>
<td>1.2729</td>
</tr>
<tr>
<td>Transportation Industry</td>
<td>6.7007</td>
<td>1</td>
<td>4.5270</td>
<td>0.2427</td>
<td>6.4474</td>
</tr>
<tr>
<td>Smart Home</td>
<td>4.1195</td>
<td>0.2209</td>
<td>1</td>
<td>0.1543</td>
<td>3.3504</td>
</tr>
<tr>
<td>Energy Industry</td>
<td>7.7373</td>
<td>4.1195</td>
<td>6.4807</td>
<td>1</td>
<td>7.6673</td>
</tr>
<tr>
<td>Retailing Industry</td>
<td>0.7856</td>
<td>0.1551</td>
<td>0.2985</td>
<td>0.1304</td>
<td>1</td>
</tr>
</tbody>
</table>

CR for this pair-wise comparison synthesised matrix was estimated equal to 0.0682 and since the number is less than 0.1, it is accepted as the upper limitation for CR. It shows a good compatibility in comparisons (Wang and Yang, 2007). Therefore, the benefit of each industry in the environmental protection was obtained in Figure 6.

**Figure 6**  The score of each industry in environmental protection criteria (see online version for colours)

Each criterion’s weight and the decision matrix were conducted to rank the industries for obtaining the Iran sustainable development. By aggregating the results of Tables 4–6 and 7, as the decision matrix, will be obtained. In fact, decision matrix is the $m \times n$ matrix, and that its $r_y$ element determines ($A_i$) $i$ rated choices, according to ($x_j$) $j$ matrix.

Each industry position in each sustainable IoT index was displayed as three-dimensional in Figure 7.
4.3 Rating industries based on sustainable IoT indices

After obtaining the weights of each index – according to Figure 3 and decision matrix (Table 7) – the prioritisation of industries to achieve sustainable IoT was obtained by ELECTRE, TOPSIS and GAHP methods. Rating the industries is obtained by GAHP method based on the scores. The ranking results are shown in Figure 8.

Because the prioritisation options in GAHP will be conducted based on the higher scores, healthcare industry with the highest score of 0.421 points is the most proper industry for achieving sustainable IoT, and after that there are: energy, smart home, transportation and finally retailing industries, respectively.
The ranking of industries was done based on the options proximity to the PIS \((D_r)\), using TOPSIS method, and after calculating each option distance from the PIS \((D_r')\) and each option distance from the NIS \((D_r'')\). The results of TOPSIS method are summarised in Table 8.

**Figure 8**  Industries scores for sustainable IoT by GAHP (see online version for colours)

<table>
<thead>
<tr>
<th>Decision matrix</th>
<th>(D_r)</th>
<th>(D_r')</th>
<th>(C_r)</th>
<th>The rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthcare industry</td>
<td>0.0576</td>
<td>0.4639</td>
<td>0.8895</td>
<td>1</td>
</tr>
<tr>
<td>Transportation industry</td>
<td>0.4256</td>
<td>0.0602</td>
<td>0.1240</td>
<td>4</td>
</tr>
<tr>
<td>Smart home</td>
<td>0.3797</td>
<td>0.1286</td>
<td>0.2530</td>
<td>3</td>
</tr>
<tr>
<td>Energy industry</td>
<td>0.2694</td>
<td>0.2727</td>
<td>0.5031</td>
<td>2</td>
</tr>
<tr>
<td>Retailing industry</td>
<td>0.4675</td>
<td>0.0000</td>
<td>0.0000</td>
<td>5</td>
</tr>
</tbody>
</table>

As it is shown, in this method, the healthcare industry has the minimum distance to the PIS and also the maximum distance to the NIS; the industry which has the top score in TOPSIS method – equal to 0.8895 – and is the best option so as to achieve sustainable IoT in Iran.

Also, the retailing industry, with the maximum distance to the PIS and the minimum distance to the NIS is deemed as the least priority for achieving sustainable IoT in Iran. However, energy, smart home and transportation industries are from the second to fourth rank. The kernels of the outranking graphs (see Figure 9) for ELECTRE, defines the prioritisation of the industries (Jabeur and Martel, 2007).

