

Design and Explanation of Measuring Model for the Impacts of Information Communication Technology on Sustainable Development

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طراحی و تبیین مدل اندازه گیری اثرات فناوری اطلاعات و ارتباطات بر توسعه پایدار

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Abstract:

This study seeks to recognize the impact of ICT development and its role in improving sustainable development indices for Iran. The role of sustainable development and ICT in various fields has been initially undertaken. Then, validated models of ICT impacts were introduced. Subsequently, the related studies in these areas were reviewed and analyzed. Next, the ICT impacts on the main dimensions of sustainable development were explained.

In this study, the mixed approach with the sequential exploratory strategy has been used. To identify the main factors of research, the experts' interviews were used. Using the interview results, the analytical model and the research questionnaire were prepared. The statistical population includes experts from the universities and industry. The quantitative information obtained through the implementation of the questionnaire. Validation of research model was examined by analytical tools (Smart PLS and SPSS). The results of this study indicates significant effects of ICT on the social dimension of sustainable development in Iran.

Keywords: Measurement model, ICT, Sustainable development, Environment, Economics, Community.

چکیده:

این مقاله درصدد شناسایی پیامدهای توسعه فاوا و نقش آن در بهبود شاخص های توسعه پایدار و نحوه اندازه گیری آن برای بوم ایران می باشد. در ابتدا به بررسی جایگاه و نقش توسعه پایدار و توسعه فاوا در حوزه های مختلف پرداخته شده و در ادامه، مدل های معتبر اثرگذاری فاوا معرفی گردیده است. پس از آن ضمن مرور پژوهش های انجام شده در خصوص ارتباط این دو عرصه، یافته های آن ها تحلیل گردیده و پیامدهای فاوا بر ابعاد اصلی توسعه پایدار تشریح شده است. در این تحقیق از روش آمیخته با خط مشی اکتشافی مرحله ای استفاده شده است. برای شناسایی عوامل اصلی تحقیق از روش کیفی و انجام مصاحبه های خبرگی استفاده گردید. با به کارگیری این نتایج، مدل تحلیلی تحقیق و پرسشنامه مربوطه تهیه و اطلاعات کمی حاصل از اجرای پرسشنامه، با ابزارهای آماری مورد تحلیل قرار گرفت. برای تحلیل داده های حاصل از پرسشنامه ها و اعتبارسنجی مدل تحقیق، از نرم افزار Smart PLS و SPSS استفاده شده است. نتایج تحلیل برای کشور ایران، مبین اثرات محسوس فاوا بر بعد اجتماعی توسعه پایدار می باشد.

واژه های کلیدی: مدل سنجش، فاوا، توسعه پایدار، محیط زیست، اقتصاد، اجتماع.

1. INTRODUCTION

The world faced two unanticipated problems of the broad environmental degradation and the spread of poverty and inequality with the current rapid growth of developing countries, particularly after World War II. Since then, definitions of the development have been revised and focused on addressing these two problems.

Social, economic, and environmental problems are visible in different forms in our country. Illiteracy, poverty, unemployment, pollution, dust, and forest degradation and similar problems affected people's lives. These problems consist wider circle but in this study sustainable development is considered.

Information and Communication Technology (ICT) is one of the important branches of science and technology which can play an effective role in modulating these effects. ICT have considerable influence on most modern societies and perhaps imagination life without it is impossible in the present century.

In this study, we identified ICT models and indicators and sustainable development. Theoretical studies were performed for this purpose. Various models of ICT development and sustainable development as well as the model that showed the interaction of these two areas were investigated. Then the records and previous studies on the subject were discussed and reviewed. These studies had two critical shortcomings. First, there was not a study which takes into account all three dimensions of sustainable development. Second, studies were generally conducted at the global level or in a set of countries. There was no particular study for Iran in history and literature.

2. MATERIALS AND METHODS

Issues about economic, social, and human development and their combination with environmental development provide a new paradigm in development field; a development which emphasizes inter-generational and intra-generational equity and social justice and environmental protection. This new paradigm which is called sustainability paradigm and sustainable development has several dimensions that environmental, economic, and social aspects are considered as the most critical

dimensions. Sustainable development has many aspects which the most important ones are listed below.

Endangering the animate species, destruction of forests and pollution of air and water, quantity or amount of energy used, and the use of hazardous materials are considered as the perspective of sustainable development from environmental aspects. A system of environmental sustainability should support the vital sources, and avoid the improper use of non-renewable resources as well as functions that lead to environmental degradation.

Economic aspects are different from financial aspects. The financial aspects associated with positive financial balance sheets and the ability of an organization to human or environmental needs, however, the economic aspects are beyond the balance sheet and include items such as global poverty, the impact of the economy on trade, investment and wealth distribution, and GNP and GDP. A stable economic system must produce goods and services which prevent the imbalance of population in different economic sectors and does not damage the agricultural and industrial production.

The social dimension is related to human and includes human rights, equal access to education and health or human exploitation and abuse are related to this dimension. A stable social system need to equitable distribution of resources and social facilities including health, education, gender equality, political accountability and participation (Zahedi, 2016).

Sustainable development is a multi-faceted notion with different dimensions, has two-way interactive communication which includes spiritual development, human development, social development, cultural development, political development, and economic development. Energy resources, natural resources, vital resources are considered environmentally sustainable development resources. Social capital (including institution-building and social cohesion) and social dynamics are regarded as the social components of sustainable development. Finally, labor, capital, technology, and information which are the infrastructure of GDP can be considered as economic components of sustainable development (Zahedi, 2016).

Table 1. Sustainable development goals and their three main dimensions

Sustainable Development Goals	Environment	Economy	Social
Goal 1: Ending Poverty		✓	
Goal 2: End hunger		✓	
Goal 3: Healthy living and promotion of well-being			✓
Goal 4: High-quality education			✓
Goal 5: Gender Justice			✓
Goal 6: Access to safe water	✓		
Goal 7: Access to clean and affordable energy	✓		
Goal 8: Sustainable economic growth and decent jobs		✓	
Goal 9: Improvement of revitalized infrastructure, sustainable industrial promotion		✓	
Goal 10: Reduce inequalities within and between countries			✓
Goal 11: Comprehensive and sustainable human settlements and cities			✓
Goal 12: Sustainable patterns of production and consumption		✓	
Goal 13: Combat climate change and its effects	✓		
Goal 14: Sustainable use of oceans, seas	✓		
Goal 15: Promote ecosystems and prevent forest destruction and biodiversity.	✓		
Goal 16: Sustainable, Justice-Oriented and Peaceful Society			✓
Goal 17: Global Partnership for Sustainable Development			✓

**Fig 1.** The tripod model of sustainability

There are many patterns of sustainable development. Given the considerable differences in their appearance, almost all of them base sustainable development on the three pillars of the environment, economy, and society. In the following Some of these models are described:

1. The tripod model of sustainability in which sustainable development has been based on three pillars of society, economy, and environment.

2. The three-sphere model which based the realization of sustainability on the understanding of three dimensions of society, economy, and environment.

**Fig 2.** Three-sphere model

Environmental, social, and economic developments have always been emphasized in different models of sustainable development. However, in addition to the above dimensions, the political and some other dimensions are considered in some of them.

