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Research Article

Is HAPS Viable for the Next-Generation Telecommunication Platform in Korea?

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HAPS is a promising technology capable of providing broadband multimedia services as an alternative to the satellite communication system or terrestrial network. In this study, economic aspects of HAPS service are analyzed, HAPS services are defined, and revenues from the defined services are forecasted assuming nine scenarios. Capital expenditure as well as operating expenditure is estimated. To evaluate the profitability of HAPS service, the net present value (NPV), payback period, and the internal rate of return (IRR) are calculated. The results show that HAPS is economically justifiable in all the scenarios. Assuming that ARPU for the service is \$35 per month in the average scenario, NPV is calculated as \$2964 million, IRR becomes 31.9%, and payback occurs in 2017, which implies that HAPS service is profitable in Korea. In addition, the results of the sensitivity analysis show that the results are fairly robust.

1. INTRODUCTION

Recent trends in the telecommunication and broadcasting market can be summarized as the digital convergence of broadband multimedia services [1]. In this drastic market changes, HAPS emerges as one of the challenging alternatives of service platform since it is expected to afford sufficient bandwidth for multimedia services for both telecommunication and broadcasting in wider areas, and to deploy the platform anywhere [2–4]. This technology is expected to combine the best features of both terrestrial and satellite delivery mechanisms and to provide not only public services such as public protection and disaster relief (PPDR), meteorological observation, and military service but also various commercial telecommunication and broadcasting services [5].

However, there is no HAPS put to practical use yet in the world, since the development of the platform requires state-of-the-art technology such as ultrathin fuel/solar cell, ultralight weight fabric, durability against an extreme environment, high confidence and high effectiveness component and so on [5, 6]. There are lots of technical risks identified during the stage of platform development, and these risks could increase the development time to reach the full broadband HAPS services, but the appropriate stepping-stone-based strategy should help mitigate this problem [7].

Perceiving those possibilities, many countries are researching related technologies enabling HAPS to be practical alternatives. In the US, Lockheed Martin is undertaking a project sponsored by Missile Defense Agency to develop an airship which stays in the stratosphere and patrols the metropolitan area. In Europe, CAPANINA project is going on to develop broadband telecommunication system based on HAPS [3, 8, 9], and a consortium called as USE HAAS which consists of more than 100 stakeholders has been organized to analyze the world state of the art including HAAS aeronautical uses, to develop tentative research objectives, and to define a technological roadmap based on the inputs given by the end-users and the possible industrial partners [8, 10]. In the CAPANINA project, Grace et al. [9, 11] investigate the viability of using aerial platform technology to deliver broadband backhaul to high-speed trains, using millimeter-wave band communications. Japan is one of the leading countries in developing broadband telecommunication system based on HAPS. Japanese engineers have demonstrated that HAPS can be a new platform to provide HDTV service and IMT-2000 WCDMA service successfully [4, 12].

In Korea, the study on the possibility of HAPS service started in 1998 by ETRI and KARI. After 2 years of research, major research projects have been launched to develop technologies related to HAPS services. In 2000, KARI and ETRI have started research projects to develop an airship and a transmitter to be operated in stratosphere, respectively.

However, for the successful introduction of HAPS in the convergence market, it must resolve several technical uncertainties including the duration of flight, quality of service, and reliability as well as conflicts with the existing terrestrial or satellite platforms. Also, the prevailing skepticism for the next-generation services must be clarified [13, 14]. More than anything else, the development of application services with HAPS and the clarification of its economic feasibility should be performed in order to achieve successful adoption of HAPS in the relevant market [2, 14].

The purpose of this paper is to provide the technoeconomic feasibility study of introducing HAPS in Korean telecommunication market. In more detail, an attempt is made to forecast the market size of HAPS services based on the planned launching schedules of the HAPS platform in Korea. By estimating the cost of providing the HAPS services as well as the revenues obtainable from the business, the profitability of the HAPS services is examined.

2. DEFINING SERVICE AND REVENUE ANALYSIS

2.1. Business model

As a broadcasting service for HAPS, super HDTV which includes two-way HDTV, VOD, and DMB is considered as a proper application service. As a telecommunication service for HAPS, HAPS 4G services which include post-Wibro service and ubiquitous service are considered as proper application services. Although PPDR and military service can be considered as noncommercial services, this research confines application services with only commercial ones.

