The Socio-Economic Impact of Allocating Spectrum for Mobile Broadband Services in Vietnam

Hanoi, Vietnam

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Report for the GSM Association

The Socio-Economic Impact of Allocating Spectrum for Mobile Broadband Services in Vietnam

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TABLE OF CONTENTS

The Socio-Economic Impact of Allocating Spectrum for Mobile Broadband Services in Vietnam iii

TABLE OF CONTENTS iv

EXECUTIVE SUMMARY 1

BACKGROUND 7

1. Spectrum Overview 7
2. Industry Classification 10
3. Vietnam's Frequency Planning on IMT 10
4. Spectrum Allocation 12
5. Vietnam's Planning on IMT Spectrum 13

PART I 14

SPECTRUM REQUIREMENT ESTIMATION FOR IMT SERVICES IN VIETNAM BY 2020 14

1 - Spectrum Requirement Estimation Report on GSMA Method 15

1.1. Introduction 15
1.2 Overview of GSMA model 15
1.3 Revised Spectrum Forecasts using GSMA Method Worldwide. 17
1.4. Analysis of Data Input in Vietnam 21
1.5. Results 30
1.6. Conclusion 34

2 - ITU-R Method 35

2.1. Methodology Overview 35
2.2. Input parameter definitions 37
2.3. Analyzing Vietnam's Market 44
2.4. Input Parameters 47
2.5. Output Results 57
2.6. The National Spectrum Requirements in other countries 59
2.7. Conclusions 60

PART II 61

THE SOCIO-ECONOMIC IMPACT OF ALLOCATING SPECTRUM FOR MOBILE BROADBAND SERVICES IN VIETNAM 61
3 - The Total Impact on Economic Growth of Spectrum 62
3.1. The main framework 62
3.2. The Revenue Forecast 64
3.3. The Economic Impact of Spectrum 67
4 - The Economic Benefits of Spectrum 77
4.1. Spectrum Allocation and Demand in Vietnam 77
4.2. Scenarios for Alternative Use of Released Spectrum 79
4.3. Economic Benefit 80
4.4. Net Economic Benefit 81
5 - The Social Benefits of Spectrum 95
5.1. Improving the Service Quality of Social Enterprise 95
5.2. The importance of an all-round increase of digitalized applications in urban services 96
5.3. Serving the modernization of rural communities 97
5.4. Other Benefits 98
CONCLUSIONS 100
Appendix- GSMA Method Tabulated Table of Calculating Spectrum Requirement by 2020 102
Annex 1 - S-Shaped Curve 104
Annex 2 - Total Impact (Leontief) 106
Annex 3- The Other Basic Factors 109
REFERENCES 111

EXECUTIVE SUMMARY

The importance of the role played by radio spectrum in modern economies has grown rapidly in recent years. In 2013, the economic impact of spectrum based services in Vietnam generated some US$ 5.1 billion in revenues alone. However, spectrum is finite. It is therefore the role of the country's policy makers to ensure various industries have fair access to this scarce resource.

Since the license of the first 2G mobile networks in Vietnam in 1993, the market has seen an impressive growth in the mobile sector. The landscape of the mobile sector has been re-shaped significantly by the decision to open up the 3G market in 2009. Market mechanisms have played a more active role in the allocation of spectrum as a result of the beauty contest decision.

Vietnam now has a great opportunity to bring the mobile broadband market up to a new level, with the Prime Minister's decision to allow the first spectrum auction of 2.6 GHz band. Mobile broadband has received a new push from the Ministry of Information and Communications with the newly ratified Circular 04/2015/TT-BTTTT to allow spectrum re-farming in the 850/900/1800 MHz for International Mobile Telecommunications (IMT).

The mobile industry has contributed steadily to the Vietnamese economy over the last 5 years, and it reached approximately 1.23% of GDP in 2013. In order to extend the success of this sector, and to regulate spectrum efficiently and transparently, regulators need to make well-informed decisions to ensure the most efficient use of the spectrum resource.

This report is jointly conducted by:

- The Faculty of Electronics & Telecommunications, VNU University of Engineering & Technology, Vietnam National University, Hanoi,
- The Economic Research Institute of Posts and Telecommunications, Posts & Telecommunications Institute of Technology.

This report answers some key questions to be addressed by the policy makers:

1. How much spectrum will be needed for IMT in Vietnam up to 2020?

2. How should the spectrum shortage of future spectrum for IMT be addressed?

3. How might these allocation strategies affect the other sectors? Which strategy will yield the most positive outcome to the economy as a whole?

