Interpretive Structural Modeling in the Adoption of IoT Services

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Abstract

This study aims to use ISM to identify the enablers affecting the acceptance of IoT services. For this purpose, this study conducted an ISM analysis and a MICMAC analysis, extracted the enablers from Internet of Things - An Action Plan for Europe published by the EU for the research, and conducted interviews and surveys. The study found that it would be preferentially necessary to prepare the base for successful IoT services through international cooperation and the security of objective data. In addition, it turned out that it would be necessary to make efforts to spread and develop IoT services by conducting R&D and implementing projects through public-private partnerships and the organization of a consultative group. Lastly, since information security and standardization are the desired objects of the IoT industry, it was found that both the government and the industrial world should focus on them. This study has significance in that it can provide practical implications for the effective acceptance of IoT services.

Keywords: Internet of Thing, Interpretive Structural Modeling, MICMAC analysis

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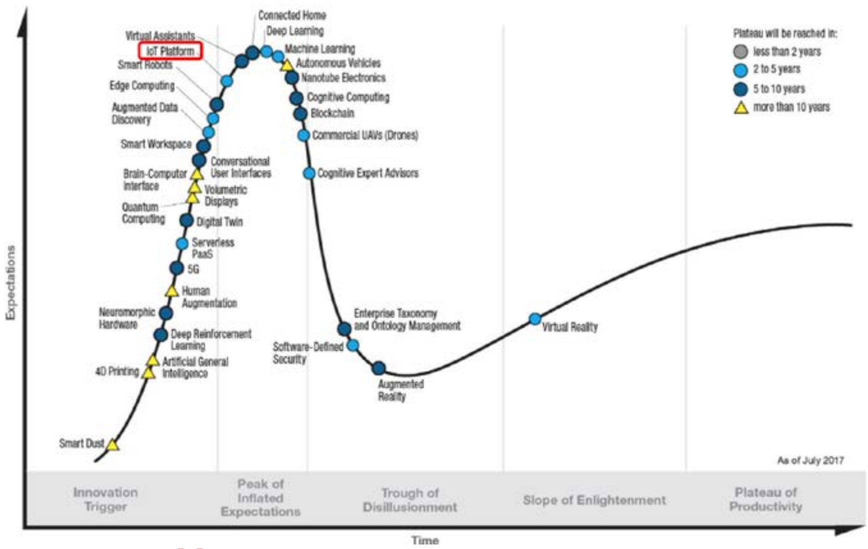
1. Introduction

From the past to the present, a new breed of innovation leaders are emerging in the era of hyper-connectivity. They, the technology-based start-ups and mobile communications companies, leverage digital technology faster than other manufacturers to continue delivering more innovative products and services to their users. Start-up and mobile communications companies that have led the evolution in innovative technologies to date are based on the inherent advantages of superior data utilization and a convenient customer experience. The key components of the innovation are M2M (Machine to Machine) and IoT (Internet of Things), and they are expanding their scope of connections to people-to-things and things-to-things as the technology involved in ICT develops.



Source: Gartner [2]

Fig. 1. Gartner Hype Cycle for Emerging Technologies, 2017

Gartner [1] predicted that IoT services would grow to 20.4 billion units by 2020. In addition, in the Hype Cycle announced by Gartner [2] each year, the IoT is emphasized as a major technology. Especially, as the services utilizing IoT, including Smart Home, Smart City, and Smart Health Care are revitalized, IoT is developed from the Internet of Things to the Internet of Everything, and now it has been developed as an Intelligent Thing utilizing AI.

Thus, it seems that in IoT services, optimally, the best "connectivity" would stand out among smart objects such as devices, sensors, actuators, and even humans [3]. As AI, machine learning and big data converge for the enhancement of this connectivity, and it is expected that IoT services would change from a horizontal market in which various individual subjects lead the business to a vertical market led by single business owners or alliances. If each service is managed by its own device and application, since the "silo" phenomenon occurs in which a barrier is formed in each service, even in the same environment, the platform initiative based on connectivity would also be a significant issue.

In spite of its brilliant appearance, in situations until now, IoT services have still been limited to the level of telecommunication companies' additional services or individual business operators' services, so comprehensive connectivity services are not implemented. In addition, start-ups related to IoT-based services attract attention, but they still show a minimum influence at the entire industry level. There are insufficient attractive services that can substitute for the existing services to the extent that this can be called the era of IoT. In addition, despite various IoT-related products and services that are steadily developed and shown in the market, there are still insufficient preparations for realistic policies and legislation. Thus, both users and business operators cannot help but face an obstacle in using and developing IoT services.

This study aims to identify the enablers of the acceptance of services based on IoT such as the roles of individuals, businesses, and governments to reach the stage of commercialization; the study classifies them hierarchically to find more realistically accessible alternatives. For this purpose, this study would investigate the complex relationships between multiple elements-related problems, utilizing brainstorming and multi-attribute decision-making tools and the Interpretive Structural Model (ISM), and then it sorts them by the importance of the problems and understands their priorities by setting directions and orders [4]. In addition, this study should alleviate ambiguity and uncertainty in the practical decision-making process by understanding the relationships of direct and indirect impacts among the components related to IoT services more accurately [5].

