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Conference Paper

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28th European Regional Conference of the International Telecommunications Society (ITS): "Competition and Regulation in the Information Age", Passau, Germany, 30th July - 2nd August, 2017

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Kim, Suwon; Nam, Chan-gi; Lee, Sangwoo; Kim, Seongcheol (2017) : A public R&D resource allocation model for 5G mobile industry in Korea, 28th European Regional Conference of the International Telecommunications Society (ITS): "Competition and Regulation in the Information Age", Passau, Germany, 30th July - 2nd August, 2017, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/169472>

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A public R&D resource allocation model for 5G mobile industry in Korea

Suwon Kim^a, Chan-gi Nam^b, Sangwoo Lee^c, Seongcheol Kim^{ad}

Abstract

5G needs to be viewed as a request for network upgrade driven by demands for innovative services, not only by demands for enhanced mobile networks per se. The R&D plan of the Korean government has been discordant with the vision of 5G, maintaining the tradition of sector- or issue-based R&D project support. This study proposed a strategic decision model for the 5G mobile industry, focusing on public R&D resource allocation, in response to the call for a revision of the ICT policy framework in Korea. The proposed model employed a criteria-based, quantitative, and comprehensive approach, using the AHP method, and an expert survey was conducted. The results showed that service platform is the critical layer that deserves priority in strategic public R&D resource input. Also, the ICT experts in Korea formed a consensus that upgrading physical networks per se is not the main driver of the next generation mobile industry, which verified the validity of the model.

Keywords: 5G mobile; R&D; resource allocation; analytic hierarchy process; policy revision

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1. Introduction

The world of ICT (information and communications technology) has been proceeding toward the next generation, namely 5th generation mobile communications. Since the introduction of the first generation mobile communications in the 1980s, it took roughly 10 years for each new generation to appear (5G Forum, 2016). It is known that the first commercial 4G mobile service was launched in late 2009, in Sweden and Norway, 9 years after the first commercial launch of 3G mobile service in Japan. As it suggests, the clock of the worldwide telecommunications society is ticking toward the realization of 5G vision sooner or later. 5G R&D projects were regularized after the announcement of a 5G development program from the ITU-R (International Telecommunications Union-Radiocommunications sector), titled as 'IMT for 2020 and beyond'.

Despite the expectation for the rosy future of 5G, a critical question remains; how can we efficiently realize the vision? Technological prospects can not solely drive innovation, but the market and social factors simultaneously affect the innovation process, either hindering or promoting it. It is surely important to predict and resolve market and social issues, so that the 5G innovation does not have to procrastinate. Nonetheless, thus far, the market and social factors have rarely been contemplated.

Meanwhile, from the national perspective, a strategic approach to 5G development is required to maximize its value, i.e. benefits over costs. Many would agree that ICT has become one of the most important competitive edges in the global market and determinants of national wealth. If they recognize 5G to be the inevitable direction to the future ICT, long-term strategies need to be developed, then infusion of the public resource in 5G R&D should be one pillar of the strategies.

Public resource allocation must be planned with careful examinations on the effectiveness and efficiency. Besides, 5G development will not be achieved without the emergence of corresponding services, thus a comprehensive development framework, from the foundational technology to service creation, needs to be adopted. Under this notion, this paper suggests a model for strategic decision of public R&D resource allocation for the 5G mobile industry in Korea, using the analytic hierarchy process (AHP) method.

2. Call for revision of 5G R&D plan in Korea

2.1. Vision of 5G

The ideal 5G mobile networks, i.e. IMT-2020 requirements, are expected to achieve roughly '1000 times improved' connectivity. Peak data rate and user experienced data rate will increase from 1Gbit/s to 20 Gbit/s and 10Mbit/s to 100 Mbit/s. Area traffic capacity and connection density should increase from 0.1 Mbit/s/m² to 10 Mbit/s/m² and from 10⁵ devices/km² to 10⁶ devices/km². Latency will decrease from 10 ms to 1 ms, while mobility will be guaranteed in 500 km/h. In addition, spectrum efficiency and network energy efficiency will be enhanced 3 times and 100 times (ITU-R, 2015). In short, the vision of 5G mobile networks is to afford much more rapid, massive, stable, and efficient connectivity to wireless communications.