Grace and Likitthanasate [15] suggested a business model for broadband services such as backhaul, WLAN trains, broadband internet, broadcast/multicast, PPDR, and remote sensing from HAPS, and showed that each service turns out to have positive cash flow. Therefore the two services, super HDTV and 4G services, defined in this study can be thought as future services evolved from the broadband services in Grace and Likitthanasate [15].

The business model for broadcasting service is assumed as follows: a HAPS provider (or a model company) rents HAPS platform to the broadcasting companies which would broadcast their programs via HAPS platform. In this contract, broadcasting companies should pay for rental fees to the HAPS provider and these rental fees are a part of the revenues. For telecommunication services, it is assumed that the HAPS provider sells 4G services to the customers directly. Thus, the subscription and usage fees gathered from HAPS subscribers are also a part of the revenues of the HAPS provider through the telecommunication services. Therefore, the revenue of our model company consists of the broadcasting rental fees from the broadcasting companies and telecommunication service revenue from the 4G subscribers. This value chain is depicted in Figure 1. The sole domestic satellite service provider, KT, in Korea has almost same business model as ours.

Grace and Likitthanasate [15] adopted a business modeling approach from the two perspectives: HAP operator and service providers. The HAP operator provides and maintains the payloads, and the service providers are responsible for the ground-user segment, billing system, and so on. Our model company integrates HAP operator provider as well as service providers, except for broadcast/multicast service.

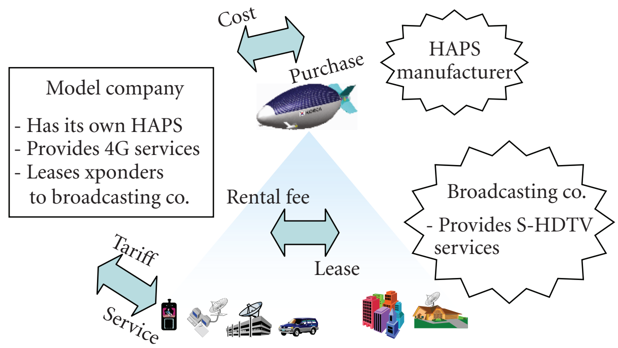

Figure 1: Value chain of the business model.

Table 1: Estimation result of the substitution-diffusion model.

Parameter	Estimates	T-value
p	2.49861E-05	1.61
q	0.820829014	17.18*
m_1	48,610,652	21.32*
m_2	−1.568E+07	−6.46*
R^2	S_1	0.9292
	S_2	0.9897

(*$P < .01$).

2.2. Demand and revenue analysis

In estimating revenues, we classified HAPS services into two categories such as telecommunication services and broadcasting services. In order to calculate the expected revenues from broadcasting services under the aforementioned business model, the number of necessary transponders and the level of transponder tariff (rental fee per payload) should be estimated. In this paper, the numerical values of them were acquired from the business data of the present satellite broadcasting market in Korea.

Table 2: Forecasting results of 3G services (unit: thousands) [1].

Year	2002	2003	2004	2005	2010
Subscribers	1,216	4,013	10,564	22,185	39,798

In order to calculate the expected revenues from telecommunication services under the telecommunication business model, the number of HAPS subscribers and average revenue per user (ARPU) estimates are needed. In this paper, the number of HAPS subscribers is forecasted analytically using diffusion-substitution model, and ARPU is assumed using the business data of the present mobile telecommunication market in Korea.

In forecasting the HAPS subscribers, the following assumptions are made: (1) the number of 4G service subscribers includes subscribers of all the broadband services regardless of the platform; (2) the former service of 4G service is equivalent to so-called IMT-2000 and we call it as 3G service; (3) the diffusion-substitution process from 3G to 4G service would be similar to the transition from pager service to mobile phone service in Korea, which implies 4G service would replace 3G very rapidly; (4) the study period is from 2011 to 2020; (5) the saturated level of subscribers is 35 million.

There might be arguments that the assumption (3) is too simple. However, it is well known that the emergence of the mobile phone service replaced the former pager service very rapidly in Korea. Thus, if we consider that 4G services would emerge along with the attractive and advanced service concepts like telecommunication-broadcasting convergence, it may well forecast 4G services' rapid substitution for 3G services. This is why we adopted the assumption.