To answer these points, Part I of this report - conducted by the Faculty of Electronics & Telecommunications, VNU University of Engineering & Technology, Vietnam National University, Hanoi - is focused on the spectrum demand based on the current statistical data and trend of the mobile market. It first estimated the spectrum demand of IMT in Vietnam by using different scenarios of data growth, considering data usage of around 4, 6 and 8 GB per unique user per month by 2020. The results of spectrum requirements are in the range of 1037 MHz to 1747 MHz for the year 2020 as shown in Figure 1 below.

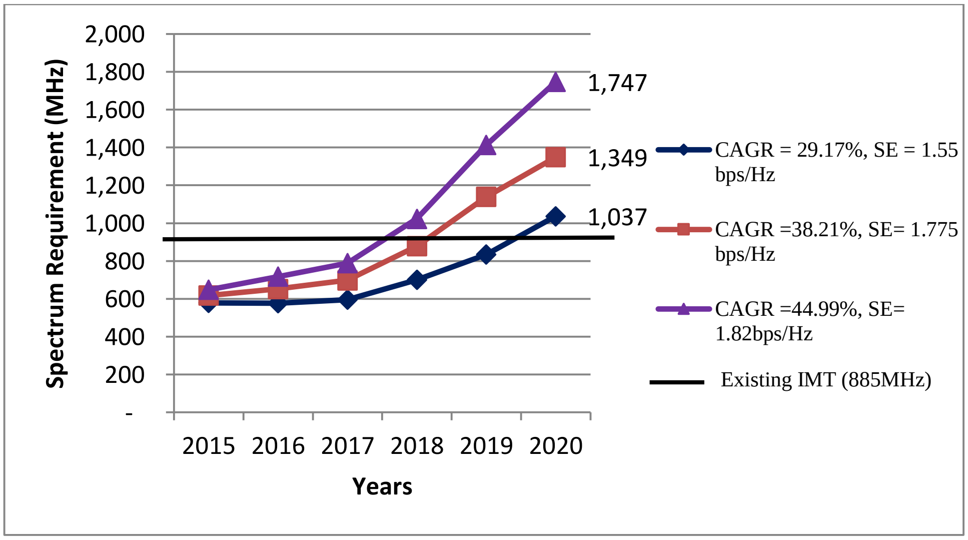

Figure 1: Vietnam Spectrum Requirement up to 2020

This report also carried out a separate study using the ITU-R methodology and it resulted to 1360 MHz required for IMT by 2020, this value places it at the middle scenario. Moreover, Cisco VNI forecasted the rest of APAC mobile data usage per unique user to be approximately 6 GB/month in 2019; this is also the middle scenario.

Based on the above estimation, we define the spectrum requirements as the middle scenario, resulting to 1349 MHz of spectrum required for IMT in 2020.

Comparing this result to the existing spectrum identified for IMT of 885 MHz (illustrated by the black horizontal line in Figure 1), there is a spectrum shortfall of over 460 MHz for the mobile industry by 2020.

Currently, the following frequency bands have been or expect to be allocated for mobile broadband in Vietnam:

Table 1: Frequency bands for mobile broadband in Vietnam

Frequency bands	Frequency range [MHz]	Reference	Remark
450 MHz	463.08-467.37; 453.08-457.37	Decision 07/2007/QĐ-BTTTT	
700 MHz	694-806		Not yet allocated
850 MHz	824 - 835; 869 - 880	Decision 25/2008/QĐ-BTTTT Circular 04/2015/TT-BTTTT	
900 MHz	880 - 915; 925 - 960	Decision 25/2008/QĐ-BTTTT Circular 04/2015/TT-BTTTT	
1800 MHz	1710 - 1780; 1805 - 1880	Decision 25/2008/QĐ-BTTTT Circular 04/2015/TT-BTTTT	
2100 MHz	1900-1980; 2010-2025; 2110 - 2170	Decision 03/2005/QĐ-BBCVT	
2.3 GHz	2300 - 2390		Not yet licensed
2.6 GHz	2500 - 2690		Not yet licensed

In total, around 370 MHz has been licensed from the 685 MHz that has been allocated to the mobile sector in Vietnam

To address the market demand for ever increasing IMT spectrum to accommodate the surge of mobile traffic the research will try to look for available spectrum. The report will suggest some potential reallocation strategies to address the shortage of spectrum for IMT. The reallocated spectrum may come from other sectors.

The second section of this report, Part II, was carried out by The Economic Research Institute of Posts and Telecommunications, Posts & Telecommunications Institute of Technology. This part determines the impact on the mobile industry and other spectrum holding industries, namely satellite, broadcasting and, civil aviation industries, to the Vietnamese economy.