The vision of 5G derives not only from 'need for speed', but from 'new demands' -- more connected devices with diverse service requirements, improved user experience, and reduction of costs (ITU-R, 2015). Someone might question whether we truly need way beyond 4G mobile networks which would afford sufficient accessibility to the Internet, especially in developed countries where 4G has successfully been diffused. If it is merely a boost of mobile Internet speed, the necessity of 5G may not be substantial and the market expectation may not be high enough to reconcile to establishment costs.

Yet, what 5G aims to support is not just stable YouTube streaming or Facebook connectivity, but qualitatively different services which have been dreamed as the future of human life. All the 'unrealistic' services, such as automated machines with context-awareness, real-time healthcare, and virtual reality, require adequate wireless network environments to be realized, and 5G is a step toward it. In other words, 5G can be a catalyst as a general purpose technology, rather than just an enhancement in telecommunications, which will transform all other industry sectors and our daily life (IHS, 2017).

Namely, 5G needs to be viewed as a request for network upgrade driven by demands for innovative services, not only by demands for enhanced mobile networks per se. If so, the antithesis will be also true; if there is no demand for innovative services, or we fail to meet the demands, 5G development is neither necessary nor promising. That is why we need a holistic approach to 5G development, embracing simultaneous and harmonious developments of other technology layers.

2.2. Review on 5G R&D plan in Korea

A consensus on the importance of performance-based government management has long been formed. Visibility of the output of a policy, first of all, is critical for public approval. Also, it

contributes to governments' efficiency improvement by minimizing the evil of bureaucracy. In addition, examination of the results functions as a feedback process, so that the policy itself, as well as the whole organization, continues to develop (Osborne, 1993).

We often witness that cost-efficiency, i.e. productivity, of governments' R&D funding is relatively weaker than that of the private sector (Levy & Terleckyj, 1983). This must derive from the fact that the process of R&D project selection, resource allocation, and performance management in private sector is much more organized and goal-oriented.

In South Korea, the Ministry of Science, ICT and Future Planning (MSIP), which administer the affairs related to national planning, management, and monitor of science and technology sectors, has appreciated 5G as one of the national growth engines and drafted its plan for 5G promotion in 2014. The MSIP expects that Korea will be the earliest country to introduce 5G services, especially through 2018 Winter Olympics in Pyeongchang, Korea. To do this, about US\$1200 million of public R&D funds will be committed until 2020 (MSIP, 2016). It reflects the perception that the next generation telecommunications should emerge with harmonious development of mobile networks as well as services on the networks.

However, looking into the plan for MSIP R&D projects implementation (MSIP, 2017), the MSIP's R&D funding seems to still isolate the 5G sector from other service sectors. They independently define Internet of Things, cloud computing, big data, mobile, security, and A.I. (artificial intelligence) from 5G, even though all the fields share quite similar vision so not separable.

In sum, the MSIP's R&D resource allocation plan for 5G is still not organized nor goal-oriented. Despite the recognition on the nature of 5G mobile communication, which does not involve network layer alone, the proposed budget plan maintains fragmented sectors including all the 'hot issues', such as A.I., IoT, and big data. As a result, the budget plan turned out to be a form of increasing or reducing the amount of funding for each item that was set in the previous year. If so, it is quite obvious that the budget plan is decided arbitrarily, relying on the previous year's budget execution, rather than with a strategic contemplation on comprehensive and long-term effects of the resource allocation.

Therefore, 5G R&D plan in Korea is required to be restructured in accordance with the need for a comprehensive approach, embracing all the technology layers relevant to 5G mobile communications. This paper suggests a strategic decision model for the 5G mobile industry in Korea, focusing on public R&D resource allocation. The model is estimated and verified

through and expert survey. Throughout the process, this paper tries to answer the research questions below.

RQ1. What are the relatively important criteria in deciding priorities of 5G sectors which need for strategic incubation from the Korean government?

RQ2. Which 5G sector does get priority when estimated based on the criteria?