ICT addresses issues such as the use of electronic computers and software so that the store, process, transfer, convert, protect, and recovery of data be safely carried out. The effect of ICT in public administration (such as urban and rural development, transport), improve the quality of life (such as health, education, environment, agriculture), knowledge sharing and improve access to information, the use of ICT in business (such as manufacturing, electronic commerce, tourism, and travel industry) is apparent.

Also, topics such as health, careers, business, security, the environment, regional development, human rights, and education are affected by ICT; while in many cases, this connection can be two-way.

ICT have positive and negative effects on sustainable development. On the one hand, the sustainable development can be realized with higher efficiency and effectiveness through ICT, on the other hand, ICT also can be an obstacle to the realization of sustainable development as a product (or service) or as a tool to empower other sectors.

There are various categories of ICT development models. In one category, these models are divided into general and special models (domain), and in another category, they are divided into micro and macro-level models, and in another place, these models are divided into functional and non-functional (non-performance) models (Sharifi et al., 2015).

The conceptual model of ICT is one of the most appropriate and most comprehensive models for IT architecture and is suitable to investigate the relationship between ICT and sustainable development. Firstly, this model has good integrity and includes the principal component of sustainable development in social, economic, environmental, and policy dimensions, and secondly, it highly coordinates with sustainable development aspects.

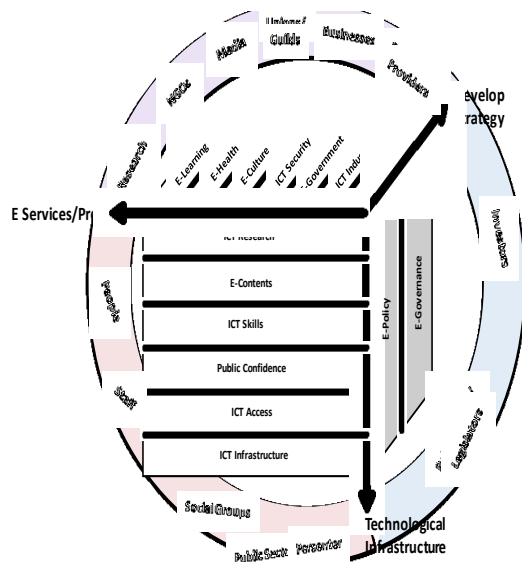


Fig 3. Conceptual model of ICT structure development

As shown in Figure 3, three-axis of development, technological infrastructure, and ICT services have been used to categorize the issues raised in this area in the three-dimensional model of the development of ICT. Technical infrastructure axis includes ICT-based research, ICT access, trust and general security, ICT skills and learning, electronic content, and infrastructure. Develop Strategy axis comprises ICT governance and policy-making and ICT coordination involved in the strategic sector. Finally, the axis of ICT services includes e-business, ICT industry, security,

government and public services, e-health, and e-learning (Sharifi et al., 2015).

The aforementioned conceptual model represents the inseparable relationship between different parts ranging from application, development strategy, and empowerment in the ICT development process.

We are aiming to investigate the effects and assess the impact of ICT on sustainable development in this study. First, we review the studies in this field, and then extract the components and dimensions in each of the concepts and investigate their relationships. Finally, we present a model for measuring these effects. This model will be useful for planning and macro decision-making in the development of ICT.

The conceptual model of ICT represents its covering on the areas including aspects and the main components of sustainable development. Therefore, it has specific effects on sustainable development (environment, economy, and society) which will be discussed below.

ICT has considerable influence on most of the modern social issues. Along with the increase of pollution caused by economic development and growth of consumption, the use of information and communication technologies in developing countries in comparison with other countries could decrease the growth of pollution and improve the quality of the environment (Azadnia & Piri, 2014).

IT reduces the need for communities to natural substances in the environment. It also reduces the amount of waste entering the environment (Houghton, 2010).

The relationship between information and communication technology and the environment is one of the complex and multi-dimensional issues. ICT can have both positive and negative effects on the stability of the environment. ICT is a powerful tool to protect the environment. The facilities which ICT provide for human communication reduce the number of natural substances in societies. It also reduces the amount of waste entering the environment. On the other hand, production and distribution of ICT devices require energy and materials, and due to their short life cycle, the amount of electronic waste entering the environment is increasing (Houghton, 2010).

About the impact of information and

communication technology on the environment, this issue can be investigated from different aspects, since examples and consequences of using this technology in various aspects of human life are apparent and can be studied. The effects of information and communication technology on the environment are divided into three separate categories

(a) First category (level one):

Consequences of environmental information and communication technology are investigated at this level which solely caused by the production and use of the equipment and tools in this field (which is called direct consequences) and is divided into two groups of positive and negative consequences. Negative consequences include those parts of environmental consequences that are obtained from the production process of ICT such as computer hardware, network cables, monitors, consequences of disposal and destruction of ICT equipment and tools, etc. Positive effects include capabilities that are obtained from production and supply of ICT products. For example, electronics indicator of pollution, electronic controls, and so on.

(b) The second category (level two):

At this level, that part of the environmental effects of ICT (such as the use of ICT in the process of production, distribution, and consumption) which influence macroeconomic sectors regarding virtualization and increasing access among economic agents is considered.

(c) The third category (third level):

This level is related to stimulation and motivation on the part of the effects of information and communication technology goes which makes the channel of higher economic growth, taking the total economy (as compared with the case where the ICT is not used) increase which is famous as the reaction and restoration effects. It is necessary to mention that the relative size of each of these effects (the three specified categories) is not equal and certainly what is posed in the form of the consequence of the use of information and communication technology in the second level is far more impressive than the other two levels (Berkhout & Hertin, 2001).

The divisions of positive and negative effects of ICT on the environment are shown in Table 2.

Table 2. Classification of positive and negative effects of ICT

	Positive effects	Negative effects
The first type of effects or direct effects	The use of ICT, such as the use of ICT for environmental monitoring and control	The environmental impacts of production and use of ICT, such as e-waste
The second type effects or indirect effects	Restructuring to the non-material	Non-complete substitution of ICT for other materials
The third type effects	Lifestyle changes such as guiding consumers towards green consumption	The reflection or return effects

Investigation of global economic developments over recent decades indicates the critical difference of these developments compared to past which most of these differences related to the revolution that has occurred in these decades. Studies indicate that information and communication technology in 1965 has allocated about 5 percent of the cost of investment of companies, this figure rose to 15% in the 1980s, and the company's information technology investment costs in the early 1990s rose to 20% and at the end of the 1990s and the threshold of the third millennium has increased to 50% of investment costs (Shiri, 2006). Information and communication technology in the economy influences both the supply side and the demand side. On the demand side through utility function influences the economic behavior of the consumer and on the supply side influences the manufacturer behavior (Moshiri & Jahangard, 2004).

Experience has shown that usually, the countries which have more accumulation of capital in the information and communication technology grow faster than countries that have less accumulation of capital in this sector (Dedrick et al., 2003).