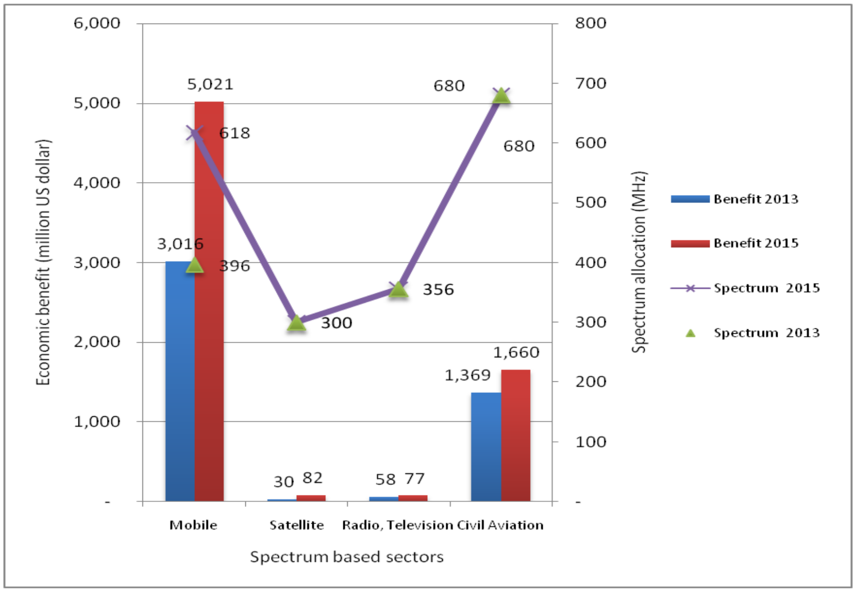

Figure 2: Economic Benefits vs. Spectrum Allocation in 2013–2015

There is a noticeable unbalance between the economic contribution and the amounts of spectrum allocated to each sector. Figure 2 shows the comparison between the percentage of spectrum holding in the frequency range 450 MHz to 5 GHz and the economic benefits of each sector.

Based on the results above, different re-allocation strategies are defined and evaluated from the economical viewpoints to address the mobile spectrum shortfall. The scenarios are defined in an incremental way, determined by the amount of spectrum allocated to the mobile industry in 2020, assuming the additional spectrum could be made available from other sectors. The scenarios under consideration are as follows:

a) 685 MHz: the base scenario where no more additional spectrum is assigned to mobile operators and their spectrum holding for mobile services stays the same as today.

b1) 855 MHz: all existing IMT identified spectrum is made available to mobile operators. This will have no impact on other sectors.

b2) 977 MHz: in addition to b1, the APT 700 band is also made available. This will impact the broadcasting industry to some degree.

b3) 1,117 MHz: in addition to b2, L-band is also added to mobile service, with no impact on the 3 other sectors under consideration.

b4) 1,267 MHz: in addition to b3, an additional 100 MHz from 2.7-2.9 GHz band and 50 MHz from other civil aviation bands is reallocated to mobile. This will not impact directly the aviation revenue and the associated economic benefits. However it will come at a cost of upgrading or moving the radars to alternative bands (total impacts of US $10 M assuming 5 civil aviation radars at US $2 M per radar).

b5) 1,367 MHz: in addition to b4, an additional 100 MHz from broadcasting services is reallocated to mobile.

b6) 1,467 MHz: in addition to b5, an additional 50 MHz from broadcast and 50 MHz from other civil aviation services are reallocated to mobile.

The authors would like to indicate that all the above scenarios are suggestions and are evaluated only from pure economic impact research view point. The authors are well aware of the difficulties in spectrum reallocation. The civil aviation bands are not easily re-farmed due to existing essential equipment. Satellite spectrum is also hard to reduce because of the operation of Vinasat-1 satellite. Spectrum from digital dividend in broadcasting sector will be the most viable way to address the shortfall of IMT spectrum. Therefore, reallocating spectrum from the broadcasting sector is considered first in our research.

Analysis from other view point is out of the scope of this research.

Figure 3 shows the combined economic benefit in 2020 for all 4 sectors under each scenario described above.