RQ3. What is the more viable investment option for each 5G sector?

3. A proposed model for strategic 5G incubation

3.1. Modeling method

Decision methods for R&D project selection and resource allocation, adopting a quantitative approach, have been one of the important topics for business and government management. The models vary generally according to the methods they employ, such as comparative or scoring methods. Meanwhile, the models share a common idea that the criteria include benefits and risks (Baker & Freeland, 1975).

In this study, the decision model uses the AHP method, which has been widely adopted as a structural approach to a decision, selection, and prioritization (Vaidya & Kumar, 2006). The AHP can incorporate both qualitative and quantitative data, regardless of the number of cases. In case of survey data, the AHP simplifies respondents' choice, because it consists of a series of direct pair-wise comparison. The results of the AHP provides relative importance of each criterion and relative superiority of each alternative, thus, in turn, abundant implications can be drawn, in addition to a clear result relevant to the purpose of the model.

In relation to R&D project selection and resource allocation, the AHP has also shown its applicability, due to its clear advantages. For example, Liberatore (1987)'s research, which is one of the earliest studies that linked R&D project selection and the AHP, showed the usefulness of an extension of the AHP for prioritization and resource allocation in the R&D environment, incorporating cost-benefit analysis. Similarly, Huang, Chu, and Chiang (2008) showed an application of the AHP in government-sponsored R&D project selection, inviting experts' evaluation. Greenberg and Nunamaker (1994), as another example, suggested that the AHP can be adopted in establishing a budgeting model for public sector organizations with multiple objectives.

3.2. Proposed model

3.2.1. Criteria

The government needs to consider various dimensions of the goal of policies and resource allocation. It does not solely involve a specific sector, but all the stakeholders including citizens, enterprises, and administrations themselves. In a specific project, the purpose of a government's policy can be very diverse depending on the defined problem and expected outcome. Nonetheless, the ultimate goals of industrial policy can be twofold; economic growth and social welfare (Bazaraa & Bouzaher, 1981). They are indeed not mutually exclusive, considering the interaction between the two concepts. Although, as the locus of ICT policy settings, the salient concern, namely focal goal, of an R&D support can lean toward one of them.

In addition, independently with the effects on the domestic economy and social welfare, the government's ICT policy can be focused on global competition. It is a consensus that the current ICT market is mostly globalized, and the competitiveness of ICT industry can be viewed as the competitiveness of a nation (Yunis, Koong, Liu, Kwan, & Tsang, 2012). Again, global ICT competition is not completely separable from the economic growth and social welfare, but it can be a focal goal of an ICT policy from the perspective of the governments, who share a mission that they need to provide a favorable playground for their national firms in the global ICT market. From this, this paper suggests a set of criteria for 5G R&D resource allocation (See Figure 1).

3.2.1.1. Economic impact

According to a market researcher IHS (2017), global 5G value chain output will reach US\$12.3 trillion in 2035, which accounts 4.6% of the whole global economy. Telecommunications sector separately will generate US\$3.5 trillion of gross output, while the rest consists of all other industries, such as manufacturing, public service, and even agriculture, to name a few. 5G's positive impacts on the national economy are twofold; 1) growth of mobile communications market and 2) creation of convergent service market.

5G is expected to be a breakthrough for mobile network operators who seek for a growth opportunity in the saturated Korean telecommunications market. A large portion of the economic impacts of 5G will flow into mobile network operators and service providers.

In the meantime, the necessity of innovation in mobile communications is not only upgrading network quality, but establishing network environments for innovative services. In the 5G vision, a further-step convergence between telecommunications and heterogeneous industry sectors is expected, so that it contributes to the growth of the related industries.

From this view, the government's decision on 5G R&D need to consider the both side of economic impacts, namely direct impacts on the telecommunications market and indirect but significant impacts on other industry sectors. The former refers to the extent to which each sector can contribute to the national economy through the growth of the telecommunication network, device, and service markets; while the latter refers to the extent to which each sector can contribute to the national economy through the creation of the convergent service markets other than telecommunications.