2. IoT Services

IoT is defined as the possibility of communication between things without human interference (ETSI), information exchange between communication stations connected to things without human interference (IEEE), intercommunication between physical and virtual things based on communications technology (ITU), and communication between things with an address in the communications interface according to the standard communication protocol (IETF). In other words, to summarize the definitions of IoT by the major ICT institutions in the world, it is the exchange of information by things themselves or with things or individuals without people's direct intervention. Atzori et al. [6] explained that interactions with all information existing in reality and the virtual world between people and things could be made as IoT expanded to the range of the Internet. In addition, they argued that the combination of three elements, including things-oriented visions, Internet-oriented visions, and semantic-oriented visions are the major components of IoT.

Such connection and convergence among IoT-related technologies can create further synergy through convergence with the existing industries. The application range and technology of IoT are expanding and being developed through connections in almost all areas including transportation and distribution (e.g.: autonomous vehicles cooperative-intelligent transport system, C-ITS), healthcare (e.g. smart healthcare wearable devices, applications), smart environment (e.g. smart home, smart factory, smart city), finance (e.g. mobile payments, FinTech) and social networks [7-9]. Gartner [1] predicted that this IoT-related market would grow up to 12.8 billion units in 2020 from 7 billion units in the consumer sector in 2018. In addition, it was predicted that, in the industrial world, too, the range of use would expand to 7.4 billion units in 2020 from 4 billion units in 2018. Especially, it was predicted that IoT would be used mostly in smart TVs and digital set-top boxes except for in automotive systems in the consumer sector, while smart electric meters (applications tailored to specific industry verticals) and commercial security cameras would be used most in the business sector.

With this growth of the IoT market, South Korea announced its "Plan for the Promotion of New Internet Industry" by the Ministry of Science, ICT and Future Planning (now, the Ministry of Science and ICT) in June 2013, and has promoted policies based on the Korea Communications Commission's "Basic Plan for the Building of the IoT base" in October 2009. In addition, through the "Basic Plan for IoT" announced in 2014, aiming to become a leading country of hyper-connected digital revolution by 2020, South Korea established plans for the promotion, including 1) creating and spreading a creative IoT service market, 2) fostering global specialized IoT companies, and 3) creating a safe and dynamic IoT development infrastructure. For the creation of an IoT service market, South Korea planned the development and support for the connected services, converged with IoT, Cloud, and Big Data along with a plan for developing an open-type platform in cooperation with global and large corporations and telecommunications firms since 2015, spreading promising services through it. Through the open platform that anyone can approach, it plans to build an environment for the development of user-centered creative IoT services and aims to achieve the innovation of products and services by utilizing collective intelligence, instead of the ideas of a small number of persons concerned with a concept of crowd-sourcing. In addition, according to the recognition that it is important to protect information and to build safe markets for products and services for the creation of safe and dynamic IoT infrastructure, it established plans for supporting the development and standardization of information protection technologies and the establishment of guidelines, creating the basis for the revitalization of the information protection industry and handling problems after they occur.

The U.S. aims to have policies for developing technologies and spreading services, recognizing IoT as a major area of future technology [10]. The U.S. is a market characterized by very active movements for creating a non-governmental IoT base that includes telecommunication firms, platforms, services, and terminal companies. In April 2008, the U.S. National Intelligence Council (NIC) selected IoT as a technology that would affect national competitiveness in various areas by 2025, establishing plans for an IT New Deal Policy in healthcare IT and a broadband supply business by 2009 and 2020. Especially, the Obama Administration had the FCC conduct government-wide activities for IoT-based creation, holding a public hearing that chip, module, terminal, and telecommunications businesses attended to enact IoT-related regulations in March 2013. In the follow-up of the public hearing in 2013, the Federal Trade Commission (FTC) advised companies to take action aimed at consumer protection by publishing the report, “Internet of Things: Privacy and Security in a Connected World” in February of 2015. The U.S. Senate Committee on Commerce, Science, and Transportation (USSCCST) held a public hearing for the legislation of "The Connected World: Examining the Internet of Things" in February 2015 for the establishment of IoT strategy for promoting economic growth and protecting consumers; it decided on five items.

The IoT service market is rapidly expanding, and to support this, each government prepares policies and bills, and engages in technical development actively in the industrial world. This study provides information for the revitalization and promotion of the IoT service industry and proposes strategic directions by finding the enablers for the acceptance of IoT, establishing relationships in the growth of the market.