The social dimension of sustainable development is concerned with the relationship between man and woman, excellence well-being, health and educational services, the development of different cultures, and equality and poverty eradication. Economists also explain the role of the social systems in achieving sustainable social development process to help the two principles of "human capital" and "social capital."

The foresight and responsibility towards future generations and their needs, public health, and attention to the health and quality of life, social justice, popular participation and emphasis on the sense of collectivism and transparent decision-making and education of people can be noted in the social dimension of sustainable development. The sustainable community is not only interested in quantitative and physical but also interested in qualitative development in this concept; it also focuses on the development of quality and looks for the steady process of life for the present generation and future generations.

The development of ICT in education programs is significant and lasting steps which can be followed by qualitative transformation of objectives, programs, methods, practices and thus the effectiveness of education. It is anticipated that longstanding policies and intractable problems, such as the applied education issues, focusing on the abilities and needs of learners, establishment of student-centrism rather than class-centrism and changing the role of the teacher as a guide for students, and finally authenticating lifelong learning will be achieved through the development of ICT; However, what is constituting educational thinking within this missing link and paying attention to it is essential is to focus on positive and negative application of information and communication technology in the education system.

Interactive Models of ICT

Numerous models have been proposed about the interaction of ICT and sustainable development. The three examples of the most valid ones followed.

The OECD proposed measurement Model of the Effects of Information Society in 2007. As seen in Figure 5, the effects of the information society are presented in two ways.

A series of these effects come from the demand side (users and applications) that their purpose includes government (through the development of e-government), individuals and households (through health and e-learning), and business (through e-commerce).

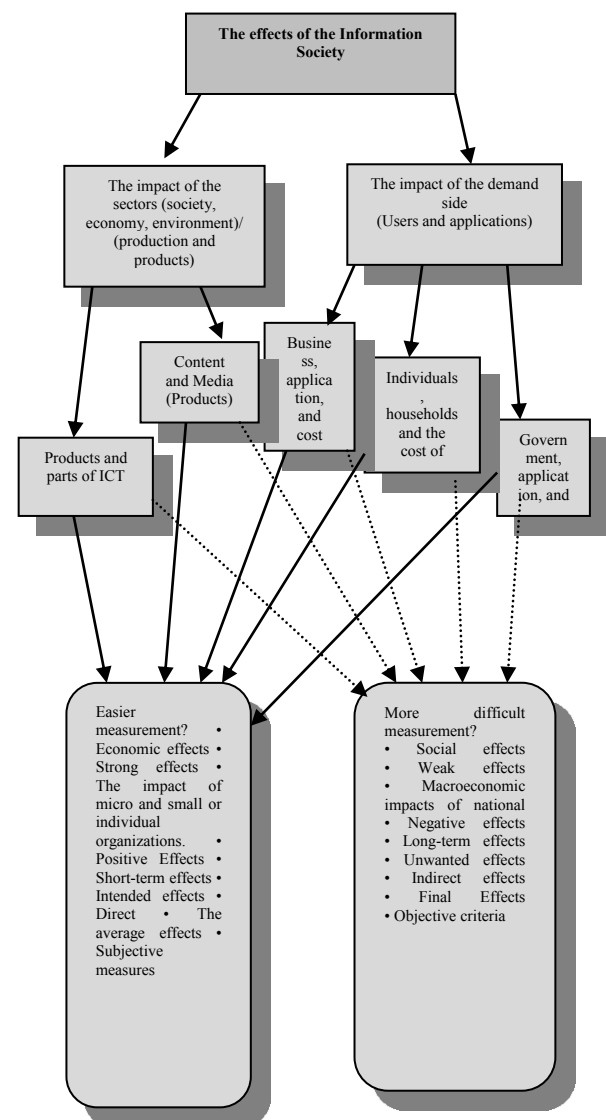


Fig 4. Measurement Model of the Effects of Information Society (UNCTAD, 2011)

The second group of these effects comes from the supply dimension (production and products) that are concerned with society, economy, and environment. The content includes media and products which are produced in different parts of Information Communication Technology.

The next model that has been developed by UNCTAD (Figure 6) shows the relationship between the effects of ICT. In this model, the positive and negative aspects of impacts of ICT which is created through supply and demand of ICT have been shown.

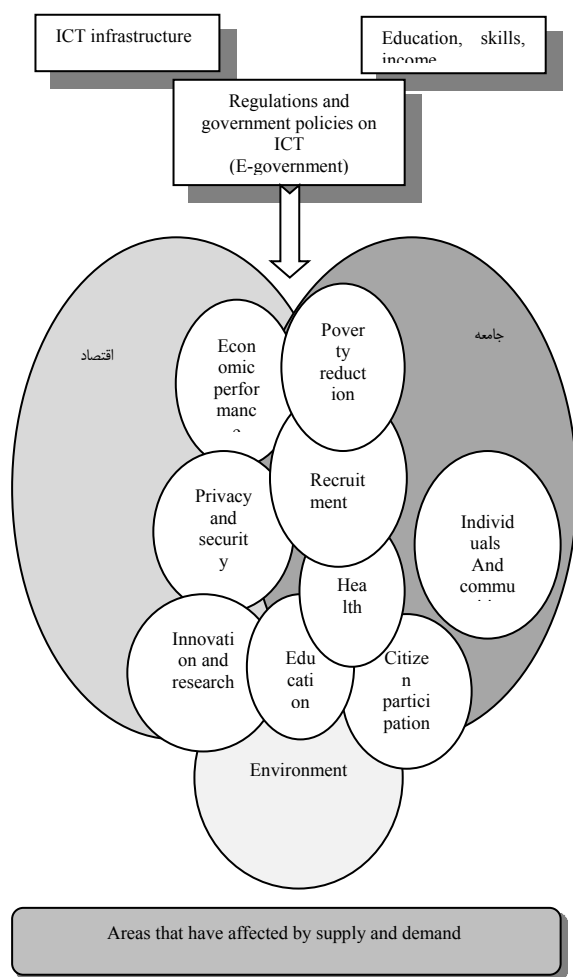


Fig 5. UNCTAD Model (UNCTAD, 2011)

This model suggests that the effects of ICT in the fields of economy, society, and the environment show themselves. These effects are formed for ICT through supply and demand and are influenced by the following factors:

- Available ICT infrastructures
- The level of education, skills, income
- Regulations and government policies on ICT and e-government development

Another model proposed by the OECD was consistent with the two previous models and is a complement to them. In the preceding models, the environment has attracted less attention. The recent model like the two preceding models separates the effects of ICT on both the supply (goods, services) and demand (users and applications), and infrastructure, content, and media are of the mediating influence.

This model indicates that supply and demand of IT affect the environment each way. That is, we have the combination of the effects of ICT supply and demand of ICT on the environment. On the other hand, there are a series of indirect

effects of ICT on environmental which can be reviewed and discussed.

Some effects of ICT on the environment include:

1. The impact of ICT supply on the environment
2. Much of these effects are due to the supply of ICT products such as computer and its auxiliary equipment, telecommunications equipment, consumer electronics products and accessories of ICT, construction of ICT equipment services, commercial software, consulting ICT services, telecommunication services, and telecommunication leased lines and the other ICT services, etc.
- 3.