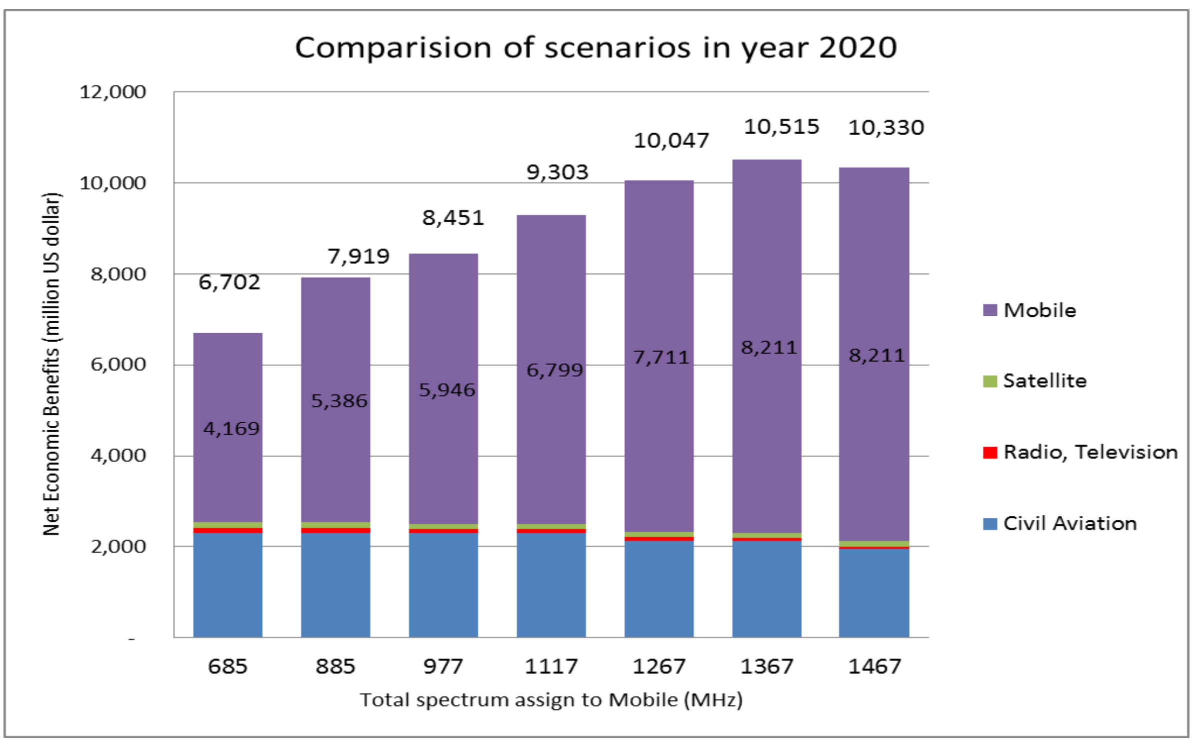

Figure 3: Comparison of scenarios for additional spectrum for mobile

The results clearly demonstrate that, although the spectrum reallocation will affect other sectors to some degree, IMT makes a significant contribution to the economy in all scenarios. This contribution is highest when all IMT spectrum demand is satisfied, i.e. in scenarios around 1,367 MHz. The combined economic benefit of all other sectors is also highest in these scenarios and not adversely affected. The total net economic benefits across all sectors do not equal twice that of IMT, representing a difference of approximately US$ 4 billion. Therefore, adequately addressing the demanded spectrum for IMT will result in a huge, sustainable gain to the Vietnamese economy overall.

In addition to the economic benefits, there is also a wealth of social benefits that are associated with a steady development of mobile broadband:

- Higher mobile penetration would stimulate innovation and create new businesses and jobs,
- Rural areas lacking the fixed infrastructure would benefit from mobile services to access communication and internet services,
- Mobile would improve public access to education and health services and e-government for all.

This report demonstrates that the mobile industry is contributing more from an economic and social standpoint than any other service using spectrum. Nevertheless, it is not the objective of this report to recommend that any of the considered services or industries should give back their entire spectrum and be discontinued. Each industry is important in its own way, and economic contribution is only one of the many important aspects to be considered when policy makers make decisions on spectrum management issues.

As with any scarce resources, striking a good balance between the needs of each sector is a complex and delicate matter. Effort must be made to ensure spectrum is used more efficiently by reducing wastage and increasing sharing among different services. If a portion of spectrum could be made available and repurposed from low-value uses to higher ones, it could greatly stimulate the economic growth for the Vietnamese market and create a win-win situation for all.

The authors of the report wish to indicate that some conclusions and views presented in this report are the views of the research groups only. As political factors into spectrum management have not been considered in this report, these views may not fully align with the current practice in Vietnam. However, it is hoped this report could be a valuable contribution toward a better policy and spectrum management in Vietnam.