On the basis of the results of ELECTRE method, the industries ranking to achieve sustainable IoT is as follows:

[Retailing < Transportation < Smart home < Energy < Healthcare]
5 Conclusions, implication, limitations and recommendations for future researches

5.1 Conclusions and implications

IoT is recognised as the next revolution of ICT (Chui et al., 2010; Gubbi et al., 2013; ITU, 2005; WEF, 2015). Various countries such as USA, England, China and India have examined IoT for their next economic boom, but on the other hand, IoT has been progressing in some developing counties and Africa; however, it is too slow (IERC, 2015). Sustainable development has attracted lots of attentions from scholars and countries as a profound concept (Antonopoulos et al., 2013; Blake, 2007; Brandli et al., 2015; Patel, 2014) and furthermore, the interaction between sustainability and innovation has been deeply considered (Brunner and Marx, 2013; Olla, 2008; Peeters et al., 2006; Weaver, 2005; Zhou et al., 2012). On the basis of the surveys, it seems that we can define the sustainable IoT as the goal-oriented utilisation of it in the industries, which enables countries to move towards the sustainable development – for obtaining the economic, social and environmental goals – and finally it can leads to sustainable competitive countries.

Iran has just recently began to support the IoT development research which is assessed by the technical, infrastructural and policy-making aspects in the Iran Telecommunication Research Center (ITRC), the subgroup of Ministry of ICT. Therefore, one of the Iran challenges is the prioritisation of industries for achieving the sustainable IoT. Recognition of the importance of this subject has been the goal of Iran’s industries prioritisation research, based on the sustainable IoT indices. Hence, the five important industries were examined based on the literature review and experts’ opinions by Iranian policy makers as to the 1404 outlook (Iran Outlook 1404, 2015) and based on the economic prosperity, quality of life and environmental protection.
On the basis of the results – of Figure 3 – the economic prosperity index in Iran is estimated more important than quality of life and environmental protection indices for developing the IoT. In this way, the weight index of economic prosperity was evaluated 60.73%, the weight index of quality of life 31.96%, and the weight index of environmental protection 7.3%.

Interestingly, the results of this research seem pertinent to Iran’s economic structure. Iran as a transition country from the factor-driven economy to an efficiency-driven economy (Schwab, 2014, p.11) has some problems such as: access to financing, inflation, exports as a percentage of GDP, women in labour force ratio to men in the country, based on the Global Competitiveness Report 2014–2015 (Schwab, 2014, p.217); hence, if IoT creates the economic prosperity in an industry, that industry will have a higher priority for economic development. Therefore, healthcare and energy industries will create the most economical welfare than other industries, respectively. Smart home, transportation and retailing industries have obtained the next priorities.

The Iranian 1404 outlook argues that in order to achieve the first rank in the region – the Middle-East – Iran requires to improve the quality of life (Iran outlook 1404, 2015), for instance, Iran has obtained the 76th place between 144 considered countries with 73.8 average in life expectancy index (Schwab, 2014, p.217).

However, Iran has the remarkable distance with Israel to obtain the first place in the region (with 10th place in the world). Therefore, to measure the IoT social sustainable development aspects in this research, the quality of life index was considered. On the basis of Figure 5, IoT development in healthcare and smart home industries will be followed by the quality of life, respectively, also, transportation, energy and retailing industries have obtained the next priorities.

The statistics have shown that, the environmental indices are not very favourable in Iran. In this regard and based on the environmental performance index (EPI) report, Iran has obtained the 83rd place between 83 countries, and to obtain the first place in the region there is a remarkable distance to reach UAE, 25th place in the world (EPI, 2015).

On the basis of the results of Figure 6, IoT development provides the most environmental protection in energy and transportation industries, respectively; also, smart home, healthcare and retailing industries have obtained the next priorities.

Because of the fact that sustainable IoT is achieved by the paying simultaneous attention to the three indices, it would be better to use the MADM method indices, including: GAHP, TOPSIS and ELECTRE. The results that are obtained in each of the three methods are in agreement with each other, and it is not required to use the ‘aggregation strategy’ for the final presentation ranking of industries.