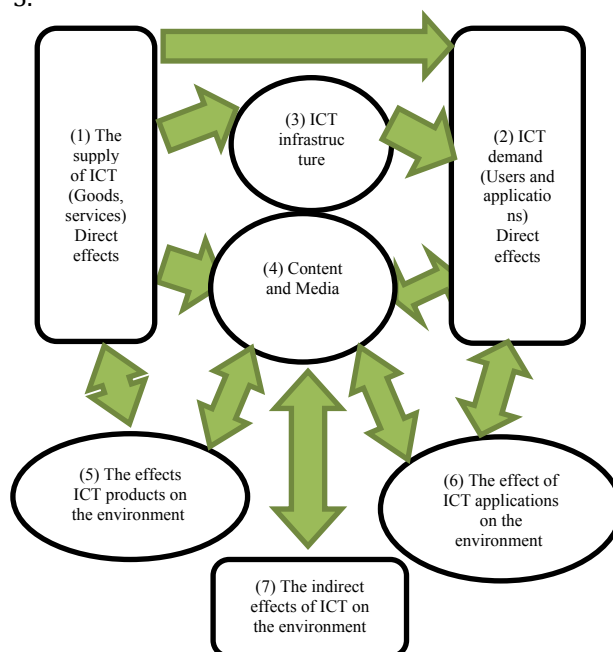


Fig 6. Conceptual model of the effects of ICT In the environment (OECD, 2009)

2. The impact of ICT demand on the environment

Some of these effects are:

(a) The effects of the use of ICT in improving environmental outcomes such as efficiency, monitoring, modeling, managing, and publishing

(b) The effects of the use of ICT which is leading to environmental damages such as energy consumption, pollution caused by the destruction of outdated equipment

3. Indirect impacts of ICT on the environment

Promotion and development of knowledge through facilities created by ICT (content and media) are of the indirect effects of ICT on the environment.

A Review Of Conducted Studies

There are different views to investigate and summarize the conducted studies. One method is to investigate the studies based on the date they have carried out that has its advantages. This method allows us to study the evolution and development of the topic. The next view is to divide the conducted studies into internal and external. The comparison of internal and external investigations will be easier in this method. The third method was to classify studies based on the themes, and its benefits are the ability to focus on different areas of research. In this study, according to the breadth of topics of ICT and sustainable development, the consolidated view with a focus on issues was selected. That is, in the first place studies were divided into the three dimensions of the effect of information and communication technology on economic growth, the impact of economic growth on the quality of the environment, and information and communication technology on the environment and in the second place with regard to the chronological order in each group of domestic studies and foreign studies will be considered separately.

The First group: In this group of reviews the effect of information and communication technology on economic growth has been investigated

Some foreign studies conducted in this group are:

Oliner and Sichel investigate the qualitative and quantitative research on the role of information and communication technology in economic growth in developing and developed countries and suggest that there is a strong positive relationship between information and communication technology ICT and economic growth in developed countries. The use of ICT has led to changes in labor composition in favor of skilled workers who are fluent in information and communication technology skills (Oliner & Sichel, 2000).

Nour in his study which is conducted in Egypt and other Arabic countries of the Persian Gulf argues that ICT in most cases has a positive correlation with economic growth, that is, economic growth increases by increasing investment in ICT and increasing the use and

application of it (Satti & Nour, 2002).

Dewan and Kraemer investigate the effect of ICT capital in developing and developed countries in their study and conclude that ICT investment yields are positive and significant in developed countries and is not substantial in developing countries (Dewan & Kraemer, 2000).

Lee and Khateri have investigated the effect of ICT on economic growth in Southeast Asia in their study. They conclude that the impact of ICT on economic growth started from capital deepening of the ICT sector in the 1990s and capital deepening of the ICT sector plays a significant role in improving labor productivity in studied countries in the second half of the twentieth century (Lee & Khateri, 2003).

Dewan and Kraemer by using the data from 36 countries during the period 1982-3 in both developed and developing countries estimate the effect of information and communication technology on economic growth. This estimation shows that the elasticity of information technology in developing countries equals the negative of 0.012 and 0.057 in developed countries (Dewan & Kraemer, 2000).

Papaioannou has investigated the effects of ICT on economic growth in developing and developed countries for the period 1993-2001 in his study and find an insignificant positive relationship between the impact of information and communication technology on economic growth and productivity for all countries under review (Papaioannou, 2004).

Oulton and Srinivasan through using new data sets in the industry level to quantify the role of information and communication technology in the productivity growth in the UK during the years 1970-2000 for 34 industries came to the conclusion that it is essential to invest in ICT and its role in economic growth is increasingly enhanced (Oulton & Srinivasan, 2005).

Ketteni through study the relationship of information and communication technology on productivity and economic growth has shown that the total investment in information and communication technology has a nonlinear effect on growth factor total productivity (Ketteni, 2012).

Mouelhi, with the aim of measuring the effect of ICT on total productivity of production of

some companies in Tunisia in a simple theoretical framework, has studied and investigated the relationship between these two categories through using data panel and approved a positive relationship between them (Mouelhi, 2009).

Lee and Khateri have investigated the effect of ICT on economic growth in Southeast Asian countries. The studies of these two show that the assistance of information and communication technology to economic growth has begun since the 1990s (Lee & Khateri, 2003).

In these countries in recent years, costs are high in the field of software development, and the increase of costs of information and communication technology in these countries has helped to control the East Asian crisis in the 1990s. High growth in demand for the electronic industry in the 1990s is mentioned as the essential factor in this regard. The results of this study show that in the second half of 1990, capital deepening played a crucial role in improving labor productivity in Asian countries. Although in the first half of 1990s capital deepening in information and communication has assisted labor productivity which has been more significant in several countries such as Hong Kong, Singapore, and South Korea. But these contributions were higher in the second half of the 1990s and led to the acceleration of investment in communication and information technology. However, high levels of cost of communication and information technology were reduced due to the crisis in East Asia in this period. During the above periods, regarding capital deepening due to the high-income share of communication and information technology Hong Kong, Korea, and Singapore gained more interest. In the Philippines in the second half of the 1990s the communications and information technology makes more capital deepening and help to economic growth and makes that economic growth does not change or in other words, at least creates the lowest effect of the East Asian crisis in this period.

According to the study of Nour, in the case of Egypt and some Persian Gulf Arab countries cost of information and communication technology in most cases has a positive correlation with economic growth (GDP). Nour in his study in Egypt and 16 Persian Gulf Arab countries states that the effect of the cost of

information and communications technology in economic development in Egypt and the Arab countries of the Persian Gulf, in most cases, correlates with the economic growth of GDP. However, their econometric studies which have investigated the expenditure of information and communication technology in the GDP of these countries in the period 1996-2001 show that the significant effect of information and communications technology on economic growth in Egypt and Persian Gulf Arab countries is obscure and suspicious. In general, information and communications technology in these countries have the positive effect; however, its significance is unknown and suspicious (Satti & Nour, 2002).