BACKGROUND

The Faculty of Electronics & Telecommunications, VNU University of Engineering & Technology, and Vietnam National University has conducted research and addressed the issue of spectrum requirements for mobile broadband services in Vietnam. The rapid growth of wireless communication development in recent years in all socio-economic aspects is the fundamental force driving the demand on spectrum uses. Authority of Radio Frequency Management (ARFM), cooperating with Posts and Telecommunications Institute of Technology undertook a rigorous assessment of the socio-economic benefits of spectrum planning in Vietnam. This includes the marginal value of spectrum to other services such as broadcasting, civil aviation and satellite communications where appropriate.

1. Spectrum Overview

Radio spectrum can be used in various applications in socio-economic life, from telecommunications, broadcasting to aviation, maritime and science services. It is an important natural and strategic resource to a nation. In recent years, the field of radio technology is entering into a prosperous era of fast development, with various innovative technologies emerging and being applied commercially in a rapid manner. The enormous economic value of radio frequency becomes a publicly-known fact. The direct contradiction between the have and have-not, abundance and shortage, high- and low-efficiency of use of the spectrum resource between different sectors has become all the more salient. On the one hand, certain units and agencies possess some spectrum band, which is kept idle and unused; while on the other hand, some overused spectrum band, with the development of new technology and an increase in the number of users and service load, becomes so crowded that it can no longer meet the needs of further development. This contradiction has, to a certain extent, constrained the further development of radio-related sectors in Vietnam.

In line with this, using traditional frequency bands for mobile broadband is becoming the undeniable trend in wireless communications. Mobile broadband can not only satisfy the growing demands of customers but also enhance the country's economics and contributing to overall social affairs.

The studies for allocating spectrum for the IMT system designed by ITU-R WP5D is used not only as reference for spectrum planning by regulatory bodies across nations around the world, but also as guidance for manufacturers, to enable economies of scale and reduce barriers for international roaming. At the moment, spectrum is allocated on a technology neutral basis for mobile services and can, in principle, be used for the deployment of any technology in the future. If reallocation is considered, care must be taken that the services in the current frequency bands, are protected from the issue of interference from adjacent bands.

In order to avoid interference among services, and to ensure an effective use of the spectrum resources, the ITU has devised radio management policy, offering planning of using spectrum from 9 kHz to 3000 GHz. Regulatory bodies around the world have correspondingly made their own radio management policy, to plan service applications on various frequency bands. In the latest version of radio management policy, various spectrum resources have been allocated for the IMT service in order to meet the increasing demands on spectrum.

International Planning on the IMT-related Spectrum

New frequency bands have been allocated for the IMT service at the following three conferences, namely WARC-92, WRC-2000, and WRC-07. Such frequency bands include 450-470 MHz, 698-960 MHz, 1710-2025 MHz, 2110-2200 MHz, 2500-2690 MHz, 2300-2400 MHz, and 3400-3600 MHz, of which 698-960 MHz and 3400-3600 MHz are not global frequency bands, which is annotated in the form of footnote by certain countries in regions.

In order to advance the global or regional integration of spectrum planning and use by mobile communication systems, to reduce inter-system interference, and to provide regulatory bodies all over the world with reference on spectrum allocation for mobile communication systems, ITU-R has carried out research on the planning and use of these spectrum bands. By the same token, it has drafted some technical recommendation - M.1036, namely “Programme for Spectrum Allocation for the IMT System”.

The Frequency Band of 450-470 MHz

Currently most countries have allocated the frequency band of 450-470 MHz to mobile and fixed services as the main service. Moreover, a certain number of countries have already deployed IMT systems on this frequency band. The frequency band of 450-470 MHz, due to its great propagation characteristics, is suitable for providing the deployment of IMT over a large-area. This is particularly important for certain developing countries or nations that need to provide broadband services in regions with low population density. At the moment, the programme for the frequency band of 450-470 MHz includes nine proposals in total: seven proposals for FDD allocation, one for TDD, and a mixed one for FDD/TDD.

The Frequency Band of 698-960 MHz

After analogue television has migrated into digital, many frequencies in the UHF band will be available for use by other systems. As the UHF band can achieve a wider coverage with better propagation than in the frequency band of 2-3 GHz, fewer base stations will be needed for covering the same area for IMT at a lower cost. For this reason the UHF band is regarded as an attractive spectrum band by mobile carriers all over the world. The WRC-07 Conference did not manage to allocate the UHF frequency band as a globally harmonized band for the IMT system. Region 1 (mainly Europe and Africa) allocated 790-862 MHz to IMT, Region 2 (Americas) 698-806 MHz, while in Region 3 (Asia-Pacific), nine countries allocated a spectrum of 92 MHz in total (698-790 MHz) to IMT. In WRC-15, Region 1 countries will allocate 694-790 MHz under agenda item 1.2.