To analyze the demand transition process from 3G to 4G services, we utilized the diffusion-substitution model of Norton and Bass [4] and it can be written as follows:

$$\begin{aligned} S_1(t) &= m_1 F(t)\left[1 - F(t-\tau_2)\right], \\ S_2(t) &= \left[m_2 + m_1 F(t)\right] F(t-\tau_2), \end{aligned} \tag{1}$$

where $F(t) = (1 - \exp[-(p+q)t])/(1 + p/q \exp[-(p+q)t])$.

In (1), the subscript $i = 1$ implies the old generation service, and $i = 2$ is the new generation service. $S_i(t)$ denotes the cumulative number of subscribers for service i by time t, m_i denotes the potential saturated level of subscribers for service i, and τ_2 is the market entry time of new service. p and q are parameters indicating interactions in the market.

The parameters of (1) were estimated using the nonlinear least square procedure of SYSLIN in SAS with the data for annual number of subscribers of pager and mobile phone services from 1985 to 2003. Table 1 shows the result of estimation.

The estimated value p, coefficient of innovation, is not significant, while the others are all significant with $P < .01$. Examinations of R^2 values indicate very good fitness for both equations. One intriguing result is the negative sign of m_2. In general, the sign of m_i is expected to be positive, in cases that each generation can do everything

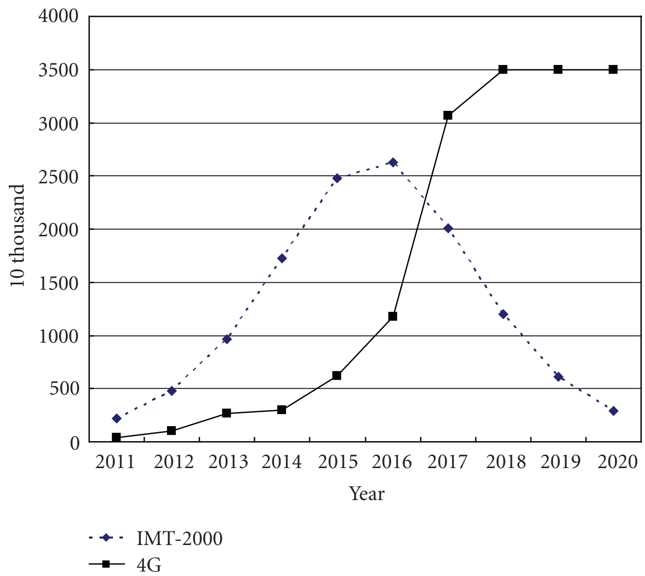

Figure 2: Demand forecasting of the 3G and 4G service subscribers.

(and possibly more) the previous generation could do, and the market does follow the substitution of actual and potential subscription from earlier generations to later generations [16]. However, Norton and Bass [17] noted that the last m_i sometimes comes out negative but they offered only the statement that they do not trust this last m_i very much.

On the other hand, Speece and Maclachlan [18] added more positive interpretation that, in negative case, the new generation service does replace the old one but does not increase the market potential. In addition, Chun and Ko [19] suggested that the reason of negative sign might come from the fact that the potential demand could be regarded not as in absolute value but in relative value compared with the competitive service. We concluded that those explanations can be applied to the result of this paper in the same way.

In applying the above estimation results to forecast 4G subscribers, we modified the potential market scale considering the market expansion of 3G and 4G telecommunication services in comparison with pager or mobile phone using the previously published forecasting results of 3G subscribers in Table 2.

Using the estimation result of Table 1 as analogy values of parameters and the number of subscribers of Table 2 as a data set, we forecasted the number of subscribers of 3G and 4G services and the results are depicted in Figure 2.

As aforementioned assumption, the forecasting result of 4G services in Figure 2 includes subscribers of all the broadband services regardless of the platform. Therefore, to separate the subscribers of only HAPS service among the total 4G subscribers, the penetration rate of HAPS service should be obtained.

In this paper, the penetration rate was calculated through benchmarking the current market structure of Korean

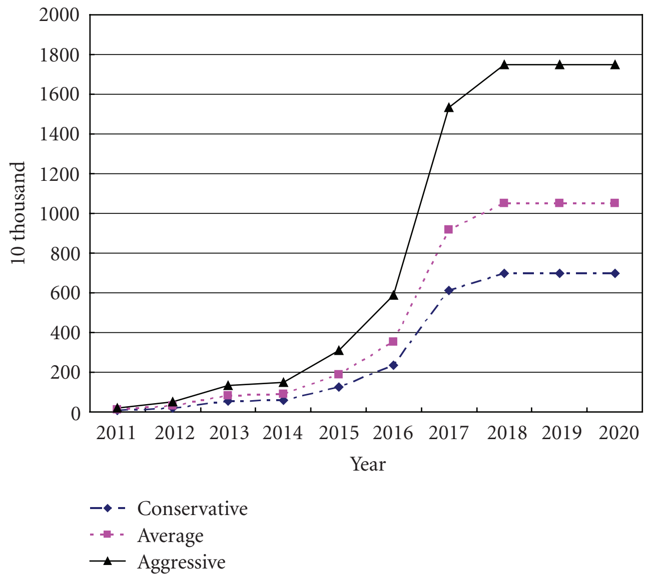

FIGURE 3: HAPS service demand forecasting result.