3.2.1.2. Consumer welfare

It is quite difficult to define social welfare, and it would vary according to the fields where it is derived from. In general, social welfare may be understood as the well-being of the members of a society or well-functioning of a social system. Meanwhile, from the perspective of welfare economics, social welfare refers to sum of economic surplus, including consumer surplus and producer surplus (Hicks, 1939). Yet, in this study, we narrow down the concept of welfare to people's quality of life, especially of users, i.e. consumers, in order to maximize the distinction between social welfare and economic impacts.

Telecommunications have contributed to the enhancement of people's quality of life, which function as a lifeline. 5G mobile network itself will provide better connectivity to its users. More importantly, it will lead to innovative services which are qualitatively different from those in the previous mobile network environment. But, unfortunately, in the early phase of ICT R&D, social dimensions are often peripheral considerations, behind economic benefits, despite its importance (Preston, 2003).

One virtue of the ICT governance should be social security for access to communication tools for the public. As mobile communication has become the most important communication tool, non-discriminant and quality mobile access is required. Assuming that the benefits of the innovation in the mobile network need to be distributed to all of the citizens, build-up and commercialization of 5G must consider general accessibility in advance. Korea indeed has an

experience of successful diffusion of broadband Internet through refined managements of both demand and supply sides of the telecommunications market (Picot & Wernick, 2007).

Meanwhile, the convergent services in the 5G vision are expected to change the process of service provision, which leads to change in people's mode of life. Many of the services will contribute to an increase in quality of life, such as public health and security, not only convenience in living.

Therefore, the proposed decision model includes 5G accessibility and life-enhancing service as criteria under the consumer welfare section. The former refers to the extent to which each sector can contribute to consumers' quality of life through the provision of 5G mobile services at a proper price; while the latter refers to the extent to which each sector can contribute to consumers' quality of life through the provision of innovative life-enhancing services at a proper price.

3.2.1.3. Global ICT leadership

Korea had enjoyed a leading position in the global, or at least in the Asian mobile technology market until 4G diffusion phase. Korea indeed has maintained the fastest average fixed and wireless Internet connection in the world for over a decade (OECD, 2015). Yet, currently, Korea has been threatened by catching-up countries, especially by China. Although once enjoyed, if Korea loses its reputation and competitive edges in ICT, the global market may not respond favorably to Korean ICT firms' international activities, including capital flows (Ren, 2014.12.30). Leadership in the global ICT market must have symbolic value as well as derivative benefits for Korean citizens as well as enterprises.

In the technology market, possession of *de facto* standards represents, in addition to utilitarian aspects, considerable stature for the level of national technology. It is no exaggeration to say that competition in the global technology society is endless warfare around standardization. Standardization is the result of a highly complicated interaction among innovation system, marketplace, and regulatory regime (Yang, Too, Lyytinene, & Ahn, 2003). In line with its nature, technological firms in the global market do not choose to adopt a standard or participate in a standard alliance only by estimated superiority of the standard, but for political reasons to win the battles (Yoo, Lyytinen, & Yang, 2005). The Korean government, its affiliated research institutions, and national technology firms also are eager to take part in the fierce competition for 5G network and related technology standards. Then, one important question must be how

to define priorities in terms of focal sectors in which never to lose, so that R&D capability are efficiently distributed.

As mentioned, Korea has enjoyed an honor as one of the countries with the most developed fixed and mobile broadband. It is well-known that Internet connectivity, especially broadband infrastructure significantly contributes to economic growth of a country (Czernich, Falck, Kretschmer, & Woessmann, 2011). In Korea, the development and diffusion process of fixed and mobile Internet had been guided by the central government, and the role of the government is assessed to have been critical for the global broadband leadership (Choudrie, Papazafeueioulou, & Lee, 2003; Lau, Kim, & Atkin, 2005).

Accordingly, the sub-criteria under the umbrella of global ICT leadership factor are standardization leadership and early diffusion of 5G. The former stands for the extent to which each sector can contribute to national competitiveness in the global ICT market through possession of standard and patent; while the latter stands for the extent to which each sector can contribute to national competitiveness in the global ICT market through early diffusion of 5G mobile communications.