3. ISM Methodology and Model Development

Interpretive Structural Modeling (ISM) was developed by the Vatel Columbus Laboratory in the United States. It is a mathematical methodology that 1) identifies the problem of the project clearly using charts, or 2) clearly distinguishes the functions consisting of complex factors [11]. Through the reachability matrix, the ISM has a characteristic that can clearly determine a correlation with each item that is complicated by a problem. Based on this, the hierarchical structure between items can be clearly identified. Singh and Kant [12] explained the seven steps of ISM as follows:

- Step 1 This step includes identifying factors that are relevant to the study's research question. The elements can be done through reviewing literature or other collective problem-solving techniques.
- Step 2 This step includes constructing contextual relationships between factors in which a type of relationship between all other factors will be assigned.
- Step 3 This step includes building up a structural self-interaction matrix (SSIM) of factors. This matrix emphasizes pair-wise relationships between factors of the system identified in Step 2.
- Step 4 This step includes establishing a matrix of reachability based on the SSIM to check the transitivity of each contextual relationship. Transitivity is used to form the fundamental assumptions in ISM that state the following: if Factor E is related to F and Factor F is related to G, then Factor E will be related to G.
- Step 5 This step includes dividing the reachability matrix into different levels according to the outcome of Step 4.
- Step 6 This step includes drawing a directed graph, also called a digraph, according to the identified relationships stated in the matrix of reachability.
- Step 7 This step includes replacing notes between factors with statements in the digraph and converting the results of ISM.

Once the factors are determined in Step 1, we perform a Structural Self-Interaction Matrix (SSIM) in Step 2 and Step 3. SSIM expresses the relationship between the factors (i.e. i and j) in four symbols: V, A, X, and O [12].

The relationship from i to j but not in both directions = V

The relationship from j to i but not in both directions = A

In both directions, the relationship from i to j = X

There is no relationship between i and j = O

In Step 4, the reachability matrix from SSIM is reconstructed using a binary matrix for calculations of driving power, dependence power, and iterations. The transitivity is checked afterwards. The driving force is the sum of the factors that are influenced by it plus itself. The dependence power is the sum of the factors that possibly influence it plus itself [13]. Singh and Kant [12] replaced the V, A, X, and O used in the SSIM with 1 or 0, and explained as follows:

If the (i, j) relationship is V, then the (i, j) relationship is assigned as 1 and the (j, i) relationship is assigned as 0.

If the (i,) relationship is A, then the (i, j) relationship is assigned as 0 and the (j, i) relationship is assigned as 1.

If the (i,) relationship is X, then the (i, j) relationship is assigned as 1 and the (j, i)

relationship is also assigned as 1.

If the (i, j) relationship is O, then the (i, j) relationship is assigned as 0 and the (j, i) relationship is also assigned as 0.

In Step 5, the reachability matrix is divided into levels. To perform this, the reachability matrix calculates the reachability set, antecedent set, and intersections of those sets for each factor. The reachability set is a factor itself, and other factors are influenced by it and the antecedent set; it is a factor itself and other factors possibly influence it. The identical factor in the reachability set and intersection sets is the top level in the ISM hierarchy. This factor does not affect any other factors except itself. Once a top-level factor is identified, it is repeatedly calculated until all the factors are stratified using the reachability matrix from which this factor is excluded.

Finally, in Step 6, a digraph is drawn based on the factor levels of Step 5. First, each element is classified into four categories (autonomous, dependent, linkage, and driver) to analyze the driving power and dependence power of each factor [14]. Then, according to the final reachability matrix in Step 5, the top-level factors are located on top of the digraph, the second-level factors are located below it, and so forth. In addition, an ISM-based model is created, with arrows displayed according to the relationship between each factor.

3.1 Identification of elements

In this study, 5 IoT experts were interviewed and surveyed with questionnaires to determine which factors are needed for adapting IoT service based on the EU 's 14 Internet Action Plans [15]. This is shown in **Table 1** below. The experts consisted of two mobile telecom experts providing IoT-based services, one start-up representative, and two professors.

Table 1. Enablers for adoption of IoT services

No.	Enablers for adoption of IoT services	
1	Governance	Establish basic principles for IoT
2	Continuous monitoring of the privacy and the protection of personal data questions	Review Data Protection Law for IoT Services
3	The “silence of the chips”	Provide users with the right to disconnect from the network environment
4	Identification of emerging risks	Establish countermeasures to resolve threats to privacy invasion information
5	IoT as a vital resource to economy and society	Consider the IoT as a socioeconomic essential infrastructure and conduct activities to protect it
6	Standards Mandate	Analyze and monitor the IoT standardization
7	Research and Development	Ongoing support for the IoT R & D program
8	Public-Private Partnership	Supporting public and private joint projects on the IoT, building public-private partnerships in green cars, energy-efficient buildings, future processes, and the future of the Internet

9	Innovation and pilot projects	Induce internet innovation through the pilot project
10	Institutional Awareness	Conduct regular meetings on IoT
11	International dialogue	Collaborate and share information on best practices and information about each country on the IoT
12	Sensor in recycling lines	Research on sensor recycling for environmental protection
13	Measuring the uptake	Obtain statistical data related to IoT, monitor distribution of IoT related technology, measuring IoT effectiveness from social and economic point of view
14	Assessment of evolution	Monitoring the evolution of IoT

3.2 Structural Self-Interaction Matrix (SSIM)

Table 2 shows the SSIMs discussed with the experts for reasonable decisions regarding IoT-based services. The conceptual relationship between each attribute factor was investigated through expert meetings. As shown in Table 2, V, A, X, and O are used for SSIM construction. The proposed 14 evaluation factors were compared with each other.