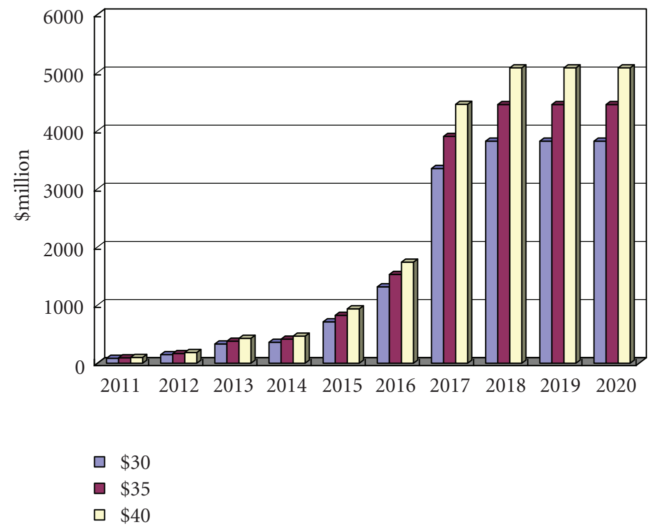

FIGURE 4: Forecasted revenues from HAPS business.

mobile phone market. Currently, three service providers—SK Telecom, KT Freetel, and LG Telecom—remain in the Korean mobile phone industry and those three companies divide the total market with the market share of 52% (SK Telecom), 32% (KT Freetel), and 16% (LG Telecom), respectively. We derive the penetration rate as if one of the three companies would decide to utilize HAPS platform as a means of providing 4G services to their customers. Thus, penetration rates used in calculating the subscribers of HAPS service are 52%, 32%, 16%, and we call them as aggressive, average, and conservative scenarios of HAPS demand, respectively.

Assuming the penetration rate of HAPS service demand as 52% (aggressive), 32% (average), 16% (conservative), the final HAPS service demand forecasting results are depicted in Figure 3. In Figure 3, it is forecasted that the number of HAPS service subscribers will start from 120 thousands in 2011 and increase up to10 million in 2020.

To calculate the revenues of HAPS telecommunication services, we assume ARPU as $35 per month which is the current APRU of mobile phone in Korea [20] and multiply it by the number of HAPS subscribers. In addition, we consider two more cases of ARPU, $30 as a cheaper scenario and $40 as an expensive one. Consequently, the forecasted revenues from HAPS business are obtained by summing broadcasting revenues and telecommunication revenues and Figure 4 illustrates the results.

3. COST ANALYSIS OF HAPS SERVICES

Since HAPS is still in developing stage worldwide and developers have been hesitant to release the cost information publicly, it is hard to figure out or estimate the actual costs accurately. Thus, we have collected cost information of platforms and facilities by informal interviews with the developers and experts in Korean research institutes. The interviews were performed in several stages similarly to Delphi method. First, the cost items are defined by the group discussion with the experts. In the next interview, the questionnaire shown in Table 3 is prepared and asked to fill out. Then, the results are reviewed by other experts, and the cost is adjusted to obtain the final estimates.

In addition, we adopt an analogy method to the satellite services for other cost information since we have reasoned that the proportional breakdown of cost to provide telecommunication services via HAPS would be similar to that of the satellite services. In particular, we have quoted cost data of Mugunghwa satellite launched by Korean Telecommunication (KT) who is a sole provider of satellite telecommunication service in Korea.

Although it is not straightforward to define the detailed specifications of facilities in the early stage of the development, at least general requirements of the facilities should be defined using the technical terms in order to estimate the cost of facilities. The general requirements of the target airship and transponder defined by the developers are summarized in Table 4. In Table 4, operational requirements as well as the airship specifications are defined.