On the basis of the results of each method of achieving the sustainable IoT in Iran, healthcare industry has been in the first priority. Ministry of Health and Medical Education of Iran is following the plans to achieve sustainable development, for instance ‘Health Industry Evolution’ plan (Ministry of Health and Medical Education, 2015). In Iran, healthcare system has been emphasised the usage of modern technology, for instance, the projects such as ‘e-Health’ has been suggested. IoT with its various applications in the fields of healthcare can help to develop such systems in all parts of the country. In this way, many applications of the IoT in the field of healthcare to increase longevity, epidemic diseases reduction, facilitating medical cares for chronic diseases, taking care of children and infants, prevention of dangerous diseases, improving the elderly’s quality of life and generally focusing on ‘real time monitoring’ of public
Internet of things in industries

healthcare. Hence the IoT development in healthcare industry in Iran is meaningful and also necessary.

On the basis of the yielded ranking, energy industry is the second priority. Iran as one of the biggest oil and gas producers can use the devices and various IoT applications in manufacturing, distributing and processing sections of petroleum industry. The applications such as controlling of oil wells, oil storage tanks, transmission and distribution lines and the petrochemical products processing, are all completely tangible using IoT – e.g., see Jasper the IoT cloud (Jasper, 2015).

There are many applications in producing the non-fossil energy section too. Using IoT technology for increasing the efficiency of the production of solar, wind energies and power generation at dams and generally smart and green energies is possible.

The third priority has been known as smart home. The construction industry in Iran has recently used the new technologies in construction and equipping and furnishing homes. Connecting the various IoT devices together at homes is defined as a form of smart home and creates a variety of facilities for domestic customers of this technology. Smart home includes the using of devices which will cause the emergence of smart home concept at homes by increasing the interconnection between people and things. The transportation industry is considered as the fourth and the retailing industry is ranked as the last priority.

In the field of policy making, according to the Porter and Kramer (2011) proposals, policy making for reviewing products and markets in selected industries by using the IoT technology is recommended. Also, redefining productivity in the value chain industries is highly recommended; by taking the advantage of this technology, using IoT and also enabling the local cluster development in each of the industries with higher priority for Iran.

From our point of view, the results of the study help the policy makers by attracting their attention to the sustainability dimensions and enable them to prioritise all industries to develop the sustainable IoT, not just focusing on the economic aspects of IoT.

Another contribution of this research is selecting the industry. By identifying the health industry as the selected industry, the Iranian policy makers are given a hand to develop the sustainable IoT.

Also, the lack of business and economic approaches in the field of IoT are completely evident. As a result, this paper tries to consider IoT as the trigger of sustainable development.

Another contribution is related to the components of sustainability’s literature. The current research tries to extend the knowledge of sustainable development by borrowing its components (economic prosperity, quality of life and environmental protection) for offering the new content named ‘Sustainable IoT’.

Also, regarding the practical and empirical contributions, based on our structured methodology, healthcare industry has been introduced to the Iranian policy makers as the selected industry that has enough potential in leading to the sustainable development. In our perspective, all countries that once tried to apply IoT as their next economical-technological driver, have to determine which industry should be chosen for embarking this path; in this regard our presented approach is a worthy manner for determining the selected industry.
5.2 Limitations and recommendations for future research

This research has some limitations. One of our real challenges was the lack of detailed information about IoT and the economical–technological experts. Another limitation of this research was examining IoT in just five selected industries of Iran – transition from factor-driven to efficiency-driven economy – that reduces the generalisation of our findings. Especially, the indices weights may be affected because of the nature of Iran’s economy, in this regard, it is suggested that the various industries in countries with innovation-driven economies, efficiency-driven economies and the countries with transition from efficiency-driven to innovation-driven economy should be surveyed separately.

As it was shown, the health industry has been known as the selected industry but up to the present there is no Roadmap or legislation for developing the sustainable IoT in the selected industry. In this regard, for the future researches, it is recommended to identify the policy makers’ challenges for developing the sustainable IoT in the selected industry.

Also, it is proposed that to make IoT more real and less risky for both policy makers and businesses, a model of IoT development in various countries should be presented, based on their needs, facilities, scopes, aims and also visions.

One of the main challenges for developing IoT is about ‘knowledge transferring’, it has been discussed as the knowledge which is embedded in the interactions of people, tools and tasks provision while they are the basis for competitive advantage in firms (Argote and Ingram, 2000). Because of the leakage of adequate IoT knowledge in the developing countries, it seems the consortiums can play a crucial role. In this regard, the international alliances between well developed and developing economics should be taken into the consideration more seriously.

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References

Internet of things in industries