Table 2. Structural self-interactive matrix (SSIM)

Enablers	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	X	X	X	X	X	X	X	X	V	V	A	X	A	X
2		X	A	A	A	O	A	O	A	A	A	O	A	A
3			X	X	O	O	O	O	O	A	O	O	O	O
4				X	X	O	X	X	X	X	X	O	X	X
5					X	X	X	X	X	X	X	X	X	X
6						X	A	A	A	X	X	O	O	V
7							X	X	X	X	X	X	X	X
8								X	X	X	X	X	X	X
9									X	X	X	X	X	X
10										X	X	X	X	X
11											X	X	X	X
12												X	O	V
13													X	X
14														X

3.3 Reachability matrix

Table 3 below shows the reachability matrix using SSIM derived from **Table 2**. For this purpose, the symbols V, A, X, and O used in **Table 2** are modified to 1 or 0. In Table 3, the driving power value indicates the total number of instances in which each factor influences other factors, including oneself. Dependence refers to the total number of instances the factors are affected by other factors. Therefore, the larger the driving power, the larger the influence of the factors on the other factors. On the other hand, the larger the dependence, the greater the influence of the factors on the other factors. This is shown in **Fig. 2**.

Table 3. Reachability Matrix using SSIM

Enablers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Driving Power
1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	**12**
2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	**2**
3	1	1	1	1	0	0	0	0	0	0	0	0	0	0	**4**
4	1	1	1	1	1	0	1	1	1	1	1	0	1	1	**12**
5	1	1	0	1	1	1	1	1	1	1	1	1	1	1	**13**
6	1	0	0	0	1	1	0	0	0	1	1	0	0	1	**6**
7	1	1	0	1	1	1	1	1	1	1	1	1	1	1	**13**
8	1	0	0	1	1	1	1	1	1	1	1	1	1	1	**12**
9	0	1	0	1	1	1	1	1	1	1	1	1	1	1	**12**
10	0	1	1	1	1	1	1	1	1	1	1	1	1	1	**13**
11	1	1	0	1	1	1	1	1	1	1	1	1	1	1	**13**
12	1	0	0	0	1	0	1	1	1	1	1	1	0	1	**9**
13	1	1	0	1	1	0	1	1	1	1	1	0	1	1	**11**
14	1	1	0	1	1	0	1	1	1	1	1	0	1	1	**11**
Dependence Power	**12**	**11**	**4**	**11**	**12**	**8**	**11**	**11**	**11**	**12**	**11**	**8**	**9**	**12**	**-**

3.4 Level Partitions

Next, based on the Reachability Matrix calculated for the stratification of each factor, Intersection, which is a common element of the Reachability Set and Antecedent Set, is calculated. The Intersection value is affected by the Reachability, and the Reachability value that does not affect other factors is placed in the uppermost stratum. **Table 4**, **5**, **6**, **7**, **8**, **9**, and **10** summarize this process, and factor F2, which does not affect other variables, is located at the top level. The same figure as **Fig. 3** can be drawn by repeating the above-mentioned method by excluding the factor that finds the position.

Table 4. Iteration 1

Enablers	Reachability	Antecedent	Intersection	Levels
1	1,2,3,4,5,6, 7,8,9,10,12,14	1,2,3,4,5,6,7, 8,11,12,13,14	1,2,3,4,5,6,7,8,12,14	
2	**1,2**	**1,2,3,4,5,7,9, 10,11,13,14**	**1,2**	**1**
3	1,2,3,4	1,3,4,10	1,3,4	
4	1,2,3,4,5,7, 8,9,10,11,13,14	1,3,4,5,7,8,9, 10,11,13,14	1,3,4,5,7,8,9, 10,11,13,14	
5	1,2,4,5,6,7, 8,9,10,11,12,13,14	1,4,5,6,7,8,9, 10,11,12,13,14	1,4,5,6,7,8,9, 10,11,12,13,14	
6	1,5,6,10 ,11,14	1,5,6,7,8,9,10,11	1,5,6,10,11	
7	1,2,4,5,6,7, 8,9,10,11,12,13,14	1,4,5,7,8,9,10, 11,12,13,14	1,4,5,7,8,9,10 ,11,12,13,14	
8	1,4,5,6,7,8, 9,10,11,12,13,14	1,4,5,7,8,9,10, 11,12,13,14	1,4,5,7,8,9,10, 11,12,13,14	
9	2,4,5,6,7,8, 9,10,11,12,13,14	1,4,5,7,8,9,10, 11,12,13,14	4,5,7,8,9,10, 11,12,13,14	
10	2,3,4,5,6,7, 8,9,10,11,12,13,14	1,4,5,6,7,8,9, 10,11,12,13,14	4,5,6,7,8,9,10 ,11,12,13,14	
11	1,2,4,5,6,7, 8,9,10,11,12,13,14	4,5,6,7,8,9,10, 11,12,13,14	4,5,6,7,8,9,10 ,11,12,13,14	
12	1,5,7,8,9, 10,11,12,14	1,5,7,8,9, 10,11,12	1,5,7,8,9, 10,11,12	
13	1,2,4,5,7, 8,9,10,11,13,14	4,5,7,8,9, 10,11,13,14	4,5,7,8,9, 10,11,13,14	
14	1,2,4,5,7, 8,9,10,11,13,14	1,4,5,6,7,8,9, 10,11,12,13,14	1,4,5,7,8,9, 10,11,13,14	