Arani and Aghei Khoundaei examined the effect of information technology on economic growth in APEC member economies. Through using the Cobb-Douglas Production Function and concerning the variable of information and communication technology and Data Panel, they concluded that a strong and significant relationship between information and communication technology and economic growth has existed in this country since 2004 (Arani & Aghei Khoundaei, 2008).

In Iran, some investigations have been done in this area. In part of the studies, the effect of the Internet on the export of the selected countries was investigated. Some other studies have investigated the impact of ICT on employment in the service sector in Iran, and other groups have tried to estimate the share of ICT on economic growth in different intervals.

Najarzadeh, Aghaei Khoundaei, and Talati have investigated the effect of information and communication on economic growth of Organization of Islamic Cooperation (OIC) countries. They made use of investment data and information and communication technology in the period 1996-2004 and analyzed using data panel method. The result indicated that there is a strong and significant relationship between economic growth and information and communication technology in these countries (Najarzadeh et al., 2007).

Asgharpour, Mohammad Zadeh, and Jalilpour have investigated the effect of the development indices on adoption of information and communication technology in selected Asian countries. Their results showed that geographical and regional differences along with some of the indicators of development

could to a large extent explain the differences in the use of information and communication technology in the countries studied (Asgharpour et al., 2007).

Moshiri and Jahangard have investigated the effects of ICT on growth and productivity of Iran economy. The results indicate the existence of a positive but insignificant and weak relationship between economic growth and information and communication technology in Iran by 1380. (Moshiri & Jahangard, 2004)

Faghih Nasiri and Goudarzi investigated the effects of information and communication technology on economic growth of 37 developed countries in their study, the results of this study showed that the cost of information and communication technology is of great importance in the economic growth of the country (Faghih Nasiri & Goudarzi, 2005).

The results of a study show that information and communication technology on economic growth in the countries surveyed (selected developing) has a significant positive effect. In other words, greater use of information and communication technology in the production process increases the economic growth in the countries surveyed including Iran (Jafari Samimi, 2013).

According to the research mentioned above and numerous opinions offered by scholars, it seems ICT is of great importance in the economic growth of these countries in developing countries, but there is no strong and lasting relationship between information and communication technology and economic growth in developing countries.

The second group: In the second group the effect of economic growth on the quality of the environment is studied. Some of the studies in this area include:

In Iran, the research has been conducted about the effects of economic growth on the environment which the first study in this field of Pajoyan and Moradhasel entitled investigating the impact of economic growth on air pollution in the form of environmental curves of Kuznets for 67 countries (Pajoyan & Moradhasel, 2007). However, other work has been done in this field after this study. For example Pour Kazemi and Ebrahimi investigated the relationship between income and the release of sulfur dioxide for Middle

Eastern countries over the period 1980 to 2003 in a study (Ebrahimi, 2008) and in another study Asgharpour and Mousavi investigated the relationship between air pollution and economic growth (testing environmental hypothesis of Kuznets) in 16 selected developed and developing countries including Iran (Asgharpour & Mousavi, 2009).

The Third group: The third group of studies includes the studies in which the effect of information and communication technology on the environment is studied. Among foreign studies carried out on this group, the following can be cited:

Plepys in his research investigates the effects of information and communication on the environment with a negative attitude. This means that if the management of production process and disposal of ICT hardware products is not done carefully, it can have serious environmental consequences. In a way that in some cases, it affects positive impacts (Plepys, 2002).

Reviews the studies carried out in the field of effects of information and communication technology, and e-business on the environment investigated all available studies including articles, research projects, dissertations, etc. They claim that both the case studies have been done on the micro level and reviews on the macro level and in the form of a statistical approach have been done, yet full convergence on the apparent effect of ICT on the process of sustainable environmental is not met.

A specific study to assess the effect of information and communication technology on the quality of the environment is not observed within the country. A review of studies on the use of ICT is still impossible to express a judgment on the sustainability of the environment and conducting new studies, and new methods are also needed.

In the comparison of the relative effects of the function of information and communication technology in two groups of countries, it can be seen that the positive impact of information and communication technology on (reducing) the quality of the environment in developing countries (Asian) is negligible. However, this effect in developed countries has emerged as significant and positive which is remarkable. This can be due to the institutionalization and

maturity of information and communication technology in developed countries.

Studies conducted on the effect of ICT on aspects of sustainable development show that the impact of ICT in this regard has not been the same for all countries. In general, it can be concluded that about the developed environmental countries, weaker effects have been observed. However, different results are obtained for developing countries, as there have been considerable effects on the social dimension and less effective or suspected economic dimensions have been reported and no positive impact on the environment.

Iran is now among developing countries. According to studies which have been reviewed, it can be predicted that the model presented in this study shows the effects of ICT on the development of social sustainability indicators with the highest value. Second, economic indexes have been influenced, and finally, the least impact was shown on environmental sustainability indexes.

3. METHODS

Different stages have been considered in the present study, the type of the research (based on the classifications listed) will be different at each step. In short, the kind of research in different phases of research considering three axes is shown in table 3.

As mentioned, a mixed strategy was used to conduct this study. In other words, two studies were conducted to investigate research questions, one with the quantitative approach and the other with the qualitative approach. In general, the heuristics methods were used for exploration, the library method for background information and research literature. Qualitative methods used to identify the main factors regarding population and quantitative methods were used to measure the main factors to reach the final model.

The integrated policy used in this study is called "exploratory stage." This policy has two stages. The collection and analysis of data qualitative are done in the first step of this policy and relying on early quantitative the collection and analysis of quantitative data is done (Creswell, 2016).

Table 3. Status of current research

The classification	First stage Qualitative analysis of model	Second stage Quantitative Analysis of model
The aim of the study	Heuristic	Explanatory
The result of the research	Fundamental	Applied
The data of the study	Qualitative	Quantitative

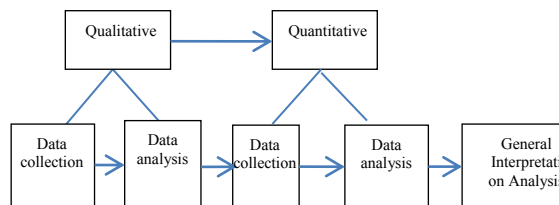


Fig 7. The chart of exploratory stage policy

The population has consisted of 12 scientific and professional experts in qualitative section. Researchers have selected them through consultation with supervisor and advisor. Of course, some of them have been introduced by the respondents (snowball sampling). Scientific experts including university professors in the fields of sustainable development and ICT and professional experts were selected from industrial managers related to ICT and sustainable development. It includes administrators, professors, faculty members and experts of Environmental Protection, Institute of Environment and Sustainable Development, Faculty of Environment at Tehran University, Allameh Tabatabaei University, Faculty of Economics at Tehran University, Faculty of Electrical Engineering at Khajeh Nasir University, Ministry of Communications and Information Technology, Communication Research Center of Iran, and professors and experts from universities and research centers related to these two areas in the country. The population in the quantitative section is comprised of 73 experts from the center as mentioned earlier in the qualitative section.

According to theoretical studies, expert consulting and interviews, seven indicators for ICT and eight indicators for sustainable development were extracted. 56 questions are needed to investigate the effect of each indicator of ICT on each of the indicators of sustainability. The questionnaire was designed on this basis. 10 sample designed

questionnaires were distributed among selected individuals, and the necessary revisions have been done according to their feedbacks then reproduced and distributed to the population.