According to the interviews with the developers of HAPS in Korea, they have anticipated to complete the development of HAPS by the end of 2010 and suggested a deployment plan as in Table 5. They have conjectured that it would take 6 years for full-scale deployment from 2011 until 2016 and 30 airships (5 spare), 3 control centers, and 8000 gap fillers would be required to cover the entire region of Korea.

It is known that a Korean mobile telecommunication company operates 12 000∼13 000 terrestrial base stations for a nationwide coverage. Since a transponder can provide 500 beams, we may need 24∼26 transponders for the same coverage. Thus, 25 transponders or airships are assumed. In Figure 5, the potential cells covered by the 25 airships are displayed in circles. The size of the each cell is determined

Table 3: Sample questionnaire.

	Module	Unit cost	No. of units required	Total cost
Airship	Envelop material			
	Envelop manufacturing			
	. . .			
	subtotal			
Transponder	Antenna			
	Modulator			
	. . .			
	subtotal			
Control center	TT & C			
	Flight dynamics system			
	. . .			
	subtotal			
Land facility	Mooring			
	Gas tank			
	. . .			
	subtotal			

Table 4: Key aspects of the airship and transponders.

	Factors	Value
Airship	Length/Max. diameter	200 m/50 m
	Mass/payload mass	20 ton/200 kg(5KW)
	Max. altitude	20 km
	Max. speed	20 m/s
	Reposing tolerance	Less than 1 km,
	Propulsion system	fuel cell, solar cell, elec. motor Power(max): 80 kW(100 kW)
	Operating time	Mote than 72 hours
Transponder	Mass	1 ton
	Size (W × H × L)	6 × 2 × 2
	No. of beams	500
	Power	20 kW

with the wave angle of 20∼30 degrees and varies depending on the population density. Since the number of beams available by a single airship is fixed, the radius of area covered by a single airship is smaller in densely populated area.

One control center is assumed to handle ten airships, and the required number of gap fillers is quoted from the Korean satellite DMB service company.

Based on the analogy mentioned above, we classified total cost into two categories such as investment on facilities and operating costs. Investment cost includes investment on a fleet of airships equipped with transponders, ground facilities such as control centers and launching facilities, and a number of gap fillers to cover the shadow regions. Additional expenses including insurance cost, supervising cost, and incidental expenses are accompanied. We do not consider R&D cost for developing HAPS since our focus is on the service market, and the service providers would purchase necessary equipments from the developers.

Based on the interviews, the major cost items of the airship and their costs are summarized in Table 6 [6]. The manufacturing cost of the first unit of airship is estimated as about \$41.75M while the manufacturing cost of the first unit of transponder is estimated as \$15M.

From the second unit of airship and transponder, we have applied learning effect in estimating the manufacturing cost. Learning effect is based on the concept that resources required to produce each additional unit decline as the total number of units produced increases. The learning effect can be expressed as a learning curve in

$$Y = AN^b, \tag{2}$$

where Y = unit value of the Nth unit, A = first unit value, N = unit number, $b = \log \phi / \log 2$.

In applying (2), the value of ϕ differs depending on the industry. According to the Cost Estimation Handbook by NASA, the value of ϕ is 0.85 for aerospace industry and 0.94 for electronics manufacturing. Thus, we applied $\phi = 0.85$ and 0.94 for the airship and transponder, respectively. The decreasing of manufacturing costs is shown in Figure 6.

The cost of control center is estimated to be \$1M, and the unit price of gap filler is quoted as \$50 000. Also, the launching facility is expected to be ready before 2011 and the estimated capital investment is \$61.8M.

Operating Expenses include labor costs, maintenance cost, utility cost, tax, general and administrative (G&A)

Table 5: Yearly required number of equipments and facilities.

year	Service area	No. of airships required	Cumulative no. of airships	No. of control centers
2011	Seoul and its vicinity	1(op.) + 1(spare)	2	1
2012	Metropolitan cities	6(op.) + 2(spare)	10	0
2013	Densely populated area	8(op.) + 2(spare)	20	1
2014	Whole country	10(op.)	30	1