Table 5. Iteration 2

Enablers	Reachability	Antecedent	Intersection	Levels
1	1,3,4,5,6,7, 8,9,10,12,14	1,3,4,5,6,7, 8,11,12,13,14	1,3,4,5,6, 7,8,12,14	
3	**1,3,4**	**1,3,4,10**	**1,3,4**	**2**
4	**1,3,4,5,7, 8,9,10,11,13,14**	**1,3,4,5,7,8, 9,10,11,13,14**	**1,3,4,5,7,8, 9,10,11,13,14**	**2**
5	**1,4,5,6,7,8, 9,10,11,12,13,14**	**1,4,5,6,7,8, 9,10,11,12,13,14**	**1,4,5,6,7,8, 9,10,11,12,13,14**	**2**
6	1,5,6, 10,11,14	1,5,6,7,8, 9,10,11	1,5,6,10,11	
7	1,4,5,6,7,8,9,10,11,1 2,13,14	1,4,5,7,8,9,10,11,12,13, 14	1,4,5,7,8,9, 10,11,12,13,14	
8	1,4,5,6,7,8, 9,10,11,12,13,14	1,4,5,7,8,9, 10,11,12,13,14	1,4,5,7,8,9, 10,11,12,13,14	
9	4,5,6,7,8,9, 10,11,12,13,14	1,4,5,7,8,9, 10,11,12,13,14	4,5,7,8,9,10, 11,12,13,14	
10	3,4,5,6,7,8,9,10,11,1 2,13,14	1,4,5,6,7,8,9,10,11,12,1 3,14	4,5,6,7,8,9,10,11,12,13, 14	

11	1,4,5,6,7,8,9,10,11,12,13,14	4,5,6,7,8,9,10,11,12,13,14	4,5,6,7,8,9,10,11,12,13,14	
12	1,5,7,8,9,10,11,12,14	1,5,7,8,9,10,11,12	1,5,7,8,9,10,11,12	
13	1,4,5,7,8,9,10,11,13,14	4,5,7,8,9,10,11,13,14	4,5,7,8,9,10,11,13,14	
14	1,4,5,7,8,9,10,11,13,14	1,4,5,6,7,8,9,10,11,12,13,14	1,4,5,7,8,9,10,11,13,14	

Table 6. Iteration 3

Enablers	Reachability	Antecedent	Intersection	Levels
1	1,6,7,8,9, 10,12,14	1,6,7,8, 11,12,13,14	1,6,7,8,12,14	
6	1,6,10,11,14	1,6,7,8,9,10,11	1,6,10,11	
7	1,6,7,8,9, 10,11,12,13,14	1,7,8,9,10, 11,12,13,14	1,7,8,9,10, 11,12,13,14	
8	1,6,7,8,9, 10,11,12,13,14	1,7,8,9,10, 11,12,13,14	1,7,8,9,10, 11,12,13,14	
9	6,7,8,9,10 ,11,12,13,14	1,7,8,9,10, 11,12,13,14	7,8,9,10, 11,12,13,14	
10	6,7,8,9,10, 11,12,13,14	1,6,7,8,9, 10,11,12,13,14	6,7,8,9,10, 11,12,13,14	
11	1,6,7,8,9, 10,11,12,13,14	6,7,8,9,10,11,12,13,14	6,7,8,9,10,11,12,13,14	
12	1,7,8,9,10,11,12,14	1,7,8,9, 10,11,12	1,7,8,9,10,11,12	
13	1,7,8,9,10,11,13,14	7,8,9,10,11,13,14	7,8,9,10,11,13,14	
14	**1,7,8,9,10,11,13,14**	**1,6,7,8,9,10, 11,12,13,14**	**1,7,8,9,10,11,13,14**	**3**