The Frequency Band of 2300-2400 MHz

There are many different services currently using the frequency band 2300-2400 MHz around the world and hence it is not a globally harmonized band for IMT. Examples of the various applications include, in Europe, CEPT which is using it for aerial remote reconnaissance, radio amateur, SAB/SAP, mobile applications, fixed radio connections, defense systems in certain countries, and radio positioning systems. Russia uses this frequency band for wireless access system. Canada allocated 2200-2300 MHz and 2360-2400 MHz for government use, while auctioned 2305-2320 MHz and 2345-2360 MHz in February, 2004 for radio communications service. Japan uses it for public services. Currently the countries that consider using this frequency band for the IMT system are mainly in the Asia-Pacific region, including China, New Zealand, South Korea, India, Vietnam and Singapore. In 2002, China in its planning, allocated this frequency band as a supplementary working frequency band to the 3G system in TDD, then in 2009; it allocated 2320-2370 MHz to the TD-SCDMA system for indoor coverage.

The frequency band of 3400-3600 MHz

Worldwide, the main services on the frequency band of 3400-3600 MHz include fixed and satellite fixed services. The WRC-07 Conference allocated the frequency band of 3400-3600 MHz for use by the IMT system, albeit not to be enforced in a uniform manner across the globe.

At the moment, internationally, the band 3400-3600 MHz is extensively used throughout the world by the fixed-satellite service (FSS) to provide a wide range of services. Even though there are options for satellite operators to use higher frequency bands such as Ku and Ka, the band 3400-3600 MHz remains the preferred choice as it is able to withstand rain attenuation. This key characteristic makes the band 3400-3600 MHz suitable in fulfilling the communication needs of countries located in high rain zones or much more separated geography.

In Vietnam, this band is allocated to fixed satellite services which is currently used by Vinasat-1 satellite network to provide a wide range of services including applications such as distance learning, telemedicine and universal access services; backhaul services (telephony, Internet); VSAT data links (e.g. bank transactions, corporate networks); distribution of TV programs; Government/emergency communication links, including disaster recovery, safety-of-life services and meteorological tracking.

2. Industry Classification

In our study, the spectrum industry is defined as those sectors that make direct use of the spectrum to supply a radio service, as well as equipment manufacturers and service providers that supply those sectors. Spectrum sectors might include:

(a) **The Cellular Telecommunications Sector** (e.g. public system for mobile communication, public mobile data network, public mobile radio, wireless broadband);

(b) **The Radio Broadcasting Sector** (e.g. digital audio broadcasting, data broadcasting, television broadcasting);

(c) **The Satellite communication Sector** (e.g. emergency telecom, satellite television, digital broadcasting, satellite broadband);

(d) **The Transportation Sector** (e.g. aviation, railway, waterway);

(e) **The Meteorology Sector**;

(f) **The National Defense Sector**;

(g) **Other Sectors**.

Due to the issue of data availability, our research has placed emphasis upon analyzing only (a), (b), (c) and (d) sectors.

3. Vietnam's Frequency Planning on IMT

The global market scale of mobile communications has manifested a trend of continuous, rapid growth, while the development of the 3G network evolving into LTE has accelerated its pace. By July, 2012, 82 LTE networks around the world have been put into commercial service, while 58 operators have been carrying out trials with the LTE networks.

Currently, Vietnam's mobile communications network is also at a crucial stage of 3G evolving into LTE. Since 2009, Vietnam initially invested in 3G technology. After 5 years of deployment, the number of subscribers in Vietnam increased from 7 million in 2009 to 29 million in 2015, one third of the population. Faced with the fast growth of mobile broadband subscribers, since 2010, Ministry of Information and Communications of Vietnam granted trial licenses which allowed 5 operators to deploy LTE trial networks. Vietnam Posts and Telecommunications Cooperation (VNPT) and Viettel Group (Viettel) have reached some promising improvements regarding broadband services delivered through the LTE trials. Now, MIC of Vietnam has decided that a 4G LTE auction would be opened no later than the beginning of 2016.

As the global mobile communications sector evolves into next-generation broadband mobile communications, the mobile broadband network plays an increasingly salient, fundamental role. Mobile broadband has become an important component of the national broadband strategy all over the world. In order to advance the evolution and development of next-generation broadband mobile communications, certain major countries have completed frequency planning for mobile broadband networks and have auctioned and issued licenses on the spectrum for mobile broadband.