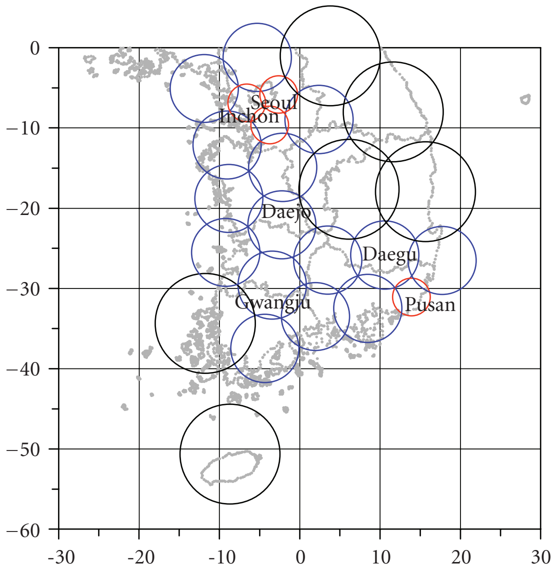

Figure 5: Airship deployment plan.

Table 6: The estimated cost for the airship.

Module	Cost ($M)
Envelop material	3.5
Envelop manufacturing	3.0
Gondola	1.5
Structure	1.5
Solar cell	2.5
Fuel cell	3.7
Emergency battery	0.3
Thrust motor system	1.0
System integration	1.0
Flight Control system	7.3
Pressure control system	1.5
Electric system	3.0
Communication devices	6.0
Ground control devices	1.0
Assembly	2.0
Test/inspection	2.0
System control devices	1.0
Total	41.75

cost. Labor expenses are estimated by multiplying the sales estimation with the average ratio of labor cost to total sales quoted from the balance sheet of KT for the recent 3years. Maintenance cost and utility cost are estimated proportional to cumulative investment. Tax is estimated as 10% of the sum of depreciation, maintenance cost, and utility cost. G&A cost is estimated by multiplying the sales estimation with the average ratio of G&A cost to total sales quoted from the balance sheet of KT for the recent 3 years. On the other hand, operating cost of launching facility is assumed to be 5% of total construction cost per year and any royalty is not considered.

Based on the above estimation, the total cost for each year is obtained by summing up the investment cost and operating costs. The results are shown in Table 7 for the case with average number of subscribers and monthly ARPU of $35. (The ARPU per month in Korean mobile telecommunication market is about $35 in 2006.)

4. ECONOMIC FEASIBILITY ANALYSIS OF HAPS

To perform economic feasibility analysis of HAPS service, cash flow is calculated based on the revenues data and total cost of each year presented in Figure 4 and Table 7. The basic assumption for the economic feasibility analysis is as follows: (1) the minimum attractive rate of return (MARR) is 8%; (2) the base period for the NPV analysis is year 2011.

The cash flow and profit for each year under average demand and ARPU of $35 per month are shown in Figure 7. Also, the results of economic feasibility analysis under different demand conditions and ARPUs are summarized in Table 8 including NPV, internal rate of return (IRR), and payback period for each scenario.

As expected, the results in Table 8 show that IRR and NPV increase as the ARPU per month increases. Under average demand and ARPU of $35 per month, the first year with profit is in year 2015, IRR is 31.9%, and payback period is 2017, which implies that HAPS service is economically justifiable. Table 8 also shows that all the 9 scenarios are economically justifiable since NPV is positive, IRR is higher than MARR, and payback is within 10 years form the service starting point.

Finally, since the estimated costs are subject to change, sensitivity analysis on the cost is performed. The cost of facilities may be larger or smaller than estimated costs as the detailed requirements are available and by the advances in technology or development of new materials. The effects of changes in investment costs on facilities are analyzed assuming that the investment costs may either increase or decrease by 10%, respectively. The results are summarized in Table 9. If the cost decreases by 10%, the overall profitability increases as expected but the payback periods remain the

Table 7: Total cost for each year (average demand, ARPU = $35/month).

Year	Capital expenditure	Maintenance cost	Utility cost	Taxes and public utilities charges	Labor cost	G&A cost	Operating cost of launching facility	Total
2010	61.80	—	—	—	—	—	—	61.80
2011	319.49	10.48	1.82	3.41	24.95	24.29	3.09	387.53
2012	565.99	29.04	5.04	10.18	44.68	43.51	3.09	701.53
2013	612.76	49.14	8.52	17.46	102.84	100.13	3.09	893.94
2014	544.03	66.99	11.62	23.75	111.99	109.04	3.09	870.51
2015	40.00	68.30	11.85	24.31	223.51	217.63	3.09	588.69
2016	40.00	69.61	12.08	24.86	414.25	403.34	3.09	967.23
2017	—	69.61	12.08	24.86	1059.15	1031.27	3.09	2200.05
2018	—	69.61	12.08	24.86	1208.29	1176.47	3.09	2494.40
2019	—	69.61	12.08	24.86	1208.29	1176.47	3.09	2494.40
2020	—	69.61	12.08	24.86	1208.29	1176.47	3.09	2494.40