Table 7. Iteration 4

Enablers	Reachability	Antecedent	Intersection	Levels
1	1,6,7,8,9,10,12	1,6,7,8,11,12,13	1,6,7,8,12	
6	**1,6,10,11**	**1,6,7,8,9,10,11**	**1,6,10,11**	**4**
7	1,6,7,8,9,10,11,12,13	1,7,8,9,10,11,12,13	1,7,8,9,10,11,12,13	
8	1,6,7,8,9,10,11,12,13	1,7,8,9,10,11,12,13	1,7,8,9,10,11,12,13	
9	6,7,8,9,10,11,12,13	1,7,8,9,10,11,12,13	7,8,9,10,11,12,13	
10	6,7,8,9,10,11,12,13	1,6,7,8,9,10,11,12,13	6,7,8,9,10,11,12,13	
11	1,6,7,8,9,10,11,12,13	6,7,8,9,10,11,12,13	6,7,8,9,10,11,12,13	
12	**1,7,8,9,10,11,12**	**1,7,8,9,10,11,12**	**1,7,8,9,10,11,12**	**4**
13	1,7,8,9,10,11,13	7,8,9,10,11,13	7,8,9,10,11,13	

Table 8. Iteration 5

Enablers	Reachability	Antecedent	Intersection	Levels
1	1,7,8,9,10	1,7,8,11,13	1,7,8	
7	**1,7,8,9,10,11,13**	**1,7,8,9,10,11,13**	**1,7,8,9,10,11,13**	**5**
8	**1,7,8,9,10,11,13**	**1,7,8,9,10,11,13**	**1,7,8,9,10,11,13**	**5**
9	**7,8,9,10,11,13**	**1,7,8,9,10,11,13**	**7,8,9,10,11,13**	**5**
10	**7,8,9,10,11,13**	**1,7,8,9,10,11,13**	**7,8,9,10,11,13**	**5**
11	1,7,8,9,10,11,13	7,8,9,10,11,13	7,8,9,10,11,13	
13	1,7,8,9,10,11,13	7,8,9,10,11,13	7,8,9,10,11,13	

Table 9. Iteration 6

Enablers	Reachability	Antecedent	Intersection	Levels
1	**1**	**1,11,13**	**1**	**6**
11	1,11,13	11,13	11,13	
13	1,11,13	11,13	11,13	

Table 10. Iteration 7

Enablers	Reachability	Antecedent	Intersection	Levels
11	**11,13**	**11,13**	**11,13**	**7**
13	**11,13**	**11,13**	**11,13**	**7**

3.5 Development of ISM model

Fig. 3 shows the result of the above ISM analysis. To sum up, what is considered most fundamental in the acceptance of IoT services includes international dialogue (11) and measuring the uptake (13). It turned out that it is necessary to share best practices and respond jointly, to supply objective data on IoT and to supply the basic and underlying materials. If the basic principles of IoT services are established through governance (1) based on these enablers, it is judged that R&D (7), public-private partnerships (8), innovation and pilot projects (9), and institutional awareness (10) can be conducted smoothly. Especially, it turned out that R&D (7), public-private partnerships (8), innovation and pilot projects (9), and institutional awareness (10) exist at the same level and have close relationships with each other. Therefore, to spread IoT services, it is necessary to make private and public joint partnerships, to continue to try them through innovation and pilot projects, and to make efforts to reorganize the system based on them.

The Standards Mandate (6) and the Sensor in Recycling Lines (12) were considered highly correlated, but in actual research, they existed at the same level but there was no correlation. It is assumed that the interconnection of objects through standardization is more important than sensor recycling. In addition, the "silence of the chips" (3), identification of emerging risks (4), and IoT as a vital resource to the economy and society (5) were found to be the factors that have a direct relationship with personal information protection. Furthermore, it is noted the questions about the continuous monitoring of privacy and the protection of personal data (2) are the elements that are most affected by other factors and the differentiation factors in the acceptance of IoT services.