With reference to an ITU estimate on the IMT frequency demand before 2007, by 2020, the spectrum demand in advanced markets worldwide will be 1720 MHz, while those in developing markets will be 1280 MHz (ITU-R M.2078). For this reason, by 2020, the frequency for mobile communications in Vietnam will experience a relatively big shortage. While further providing a scientific planning and rational allocation of the radio spectrum resources among all services, MIC of Vietnam needs also to take into consideration the demands on the frequency resource by radio networks.

Mobile broadband development strategies in Vietnam cover both licensed and un-licensed frequency bands, improving the spectrum usage. However, since the special features of the geography of Vietnam, and the vital importance of broadband services to rural areas, Vietnam is now supporting the use of the frequency band below 1 GHz. Other services utilizing this spectrum band, for instance, analogue broadcasting may be considered for reallocation to free up this band for mobile broadband. ARFM has planned the two bands 2.3 GHz and 2.6 GHz for mobile broadband in line with the dominant technology of LTE 4G in these two bands. However, due to the question on the investment costs for LTE in high bands as well as the low domestic demand on 4G services at present, most of operators prefer to re-farm low bands for LTE 4G.

Satisfying the demand of the market, MIC has issued a Circular 04/2015/TT_BTTTT, dated 10th March 2015, relating to a revised 900 MHz plan which allows technology neutrality in this band.

In this Circular, frequency bands 824-835 MHz, 869-915 MHz, 925-960 MHz are now officially granted to the existing mobile operators to deploy WCDMA systems and other upgraded releases. This Circular also allowed the existing operators in frequency bands 1710-1785 MHz and 1805-1880 MHz to deploy IMT standard mobile networks (LTE, LTE-advanced and other upgraded releases).

Another solution is digital broadcasting. Digital Terrestrial TV transition is anticipated to be completed by 2020 nationwide. However, taking into account that by 2018 most of main provinces will complete the analogue switch-off, Vietnam is now considering granting the mobile broadband licenses in 700 MHz band before 2018.

4. Spectrum Allocation

"National Radio Frequency Allocation Table" (hereafter referred to NRFAT) is the framework documentation for the radio frequency allocation, allotment and assignment, which has specific regulations in designated conditions for terrestrial radio, space radio and radio astronomy. According to the latest revised NRFAT, the status of the frequency allocation in Vietnam is as follows:

Table 1: Spectrum allocation in Vietnam[1]

Sector	Spectrum Range	Spectrum Bandwidth
International Mobile Telecom (IMT)	463.08-467.37/453.08-457.37 MHz; 824-835/869-880 MHz; 880-915/925-960 MHz; 1710-1785/1805-1880 MHz, 1900 – 1980/ 2010 - 2025; 2110 – 2170; 2300-2390 MHz , 2500- 2570/2620-2960 MHz	685
Satellite	137 MHz-138 MHz, 148-150 MHz, 387-406 MHz, 432-438 MHz, 3400-3600 MHz, 3600-3800 MHz, 3800 MHz-4200 MHz, 4200 MHz-4400 MHz	800

Broadcasting	470 MHz-806 MHz	336
Civil Aviation	328.6-335.4 MHz, 118-137 MHz ,108-118 MHz, 960-1215 MHz, 2.7-2.9 GHz, 1.25-1.35 GHz 1030 MHz- 1090 MHz.	680

5. Vietnam's Planning on IMT Spectrum

Mobile communications spectrum allocation includes three components: spectrum for the second-generation mobile cellular communications system, spectrum for the third-generation mobile communications system, and spectrum for LTE.

The frequency bands in the spectrum for the second-generation mobile cellular communications system are all FDD bands, including GSM and CDMA bands: the former including 880-915/930-960 MHz and 1710-1780/1805-1880 MHz. The CDMA ones are 824-835/870-880 MHz, with CDMA now obsolete; the service is no longer running in this band.

The working frequency bands for the third-generation public mobile communications system include:

(a) **Main working frequency bands:**

In FDD format: 1920-1980 MHz / 2110-2170 MHz;

In TDD format: 1900-1920 MHz/ 2010-2025 MHz;

(b) **Supplementary working frequency bands:**

In FDD format: 1710-1785 MHz/1805-1880 MHz; 2500-2570 MHz/2620-2690 MHz

In TDD format: 2300-2390 MHz, 2575-2615 MHz

Currently, the total amount of spectrum allocated for IMT is 685 MHz, namely:

FDD: the frequency bands of 824-835/869-880 MHz, 880-915/925-960 MHz, 1710-1780/1805-1880 MHz, 1920-1980 MHz / 2110-2170 MHz, 2500-2570/2620-2960 MHz;

TDD: the frequency bands of 1900-1920 MHz, 2010-2025 MHz, and 2300-2390 MHz, 2575-2615 MHz

PART I

SPECTRUM REQUIREMENT ESTIMATION FOR IMT SERVICES IN VIETNAM BY 2020

1 - Spectrum Requirement Estimation Report on GSMA Method

1.1. Introduction

Spectrum requirement estimation for forthcoming years is an important task of policy makers in telecommunications field. In this section, we use the Spectrum Requirement Model proposed by GSMA to estimate required spectrum by 2020 for Vietnam.