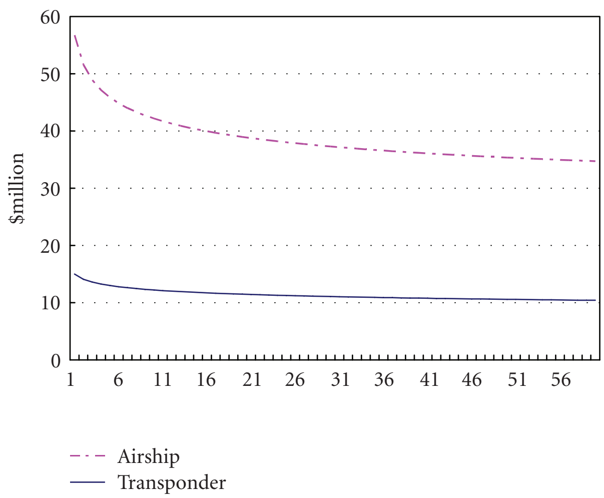

Figure 6: The manufacturing cost reduction by the learning curve.

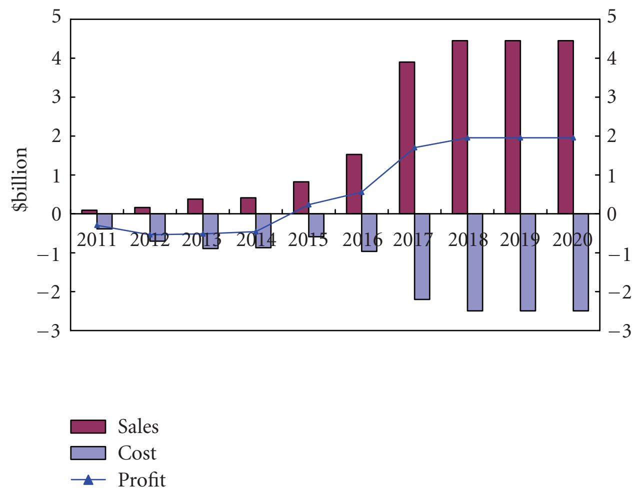

Figure 7: Cash flow and profit (average demand, ARPU = $35/month).

Table 8: Results of economic feasibility analysis.

Demand		ARPU ($/month) 30	35	40
Conservative	NPV*($M)	766	1,254	1,743
	IRR(%)	15.7%	19.9%	23.7%
	payback	2019	2018	2018
Average	NPV*($M)	2,231	2,964	3,697
	IRR(%)	27.1%	31.9%	36.2%
	payback	2018	2017	2017
Aggressive	NPV*($M)	5,163	6,384	7,605
	IRR(%)	44.0%	49.9%	55.4%
	payback	2017	2017	2017

*as of 2011.

same except the last case. The results of increase in cost by 10% show similar trends except that the profitability reduces.

5. CONCLUSION

S-HDTV (100 Mbps, bidirectional) and 4G service (100 Mbps) can be considered as proper application services for HAPS. A new broadcasting provider is assumed to get the permission to use HAPS platform for S-HDTV. The number of HAPS 4G subscribers is forecasted as 120 000 in 2011 and is growing up to 10 million in 2020 under the average demand scenario. Assuming that ARPU for the 4G service is $35 per month in the average scenario, NPV is calculated as $2,964 million, IRR becomes 31.9%, and payback occurs in 2017, which implies that HAPS service is profitable in Korea.

However, we should be cautious to conclude that HAPS service is profitable in Korea. First, the technological development would not advance as expected, which may threaten the provision of HAPS and consequently delay the service

Table 9: Sensitivity analysis on the investment cost.