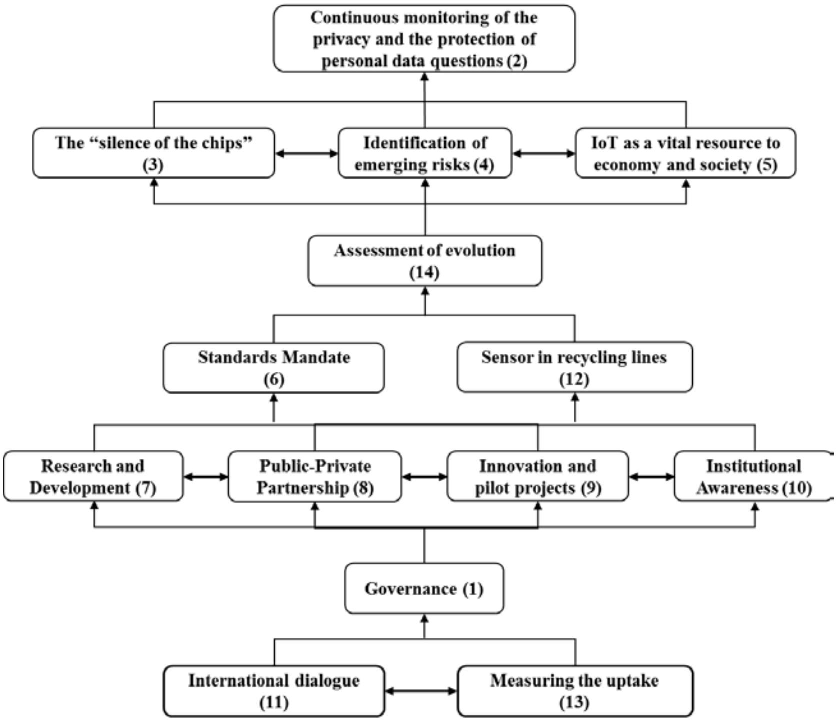


Fig. 3. ISM-based model for IoT Services key enablers

3.6 MICMAC analysis

Matrice d'Impacts Croises-Multipication Applique´ an Classment (MICMAC) analysis is a method of analyzing the driving and dependence power of enablers [16] based on the multi-attributes of matrices [17-18]. Each enabler is divided into four quadrants, including autonomous, dependent, linkage, and independent sections according to the outcomes of driving and dependence power. Singh and Kant [12] and Raj et al. [16] described four categories according to driving and dependence power like those in Table 11.

Table 11. Four Categories of Driving power and dependence diagram

Categories	Driving Power	Dependence Power	Description
Autonomous	Weak	Weak	The autonomous enablers do not have much influence on the other variables of the system.
Linkage	Strong	Strong	Any action on lingkage enablers will have an effect on others and also a feed back effect on themselves. * Key enablers
Dependent	Weak	Strong	The dependent enablers represent desired objectives for organisation
Drivers (Independent)	Strong	Weak	The independent enablers will help organisations to achieve their desired objective. * Key enablers

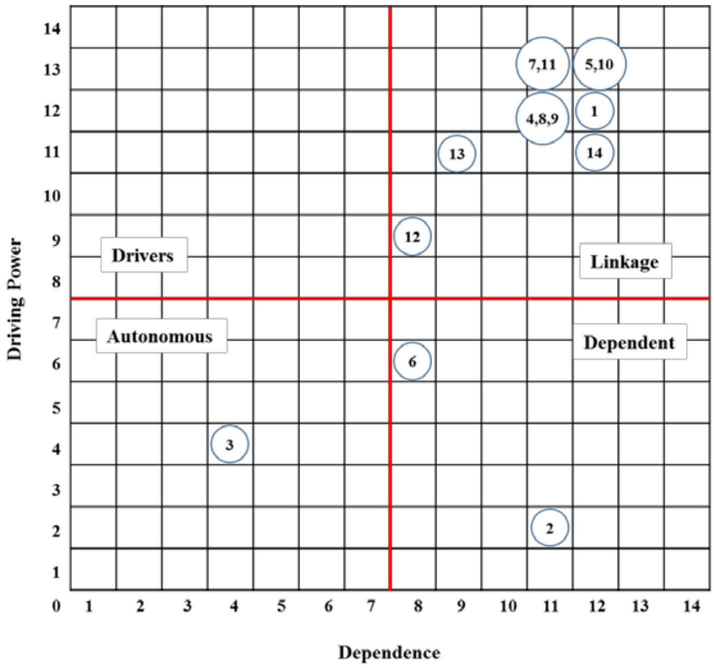


Fig. 4. Driving Power and Dependence Diagram

Through the MICMAC analysis method, a Driving Power and Dependence Diagram was drawn like the one in **Fig. 4**. First, "the silence of the chips" (3) was an autonomous enabler. This means that the disconnection permission of a network does not affect consumers' acceptance of IoT services. Second, continuous monitoring of the privacy and the protection of personal data questions (2) and standards mandates (6) were dependent enablers. In other words, since the work for data protection and standardization is a goal that should be achieved by the IoT industry, both the government and the industrial world should pay attention. Third, linkage enablers included governance (1), identification of emerging risks (4), IoT as a vital resource to economy and society (5), R&D (7), public-private partnerships (8), innovation and pilot projects (9), institutional awareness (10), international dialogue (11), a sensor in recycling lines (12), measuring the uptake (13), and assessment of evolution (14). These factors show strong driving power and high dependence. In addition, since these factors affect the essence and evaluation of IoT services, they should be treated as major factors for the successful acceptance and commercialization of IoT services.

4. Conclusion

This study aims to identify the enablers of the acceptance of services based on IoT, and to propose implications for the commercialization of the services by hierarchically classifying them. For this purpose, based on 14 action plans for IoT in the EU, this study extracted the major enablers by conducting interviews and surveys with five IoT experts. Based on this, the study conducted ISM and MICMAC analyses. The results of the study are as follows.

First, for the successful commercialization of IoT services, it was found that information exchange and collective response throughout the world, and the accumulation of materials through data collection, should take precedence. It is necessary to prepare the foundation for

IoT services by preparing policies and legislation. Second, it is necessary to continue to make efforts to spread and develop IoT services by establishing a public-private cooperation system in R&D and project performance. Third, since the protection of personal information and data and the standardization of services are matters required in all services based on ICT as well as the IoT industry, countermeasures for this are needed by the government and industrial world.