According to the investigation of the model presented in Fig. 5, 6 and seven from section 2.6 and summarizing the considerations taken into account in the following results were obtained regarding the effect of ICT on sustainable development.

1. Two main aspects of supply and demand have been considered to develop ICT.

2. The supply of ICT is based on three components of infrastructure (including hardware products and ICT), media (including tools and information exchange systems), and content (including text, audio, image, and video).

3. The demand for services is mainly seen in the fields of education, business, health, and government services. Therefore, the components of e-learning, e-health, and e-government can be considered for it.

4. The main aspects of sustainable development include environment, economy, and society. Several factors are taken into account for sustainable development. Eight universal leading indicators are among them that favorably cover three mentioned dimensions.

The statistical population of this research is a qualitative group of experts and experts in the field of science and technology and the references introduced by them. The scientific experts include university professors in the fields of sustainable development and ICT and have been selected by professional experts from ICT industry and sustainable development managers.

Qualitative section: Identification of the primary research elements was carried out through an in-depth interview. The number of samples in this section increased so that all the factors were identified. Accordingly, the number of samples increased proportionally to the sample size needed to reach saturation in the sample, with 14 specialized interviews.

Quantitative section: After completing the survey, a total of 103 experts and qualified experts were identified. The completed questionnaire consists of 50 questions, which is related to 10 model structures. The answers to each question are chosen from a seven-level

Likert Scale. This questionnaire was sent to the statistical community for print samples or online for selected samples. 82 questions were completed and returned wholly and entirely. Twelve questions were returned and nine questions.

Sampling method in the qualitative section of research was preferred or targeted sampling. This means that some scientific experts and professional experts judged by the researcher were chosen as the sample and interviewed with them. The interview process continued with the introduction of someone from one person to another, where the same issues were mentioned, and repeated material was raised. The number of samples was proportional to the sample size required to reach saturation in the sample. The sampling method was quantitative realization through questionnaires and categorized. Sample classes include organizations and relevant scientific and technical centers such as the Environmental Protection Agency, the Ministry of Communications and Information Technology, and the professors and experts of universities and research centers related to the two areas of the country through their headquarters in Tehran.

In mixed research strategies, the words "validity" or "quality of inference" are usually referred to as the amount of validity of the data and the results derived from them. In these methods, researchers collect and analyze both forms of qualitative and quantitative data.

For gradual assurance of validity and reliability during the qualitative research process, a mechanism called "research audit" is used. These mechanisms are injected at each stage of the research, by identifying and correcting the errors before influencing the pattern and, before analyzing, distorting some valid research findings. Therefore, in the content analysis stage, using the experts' opinions, we try to ensure that the quality of the content analysis is implemented and experts verify its credibility. In the quantitative part, the content validity of the questionnaire is measured by a survey of experts who have knowledge and experience in this field of research. Thus, the content validity of the research questionnaire is confirmed by providing it to the experts and receiving their corrective comments. Meanwhile, with the confirmatory factor analysis done for the

questionnaire, structural validity is also extracted.

Reliability in the qualitative section:

To know the reliability, the in-area agreement was used in the qualitative section. Reliability in content analysis is a crucial concept. Calculating the reliability of the performed coding was done as follows:

$$\text{Sustainability} = \frac{2M}{N_1 + N_2}$$

In the above formula, M is the number of similar cases encoded between two encoders that There was an agreement between them and N1 and N2 are respectively the total numbers of encoded cases encoded by the first and second encoders.

In the above formula, M is the number of similar cases encoded between two encoders that There was an agreement between them and N1 and N2 are respectively the total numbers of encoded cases encoded by the first and second encoders (Beyabangard, 2003).

In the quantitative section, Cronbach's alpha method was used to calculate the reliability of the research tool. The range of reliability is from zero (non-communication) to +1 (full contact). The reliability coefficient indicates how much the instrument measures the stable characteristics of the subject or its variable and temporary characteristics.

Table 4. Total reliability of the questionnaire

Cronbach's alpha	The number of final questions
0.873	50

The reliability of each dimension is separate as follows:

As it can be seen, all variables with the reliability of above 0.71 are therefore required for reliability.

For quantitative analysis, descriptive statistics such as concentration and dispersion indices (mean, standard deviation, frequency, and percentage by the factor) and inferential statistical methods such as mean tests of correlation tests and confirmatory factor analysis methods are used. SPSS and SmartPLS software are used for descriptive and inferential statistical methods.

By the results of library studies and collecting

data from organizations, universities, specialist interviews, the main indicators of ICT development and sustainable development to establish the conceptual model of research were extracted. In this model, the three dimensions of sustainable development include the economy, community and environment and the seven dimensions of ICT development including products, media, content, government, trade, health and e-learning were illustrated. Considering the nature of 17 goals of Sustainable Development, they can be categorized into three environmental, economic and social groups that are the main dimensions of sustainable development.

Table 1, shows the seventeen goals of sustainable development. They are differentiated according to the three main dimensions of sustainable development (Javaheryan, 2016).

4. RESEARCH FINDINGS

In this section, research findings will be analyzed in two qualitative and quantitative sections. Given that the present research is an interdisciplinary research and requires the compilation of qualitative and quantitative data in the fields of ICT and sustainable development, which consists of different parts of the environment, economy, and society. The statistical community was selected to have the coverage and credibility required for the areas mentioned.

To collect qualitative data, in addition to the documents reviewed in the field of theoretical studies and secondary sources, many expert interviews with experts in various research centers and universities were have done.

A. Open Coding: To extract the factors influencing the research, all interviews were first implemented separately and all the statements and sentences related to ICT and sustainable development were reviewed, and coding was done. At that stage, 205 codes were identified.

B. Concept coding: At this stage, all the open codes obtained from the first stage (open coding) were based on the relationship between the central concepts were put together. The similar corresponding was put together, and according to qualitative studies, 57 concepts were identified.

Table 5. ICT Development Dimensions

Products	Content	Media	E-government	E-commerce	E-health
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Table 6. Sustainable Development Dimensions

Environment	Economy	Society
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A. Selection (Category) coding: At the last stage of coding, the conceptual codes of the previous step (Concept coding) were grouped. The 57 identified concepts were classified into ten categories in the last stage. Table 5 and table 6 show the summarized results of the above codes.

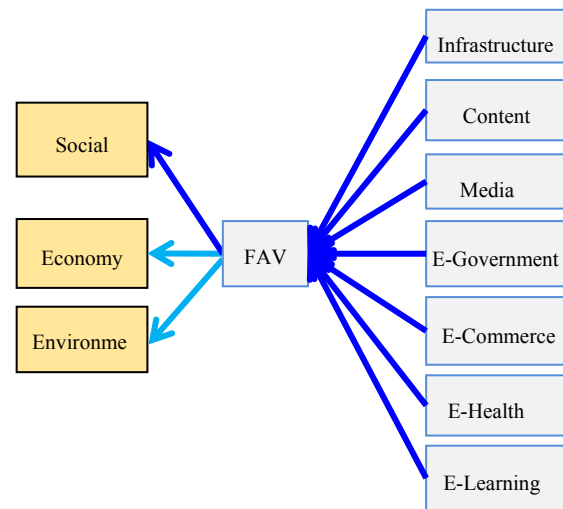
Dimensions of sustainable development were limited to the environment, economics, and society, and for IT infrastructure, content, media, e-government, e-business, e-health, and e-learning were identified as the pillars of ICT development. The indicators of each of the above dimensions were determined according to theoretical studies and qualitative interviews conducted.