3.2.2. Alternatives

3.2.2.1. Focal layers

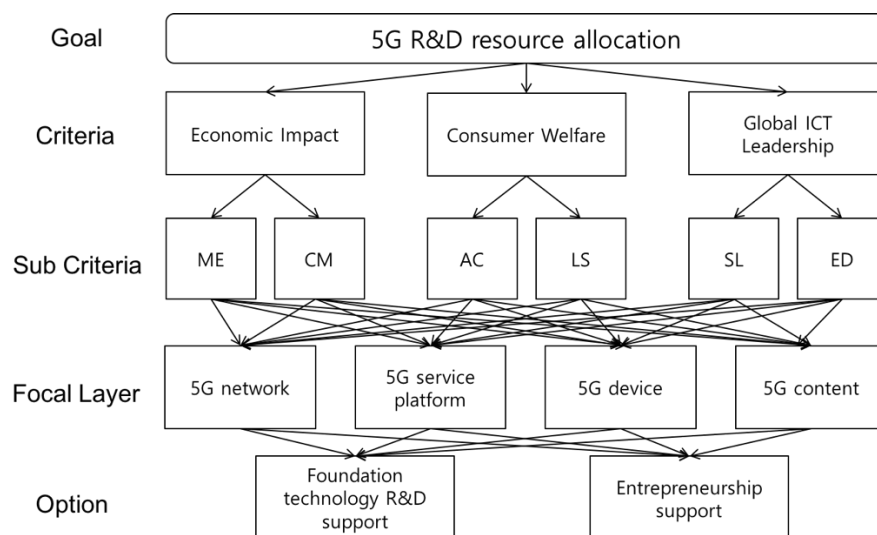
As discussed, the Korean government, i.e. the MSIP, plan its R&D budget to be distributed according to arbitrarily defined technology fields mainly based on hot issues, such as IoT, UHD, big data, and 5G network separately. However, 5G needs to be viewed as a simultaneous progress of networks and services, involving all the layers, namely network, platform, device, and content, thus none of them can be neglected.

Yet, under a priority evaluation with consideration for the market and social circumstance, urgency and importance of sectors need to be determined, so that limited R&D resources are properly allocated. To do this, the government's R&D planning needs to be revised with a comprehensive framework embracing all relevant ICT sectors under a big picture of the next generation mobile communications. This paper suggests an alternative level in the proposed model, employing the CPND concept, which is a traditional but still powerful categorization in the ICT value network(Fransman, 2010: 8-10).

3.2.2.2. Public support options

When the relative importance of the 5G layers is determined, the next question should be how to promote them in accordance with each layer's distinct needs for public support. The public support, i.e. R&D resource allocation, has two options; foundational technology development support and entrepreneurship support. Not only the network layer, but all the other layers require substantial progress in foundation technology in order to meet the technological requirements for the provision of an innovative service. For example, for the provision of mobile UHD TV, in addition to sufficient data rate, UHD TV content production and processing, display and computing, and content distribution network technology must reach the least requirements. Likewise, such innovative services will emerge from entrepreneurship originating from each layer. For instance, an advanced healthcare service can be the output of a medical institution, a big-data analytics company, a network operator, or a medical device maker.

None of the necessity of simultaneous development of foundation technology and the potential of entrepreneurship capacity in all the layers can be neglected. Nonetheless, the amount of R&D resource input in each option can be determined according to the priorities and weights with consideration for the national market conditions and strategic objectives. Therefore, the proposed model also includes R&D resource allocation options which can be applied within each technology layer.



Note. ME=telecommunications market expansion; CM=convergence market creation; AC=accessibility; LS=life-enhancing service; SL=standard/patent leadership; ED=early diffusion of 5G

Figure 1. An AHP model for 5G R&D resource allocation

4. Model estimation

4.1. Expert survey procedure

In order to estimate the relative importance of the criteria and weights of the alternatives in the proposed model, an expert survey was conducted. The samples were chosen according to their expertise in ICT market, industry, and policy research. An email was sent to about 60 experts and 40 samples responded (Table 1). The samples in universities are Ph.D.s and Ph.D. candidates who have currently participated in long-term research projects related to future spectrum-based industry and IoT. The corporate samples were chosen from in-house research teams in ICT companies, including a mobile network operator, a mobile service platform provider, and an Internet service provider. The research institute refers to one of the major government-affiliated institutes for ICT policy research. The respondents reported their specialty as in broadcasting, telecommunications, the Internet, content, device, and others. 15 of them had more than 10 years of experience in the ICT research field, while 2 of them had less than 2 years of experience.