	Demand		ARPU ($/month)		
			30	35	40
10% cost decrease	Conservative	NPV*($M)	973	1,462	1,950
		IRR(%)	18.5%	22.8%	26.6%
		payback	2019	2018	2018
	Average	NPV*($M)	2,439	3,171	3,904
		IRR(%)	30.2%	35.1%	39.7%
		payback	2018	2017	2017
	Aggressive	NPV*($M)	5,370	6,591	7,812
		IRR(%)	47.8%	54.1%	59.9%
		payback	2017	2017	2016
10% cost increase	Conservative	NPV*($M)	515	1,004	1,492
		IRR(%)	12.9%	17.0%	20.6%
		payback	2019	2019	2018
	Average	NPV*($M)	1,981	2,714	3,446
		IRR(%)	24.0%	28.6%	32.7%
		payback	2018	2018	2017
	Aggressive	NPV*($M)	4,912	6,133	7,355
		IRR(%)	40.2%	45.8%	51.0%
		payback	2017	2017	2017

*as of 2011.

schedule. Second, the cost and revenue forecasts are subject to change. This study has been made in the very early stage when there is no commercial HAPS system available in the world. Therefore, it is very hard to obtain reliable data, which in turn reduce the accuracy of the results. Third, risk factors are not explicitly included in the analysis.

REFERENCES

[1] S. H. Kim, "2010: The future of information and telecommunication services," KISDI, 2004.

[2] J. Ahn, J. Kim, C. Park, and D. Lee, "An analysis of HAPS application services and its economic feasibility study," ETRI, 2005.

[3] D. Grace, M. Mohorcic, J. Horwath, M. H. Capstick, M. Bobbio Pallavicini, and M. Fitch, "Communications from aerial platform networks delivering broadband for all—an overview of the CAPANINA project," in *Proceedings of the International HAPS Workshop*, Seoul, Korea, November 2004.

[4] R. Miura, "R&D activities on the wireless systems using stratospheric platform in Japan," in *Proceedings of the International HAPS Workshop*, Seoul, Korea, November 2004.

[5] J. Ahn, J. Kim, D. Lee, and D. Ahn, "A competitive analysis on the network infrastructures of WiBro service in Korea," in *Proceedings of the 25th AIAA International Communications Satellite Systems Conference (ICSSC '07)*, Seoul, Korea, April 2007.

[6] J. Kim, J. Ahn, and D. Lee, "An economic analysis of High Altitude Long Endurance Airships project," KARI, 2005.

[7] CAPANINA Project Deliverable, "D12—Delivering Broadband for All from Aerial Platforms including commercial and technical risk assessments," CAP-D12-WP12-BT-PUB-01, 2005.

[8] T. Tozer, "HAPS R&D in Europe," in *Proceedings of the International HAPS Workshop*, Seoul, Korea, 2006.

[9] CAPANINA Project Deliverable, "D26—Applications and Business Models for HAP Delivery," CAP-D26-WP10-BT-PUB-01, 2007.

[10] http://www.usehaas.org.

[11] D. Grace, M. H. Capstick, M. Mohorcic, J. Horwath, M. B. Pallavicini, and M. Fitch, "Integrating users into the wider broadband network via high altitude platforms," *IEEE Wireless Communications*, vol. 12, no. 5, pp. 98–105, 2005.

[12] R. Miura, "R&D update on HAP in NICT," in *Proceedings of the International HAPS Workshop*, Seoul, Korea, 2006.

[13] D. Ahn, J. Park, B. Koo, and P. Lee, "A study on the stratospheric communication system technology," ETRI, 2001.

[14] J. Ahn, J. Kim, and D. Lee, "An analysis on the economic evaluation of the HAPS system," *IE Interfaces*, vol. 17, pp. 62–68, 2005.

[15] D. Grace and P. Likitthanasate, "A business modeling approach for broadband services from high altitude platforms," in *Proceedings of the 13th International Conference on Telecommunications (ICT '06)*, Funchal, Portugal, May 2006.

[16] J. A. Norton and F. M. Bass, "A diffusion theory model of adoption and substitution for successive generations of high-technology products," *Management Science*, vol. 33, no. 9, pp. 1069–1086, 1987.

[17] J. A. Norton and F. M. Bass, "Evolution of technological generations: the law of capture," *Sloan Management Review*, vol. 33, no. 2, pp. 66–77, 1992.

[18] M. W. Speece and D. L. Maclachlan, "Application of a multi-generation diffusion model to milk container technology," *Technological Forecasting and Social Change*, vol. 49, no. 3, pp. 281–295, 1995.

[19] Y. S. Chun and Y. K. Ko, "A Study on the Dynamic Behavior of mobile telecommunication market due to the emergence of new services," *Journal of Information Strategy Development*, vol. 7, no. 1, pp. 129–149, 2000.

[20] Marketing Inside, "Survey of tariff of mobile phone subscribers," Telecom report, 2006.