Considering the results, the analytical model of the research was proposed as follows.

In this stage of research to verify the analytical model of the study three following hypotheses were considered:

1. ICT development has a positive and significant impact on the social dimension of sustainable development
2. ICT development has a positive and significant impact on the economic dimension of sustainable development
3. ICT development has a positive and significant impact on the environmental dimension of sustainable development

In this study, to avoid the limitations of the covariance-based approach to distributed properties, the type of variables (reflective and developmental component) the based on (PLS) is approach is used. Also, because of the hierarchical nature of the understudy model, it is also consistent with the characteristics of the component-based approach (Fornell & Bookstein, 1982).

**Fig 8.** Analytical model of the research

PLS models are evaluated and interpreted in two stages: a) Validity and reliability evaluation of models; b) Structural model evaluation (Tenenhaus, 2008).

The reliability of the measuring instrument is measured in two parts, one of them is reliability relation of each reflector and the corresponding structure, which is indicated by the load value, and the other is the composite stability of all reflective references with the corresponding structure which is used to determine the internal correlation of the measuring instrument. The appropriate stability value for each reagent with its corresponding structure is at least 0.7 (Azar et al., 2011).

If the removal of a reagent leads to an increase in convergent validity and composite reliability higher than the proposed threshold (0.7 and 0.5, respectively), they should be removed. Otherwise, these reagents remain in the model. According to the results of statistical analysis, composite reliability and convergent validity of these variables are more than 0.7 and 0.5, respectively. Therefore, they remain in the model.

The significance test of path coefficients of the structural model and the coefficient of determination indicates that all of them are statistically significant and their effect is confirmed. This means that the change in any of these dimensions could lead to a change in the development of ICT and sustainable development.

As shown in table 7, the reliability of the reagents and the composite stability of the model is more than the proposed thresholds, so the reliability of the measuring instrument is confirmed.

About the above table, the average of the variance of the extracted variables is more than 0.5, so the convergent validity of the model is verified.

Table 8 shows the average variance extracted.

Table 7. Reliability of the dimensions of the variables

Reliability of the dimensions of the variables	Variable	Total reliability
0.848	ICT development	0.873
0.737	Social Development	
0.740	Economic Development	
0.894	Development of the environment	

Table 8. The test results of the research hypotheses

The amount of confirmed effect	Accept/Disapprove Hypothesis	Probable value T	Effect level	Hypotheses	Hypo.
0.29	Accepted	1.73	0.29	ICT development has a positive and significant impact on the social dimension of sustainable development.	1
----	Failed	0.80	0.19	ICT development has a positive and significant impact on the economic dimension of sustainable development.	2
----	Failed	0.73	0.14	ICT development has a positive and significant impact on the environmental dimension of sustainable development.	3

The results of the quantitative analysis are:

- Considering the results of quantitative analysis about the coefficients of the model's path, among the dimensions of ICT development, respectively, the content dimension and e-government have the most impact on ICT development, but electronic health has the least effect. Among the dimensions of sustainable development, the economy is the most critical aspect.

- According to the quantitative analysis results, in relation to the significance of the structural coefficient of the model, in examining the probable value with respect to statistical T, that is greater than 1.64, we can say that all relations between the three dimensions with the sustainable development is verified and all three dimensions can be used in various analyzes for hypotheses test. Also, among the mentioned dimensions, social and economic dimensions most closely related to their main variable.
- Regarding the result of the quantitative analysis, in relation to the significant structural coefficient of the model, in examining the probable value with respect to statistical T is higher than 1.64, it can be said that all relations between the seven dimensions of ICT It is meaningful, and all 7 dimensions can be used in different analyzes. Also, the two aspects of content and e-commerce have the most significant relationship with their main variables, i.e., of ICT.
- Due to the quantitative analysis results, it can be concluded that the path coefficient between the two primary variables is 0.33. This indicates that ICT development has a positive effect on sustainable development.
- Given the calculated value of statistical T, it can be concluded that the effect of ICT on sustainable development is not statistically significant.

According to the results of quantitative analysis, we conclude that ICT development has the most significant impact on society, then on the economy and it has the lowest impact on the environment.

5. FINAL MODEL

Given the results of the qualitative and quantitative section, statistical analysis and test hypotheses, the final model of research is presented in Figure 9.

The path coefficient of each construct that exhibits its effectiveness in the corresponding variable or structure is shown in this Figure. Apart from the two dashed line, other routes have been verified. According to the path coefficients, more media dimensions have a role and impact in developing ICT in Iran. The path factor is the social development dimension

of the sustainable development of 0.29% and suggests that for each 1% development of ICT the development of sustainable social development. Concerning theoretical studies and that Iran is among developing countries, the results of research and statistical analysis show that the development of ICT in Iran has a similar situation with the countries as mentioned earlier.

6. RESEARCH LIMITATIONS

Each research is usually confronted with limitations due to its characteristics. These constraints slow the research procedure and decrease its accuracy, and in some cases, it leads to the failure to implement and stop the research. This research is not an exception and has been confronted with some limitations. Some of these limitations are explained in fig. 9.

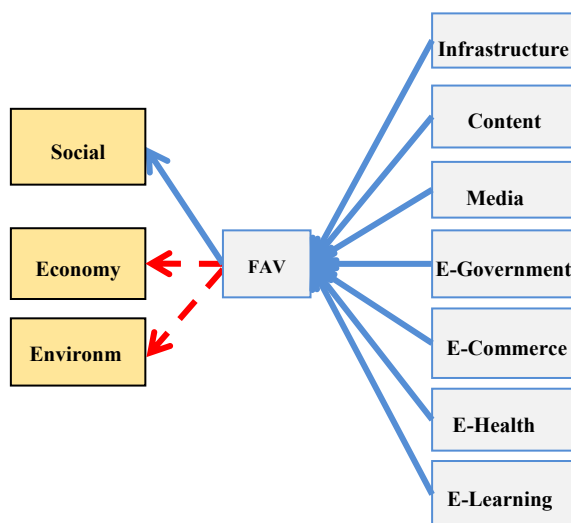


Fig 9. Final Model of research

The scope of the research area

Since the statistical society of the research is very extensive and includes diverse and scattered sections, access to all parts of it is difficult, and it was one of the primary constraints of the research.

The interdisciplinary nature of the research and the limited number of leading experts in all areas of the research was the other main constraint.

For expert interviews and responding to questionnaires, the need to refer people to all areas of research is critical. These domains

include at least the various dimensions of ICT and sustainable development.

Therefore, in this research, the ultimate effort was made to reach these people. Despite significant successes, there are undoubtedly other people who cannot be interviewed with them.