Table 1. Respondents' background

Demographics	Gender		Age	
	Male	26	20s	10
	Female	14	30s	13
			40s	11
			50s	5
			60s	1
Affiliation	Corporate		11	
	Research institute		7	
	University		22	
Specialty	Broadcasting		3	
	Telecommunications		16	
	Internet		15	
	Content		3	
	Device		2	
	Others		1	
Experience	Less than 2 years		3	
	2 - 4 years		6	
	4 - 6 years		9	
	6 - 8 years		5	
	8 - 10 years		2	
	More than 10 years		15	

The experts were asked to indicate relative importance and superiority in a series of pairwise comparison between the criteria and alternatives. Nine point scale was used; 1 = equal importance(superiority), 3 = moderate importance, 5 = strong importance, 7 = very strong importance; 9 = absolute importance.

The data were analyzed using a technical computing software Matlab. 28 out of 40 (70%) answers were found to have consistency ratio (CR) below 0.2. In general, answers with CR below 0.1 is considered to have an appropriate level of consistency. However, in social studies, especially when a survey method is employed, CR up to 0.2 is additionally tolerated, taking into account the difficulties in securing independence between hierarchies and in overcoming the cognitive burden on respondents (Saaty, 1983).

4.2. Results

4.2.1. Criteria weight

As shown in Table 2, the ICT experts in Korea weighted more on *consumer welfare* (.442) and *economic impact* (.401) than on *global ICT leadership* (.157), as the criteria for determining the priorities of the alternatives in public R&D resource allocation model. The relative importance of *economic impact* and *consumer welfare* did not yield a substantial difference, while that of *global ICT leadership* was quite lower than the two criteria.

Table 2. Criteria weights

Criteria	Weight (W_{C1})	Sub-criteria	Local score (W_{C2})	Criteria weight (W_C)	Rank
Economic Impact	.401	Telecommunications market expansion (TM)	.199	.080	5
		Convergence market creation (CM)	.801	.321	1
Consumer Welfare	.442	Accessibility (AC)	.322	.142	3
		Life-enhancing service (LS)	.678	.300	2
Global ICT Leadership	.157	Standard/patent leadership (SL)	.703	.111	4
		Early diffusion of 5G (ED)	.297	.047	6

In terms of the sub-criteria within *economic impact*, *convergence market creation* (.801) earned a significantly larger local score than *telecommunications market expansion* (.199). In *consumer welfare*, likewise, *life-enhancing service* (.678) scored fairly more than *accessibility* (.322). Meanwhile, in *global ICT leadership*, *standard/patent leadership* (.703) was considered more important than *early diffusion of 5G* (.297).

As a result, the final criteria weights (W_C), which are the products of the first level weights and the second level local scores ($W_{C1} * W_{C2}$), showed that the most important criteria in the model are *convergence market creation* (.321) and *life-enhancing service* (.300). *Accessibility* (.142) and *standard/patent leadership* (.111) were ranked the third and fourth.

Telecommunications market expansion (.080) and *early diffusion of 5G* (.047) were considered the least important.

4.2.2. Alternative priority

4.2.2.1. Focal layer priority

As reported in Table 3, when *telecommunications market expansion* was the criterion, the ICT experts perceived *service platform* (.328) as the primary layer needing R&D resource input. *Network* (.275) and *content* (.234) scored at a similar level, while *device* (.162) scored the least. In terms of *convergence market creation*, *service platform* (.445) was found to have a substantially larger priority than *network* (.171), *device* (.176), and *content* (.208).