The implications of this study are as follows. First, despite IoT-based services that have been launched with many products, they have not yet kept themselves on track compared to the investment or interest of various economic entities because there is not a sufficient measurement of social and economic effects through international collaboration and objective data collection. Accordingly, the government, industrial world, and academics should discuss effectiveness, plan for improvements in and policy directions of IoT, and organize a consortium for international cooperation, holding regular meetings and academic conferences to promote joint R&D.

In addition, it is of major significance that this study found sequential improvements by separating the upper level from the lower level, concerning various enablers using ISM. This provides implications for the effective adaptation of IoT services to various economic entities in the future, and it is expected that the government can be referred to as the main discussion entity in the working group.

The limitation of this study is that when brainstorming was performed, only the factors published by the EU were used, while more factors could have been identified for research. In addition, a pool of five experts was consulted for the interviews, but it would be beneficial to conduct interviews with more experts.

References

[1] Gartner, “Gartner Says 8.4 Billion Connected "Things" Will Be in Use in 2017, Up 31 Percent From 2016,” 2017.

[2] Gartner, “Top Trends in the Gartner Hype Cycle for Emerging Technologies, 20,” 2017. Article (CrossRef Link).

[3] Meesun Kim, Hyun Ahn and Kwanghoon Pio Kim, “Process-Aware Internet of Things: A Conceptual Extension of the Internet of Things Framework and Architecture,” *KSII Transactions on Internet and Information Systems(TIIS)*, vol. 10, no. 8, pp. 4008-4022, 2016. Article (CrossRef Link).

[4] Duleba, S., Shimazaki, Y., and Mishina, T., “An analysis on the connections of factors in a public transport system by AHP-ISM,” *Transport*, vol. 28, no. 4, pp. 404-412, 2013. Article (CrossRef Link).

[5] Attri, R., Dev, N., and Sharma, V., “Interpretive structural modelling (ISM) approach: an overview,” *Research Journal of Management Sciences*, vol. 2, no. 2, pp. 3-8, 2013. Article (CrossRef Link).

[6] Atzori, L., Iera, A. and Morabito, G., “The internet of things: A survey”, *Computer networks*, vol. 54, no. 15, pp. 2787-2805, 2010. Article (CrossRef Link).

[7] Sangmin Lee, "Evaluation of Mobile Application in User’s Perspective: Case of P2P Lending Apps in FinTech Industry," *KSII Transactions on Internet and Information Systems*, vol. 11, no. 2, pp. 1105-1117, 2017. Article (CrossRef Link).

[8] Daebum Ji, Jeongil Choi and Yonghee Kim, “An Exploratory Study on Customer-oriented Attributes for the Revitalization of Digital Healthcare Service :Using Interpretive Structural Modeling,” *Journal of Information Technology Services*, vol. 17, no. 1, pp. 105-119, 2018.

[9] Seul-Ki Choi, Chung-Huang Yang and Jin Kwak, "System Hardening and Security Monitoring for IoT Devices to Mitigate IoT Security Vulnerabilities and Threats," *KSII Transactions on Internet and Information Systems*, vol. 12, no. 2, pp. 906-918, 2018. Article (CrossRef Link).

[10] Ju, D. Y. and Kim, J. K., "Hyper connectivity era, Activation plan of creative convergence of IoT," *KIET*, 2014. Article (CrossRef Link).

[11] Kumar, D. T., Palaniappan, M., Kannan, D., and Shankar, K. M., "Analyzing the CSR issues behind the supplier selection process using ISM approach," *Resources, Conservation and Recycling*, vol. 92, pp. 268-278, 2014. Article (CrossRef Link).

[12] Singh, M. D. and Kant, R., "Knowledge management barriers: An interpretive structural modeling approach," in *Proc. of 2007 IEEE International Conference on Industrial Engineering and Engineering Management*, pp. 2091-2095, 2007. Article (CrossRef Link).

[13] Wong, J. K. W. and Leung, J. K. L., "Modelling factors influencing the adoption of smart-home technologies," *Facilities*, vol. 34, no. 13-14, pp. 906-923, 2016. Article (CrossRef Link).

[14] Mandal, A. and Deshmukh, S. G., "Vendor selection using interpretive structural management," *International Journal of Operations & Production Management*, vol. 14, no. 6, pp. 52-59, 1994. Article (CrossRef Link).

[15] European Commission, "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Internet of Things : an action plan for Europe," 2009. Article (CrossRef Link).

[16] Raj, T., Shankar, R., and Suhaib, M., "An ISM approach for modelling the enablers of flexible manufacturing system: the case for India," *International Journal of Production Research*, vol. 46, no. 24, pp. 6883-6912, 2008.

[17] Sharma, S., Shimp, T. A., and Shin, J., "Consumer ethnocentrism: A test of antecedents and moderators," *Journal of the academy of marketing science*, vol. 23, no. 1, pp. 26-37, 1994. Article (CrossRef Link).

[18] Gothwal, S., and Raj, T., "Analyzing the factors affecting the flexibility in FMS using weighted interpretive structural modeling (WISM) approach," *International Journal of System Assurance Engineering and Management*, vol. 8, no. 2, pp. 408-422, 2017. Article (CrossRef Link).

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