The multiplicity of indices required for model analysis

As we saw in the theoretical section and specialized interviews, a large number of indicators were presented in the field of research. In this research, as far as practically possible, we were able to extract and analyze these indices. Naturally, in such study, if more funds were available, sufficient time, and a complete research group could be used, further indicators would increase the accuracy and coverage of the research.

Honestly answer some of the contacts to some questions in the questionnaire

By reviewing the received questionnaires, some respondents considered some questions about social and economic justice in Iranian society and did not have the necessary honesty. This has led to a high degree of variance in response to a small number of questions.

7. FUTURE STUDIES

Considering the existence of several indicators in the areas of sustainable development and ICT, the inclusion of more detailed indicators in the analysis can lead to more accurate results. Therefore, it is suggested that this research is done with more detailed indicators and other dimensions of these two domains.

This research has been done using qualitative and quantitative methods with the data obtained from the questionnaire. It is suggested that this research is repeated with the use of experimental data. If you have access to experimental data, the result will be more accurate.

Considering the difference in the impact of ICT on promoting sustainable development and its dimensions in developed and developing countries, studies will be beneficial for the pathology of this issue and its causes, and its results can be used in the program. The future

and future policies in these two areas will be for our country, Iran.

8. DISCUSSION AND CONCLUSION

The results of the statistical analysis obtained from this study indicate that Iranian conditions are also the same as the conditions of other Middle East countries. Studies related to the impact of ICT on sustainable development dimensions showed that these effects were not as the same for all countries. It is generally

possible to conclude that it is positive for developed countries to promote sustainable development goals in all three main dimensions (economy, social and in the environment. But there are different results for developing countries including Iran. These results show High positive effects on the social dimension, a low positive impact on economy dimension but have not been reported a positive impact on the environment.

REFERENCES

- Asari Arani A. and Aghaekhondae, M. (2008). The impact of ICT on economic growth in OPEC. *Journal of Economic Research*, 8(2), 63-82.
- Asgharpour H, M.P., Jalil Poor S. (2007). The Effect of ICT on economic growth in member countries of the Organization of Islamic Conference (OIC). *Journal of Business Research*, 12(3), 22-51.
- Asgharpour H. and Mousavi, S. (2009). Testing Environmental Kuznets hypothesis: Use of Consolidated Collective technic. *Journal of Economic Science*, 3, 1-20.
- Azadnia M. and Piri, M. (2014). Providing a model for measuring the impact of ICT on the environment, in International Conference on Development and Business Excellence, 6-7.
- Azar, A., Gholamzadeh, R., Ghanavati, M.(2011) Route-Structural Modeling in Management. Tehran: Negahe Danesh Publication.
- Berkhout, F. and Hertin, J. (2001). Impacts of information and communication technologies on environmental sustainability: Speculations and evidence. Report to the OECD, Brighton, 21.
- Beybangrad, I. (2003). Research Methods in Psychology and Educational Sciences, Tehran. Iran: Payame Noor University.
- Creswell, J. W. and Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approach. California: Sage publications.
- Dedrick, J., Gurbaxani, V. and Kraemer, K. L. (2003). Information technology and economic performance: A critical review of the empirical evidence. *ACM Computing Surveys (CSUR)*, 35(1), 1-28.
- Dewan, S. and Kraemer, K. L. (2000). Information technology and productivity: Evidence from country-level data. *Management Science*, 46(4), 548-562.
- Faghih Nasiri, M. and Goudarzi, A. (2005). Investigating the effects of ICT and economic growth in selected countries panel data method. *Modern Economics and Business Journal*, 8(11), 73-94.
- Fornell, C. and Bookstein, F. L. (1982). Two structural equation models: LISREL and PLS applied to consumer exit-voice theory. *Journal of Marketing research*, 19(4), 440-452.
- Houghton, J. (2010). ICTs and the environment in developing countries: Opportunities and developments. The development dimension ICTs for development improving policy coherence: improving policy coherence, 149.
- Jafari Samimi, A. and Chehrghani, A. (2013). Ethical economy and history of economic thought. Nouralm Publication, Hamedan, 200.
- Javaherian, Z., Fatehvahdati, A., Rahmati, A. and Zamani, L. (2006). Sustainable Development Goals, Tehran: Hakk Publication.
- Lee, M. and Khatri, M. Y. (2003). Information technology and productivity growth in Asia, *International Monetary Fund*, 3(15), 1-16.
- Mamuneas, T. and Ketteni, E. (2012). Growth Accounting: A European Comparison. *Cyprus Economic Policy Review*, 6(2), 67-79.
- Moshiri, S. and Jahangard, S. (2004). Information and Communication technology

- and economic growth of Iran. *Iranian Journal of Economic Research*, 17(22), 255-276.
- Mouelhi, R. B. A. (2009). Impact of the adoption of information and communication technologies on firm efficiency in the Tunisian manufacturing sector. *Economic Modelling*, 26(5), 961-967.
- Najarzadeh, R. & Tal'ati M. (2007). The effects of ICT on economic growth in member countries of the Organization of Islamic Conference (OIC). *Journal of Business Research*, 11(44), 49-78.
- Oliner, S. and Sichel, D. E. (2000). The resurgence of growth in the late 1990s: is information technology the story?. *Journal of economic perspectives*, 14(4), 3-22.
- Organisation for Economic Co-operation and Development. (2009). Measuring the Relationship between ICT and the Environment, OECD, 9.
- Oulton, N. and Srinivasan, S. (2005). Productivity growth and the role of ICT in the United Kingdom: an industry view, 1970-2000. Centre for Economic Performance, London School of Economics and Political Science.
- Pajoyan, J. and Morad, H. N. (2007). Effect of Economic Growth on Air Pollution. *Economic Researches Journal*, 4, 141-160.
- Papaioannou, S. K. (2004). FDI and ICT Innovation Effect on productivity growth: A Comparison between developing and developed countries. Athens University of Economics and Business, Athens, Greece.
- Plepys, A. (2002). The grey side of ICT. *Environmental Impact Assessment Review*, 22(5), 509-523.
- Pourkazemi, M. and Ebrahimi, I. (2008) Examining Environmental Kuznets Curve in the Middle East. *Quarterly Journal of Economic Research*, 10 (34), 57-71.
- Satti, S. and Nour, S. (2002). The Impact of ICT on Economic Development in the Arab World: A comparative study of Egypt and the Gulf countries. *Economic Research Forum*, Working Papers 0237, revised 05 Dec 2002.
- Sharifi, A., Ghavamifar, A. and Fasanqari, M. (2014). Design and development of IT-based architecture. Tehran: Paeiz Publications, P.508.
- Shiri, B. (2006). ICT Strategy and Economic Development. *Tadbir*, 17(172) 31-34.
- Tenenhaus, M. (2008). Component-based structural equation modeling. *Total quality management*, 19(7-8), 871-886.
- United Nations Conference on Trade and Development (UNCTAD). (2011). Measuring the Impacts of Information and Communication Technology for Development, United Nations, 3-5
- Zahedi, S. (2012). Sustainable Development. Tehran: SAMT Publications, P.255.