When *accessibility* was the criterion, *network* (.477) showed a remarkable priority than *service platform* (.207), *device* (.173), and *content* (.143). In the meantime, with regard to the *life-enhancing service* criterion, *service platform* (.413) was perceived to be the primary layer, while the other layers were ranked in order of *content* (.282), *device* (.157), and *network* (.148).

Table 3. Local scores of focal layers

	5G network		5G service platform		5G device		5G content	
	Alternative local score 1 (W_{A1})	Rank	Alternative local score 1 (W_{A1})	Rank	Alternative local score 1 (W_{A1})	Rank	Alternative local score 1 (W_{A1})	Rank
TM	.275	4	.328	3	.162	5	.234	2
CM	.171	5	.445	1	.176	3	.208	3
AC	.477	1	.207	5	.173	4	.143	5
LS	.148	6	.413	2	.157	6	.282	1
SL	.338	3	.227	4	.301	1	.134	6
ED	.382	2	.199	6	.257	2	.162	4

Note. The acronyms refer to the sub-criteria (see Table 2); Rank=rank of the criteria by the local scores a layer obtained

In terms of *standard/patent leadership*, *network* (.338) and *device* (.301) earned a similar level of local scores, whereas *content* (.134) showed a quite lower priority than the third-ranked *service platform* (.227). Finally, when *early diffusion of 5G* was the criterion, the layers were ranked in order of *network* (.382), *device* (.257), *service platform* (.199), and *content* (.162).

As a result, looking into the total weights 1, which are the aggregated products of the criteria weights and alternative local scores 1 ($\sum W_C * W_{A1}$), *service platform* (.357) was perceived to be the primary layer to invest in. The other layers yielded total weights in order of *network* (.244), *content* (.213), and *device* (.186), but the gaps between them were not substantially wide.

Table 4. Total weights of focal layers

	5G network			5G service platform		5G device		5G content	
	Criteria weight (W_C)	Alternative weight 1 ($W_C^* W_{A1}$)	Rank	Alternative weight 1 ($W_C^* W_{A1}$)	Rank	Alternative weight 1 ($W_C^* W_{A1}$)	Rank	Alternative weight 1 ($W_C^* W_{A1}$)	Rank
TM	.080	.022	2	.026	1	.013	4	.019	3
CM	.321	.055	4	.143	1	.057	3	.067	2
AC	.142	.068	1	.029	2	.025	3	.020	4
LS	.300	.044	4	.124	1	.047	3	.084	2
SL	.111	.037	1	.025	3	.033	2	.015	4
ED	.047	.018	1	.009	3	.012	2	.008	4
Total weight 1 ($\sum W_C^* W_{A1}$)		.244	2	.357	1	.186	4	.213	3

Note. The acronyms refer to the sub-criteria (see Table 2); Rank=rank of the alternatives by the alternative weight 1 and the total weight 1

4.2.2.2. Investment option priority

Alternative local score 2 (W_{A2}) in Table 5 stands for the priority weights of investment options within each layer. In the *network* layer, investment in *foundation technology R&D support* (.754) was a more viable option than *entrepreneurship support* (.246). In contrast, in the *content* layer, *entrepreneurship support* (.781) was significantly appreciated than *foundation technology R&D support* (.219). Likewise, although the gaps are narrower, the ICT experts weighted more on *entrepreneurship support* than *foundation technology R&D support* in the *service platform* layer (ES=.664; FT=.336) and in the *device* layer (ES=.531; FT=.469).

Table 5. Local scores and total weights of investment options

	5G network		5G service platform		5G device		5G content	
	FT	ES	FT	ES	FT	ES	FT	ES
Alternative local score 2 (W_{A2})	.754	.246	.336	.664	.469	.531	.219	.781
Total weight 2 ($W_{A2}^* \sum W_C^* W_{A1}$)	.184	.060	.120	.237	.087	.099	.047	.166
Rank	2	7	4	1	6	5	8	3

Note. FT=foundation technology R&D support; ES=entrepreneurship support

Finally, the total weights 2, which are the products of total weights 1 and alternative local scores 2 ($W_{A2}^* \sum W_C^* W_{A1}$), show the proportions that the alternatives should account for in the entire public 5G R&D resource. *Entrepreneurship support* in the *service platform* layer (.237) and in the *content* layer (.166) were ranked the first and the third, while *foundation technology R&D support* in the *network* layer (.184) was the second. The alternatives with the least shares

were *entrepreneurship support* in the *network* layer (.060) and *foundation technology R&D support* in the *content* layer (.047).

4.3. Findings

The key findings of the expert survey are threefold. First, the relative importance of the criteria suggests a quite clear message that the ICT experts in Korea share a common understanding of the nature of the 5G mobile industry. That is, upgrading physical networks per se is not the main driver of the next generation mobile industry. Instead, what contributes to the national economy and the welfare of people will be the innovative services delivered through it. Likewise, as the lowest importance of early diffusion of 5G and telecommunications market expansion as the criteria implies, it is time to get out of the network-oriented policy frame.

Second, service platform was considered to be the critical layer that deserves public R&D resource, mainly due to its expected contributions to convergence market creation and life-enhancing service provision. Public resource input in the network layer was the second preferred alternative, which is expected to increase mobile accessibility, global standard/patent leadership, and early diffusion of the 5G mobile network. Also, although the content layer was rated lower, taking into account its expected contributions to the most important criteria, namely convergence market creation and life-enhancing service provision, the needs for R&D resource input in this layer should not be neglected.

Third, a broad distinction between the priorities of the investment options by each layer was found. The needs for foundation technology R&D support was only highlighted in the network layer, while entrepreneurship support was weighted more in the other layers.

5. Conclusions

This study proposed a decision model for public R&D resource allocation in the 5G mobile industry, in response to the call for a revision of the ICT policy framework in Korea. The R&D plan of the MSIP has been discordant with the vision of 5G, maintaining the tradition of sector- or issue-based R&D project support. The proposed model employed a criteria-based quantitative approach and tried to embrace all the relevant technical layers and investment options.

Indeed, the model should be viewed as an exemplification of such approach. Nonetheless, the findings from the expert survey verified its validity to a certain level. First, the ICT experts formed a consensus that the network layer or the telecommunication market alone cannot be the enabler of the innovations toward the next generation mobile industry. It reinforces the necessity of reinvention of the ICT policy frameworks including R&D planning.

Second, the criteria led to the distinctions between the layers reflecting the expected contributions of each alternative. This implies that, when a criteria-based quantitative approach is adopted, we can systemically review the pros and cons of alternatives.

Third, the distinctions between the investment options along with the layers revealed that R&D plan for each layer requires different objective settings. When an R&D plan is fragmented and keeps merely patching up, defining the goals of the plan, setting aside developing appropriate strategies, would be arbitrary and inconsistent.

In sum, the major contribution of this study is that it showed a direction of revision of 5G R&D planning framework. However, although this paper tried to support the validity of the proposed model through an expert survey, it still remains rough and only ideal without considerations on the practical barriers. One of the critical limitations of the model is that independence between the levels and criteria has yet to be verified. We expect further research to employ a more sophisticated process for criteria selection and model construction, such as the Delphi method.

In addition, a systemic bias is suspected due to inequality in the specialty of the respondents, because the telecommunications and Internet experts outnumbered. However, looking into the scores each layer obtained, it was hard to find any evidence of one-sided evaluations.

This study only considered the 5G mobile industry, but such strategic modeling approach for public R&D planning can be applied to the whole ICT and media industry. It is believed that the governments' ICT policy making process must be revised incorporating strategic and systematic methodologies under consideration of comprehensive and long-term effects. Then, reviewing the entire ICT R&D policy and decision process, applying proper evaluation and revision methods, and suggesting practical public ICT R&D model will be important assignments for industry researchers.

Acknowledgements

This research was supported by National Research Foundation (NRF) of South Korea grant funded by the Korean government [NRF-2016S1A3A2924760]; MSIP(Ministry of Science, ICT and Future Planning), Korea, under the CPRC(Communication Policy Research Center) support program [IITP-2016-R7118-16-1025] supervised by the IITP(Institute for Information & communications Technology Promotion).

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