1.2 Overview of GSMA model

The spectrum model proposed by GSMA estimates the future spectrum requirement for a given number of cell sites and presents the relationship between numbers of cell sites and spectrum required for a given network load. It has been designed so that it can be readily applied to different countries and markets around the world. At a high level, spectrum requirement is determined by considering:

- The existing number of base station sites within a given market and the scope for future site densification.
- Spectrum efficiency: The capacity of each site is determined by basic spectral efficiency for the technology, the number of sectors per site, signaling overhead and a quality margin that will ensure good quality and low delay.
- The traffic load per site: The model accepts voice and data traffic forecasts in various formats. Cisco regional forecasts of monthly usage have been used for these forecasts and are converted to busy hour Mbps for the most congested cell sites.

Figure 1 -1 shows the main steps in the analysis. The model allows information to be input in a number of different ways but the basic calculation is straightforward and given by:

$$S = (T/N \times M) / C$$

where: S = Spectrum (MHz)

T = Total Traffic (Mbps)

N = Number of Macro Cells

M = Load Multiplier for highly congested sites

C = Capacity of site (Mbps/MHz).

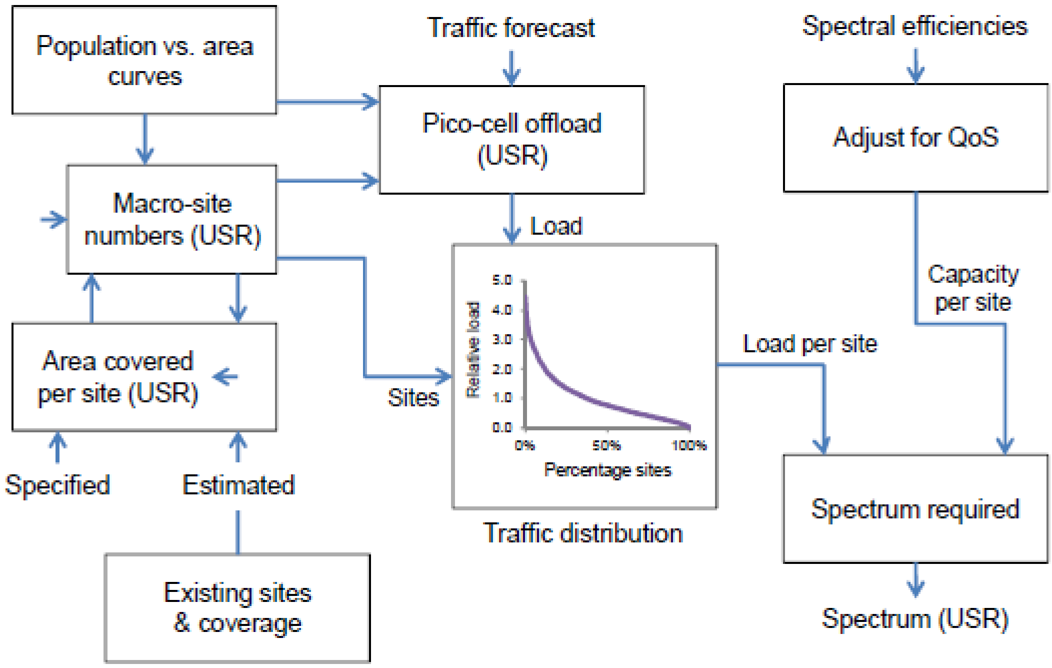

Figure 1- 1: Functional Block Diagram

The key parameters of this equation are discussed further below.

- Number of cell sites (*N*): The number of cell sites at the end of the plan is given by the number of existing sites and assumed rates of site densification. Sites are split between urban, suburban and rural areas.
- Traffic (*T*): The model currently takes forecasts of regional monthly mobile data traffic (in millions of GB) and monthly voice minutes of usage. These are converted to average busy hour site traffic (*T*).
- Site capacity (*C*): Site capacity in Mbps/MHz is obtained by multiplying spectrum efficiencies in urban, suburban and rural environments by the average sectors per site. The resulting site capacities relate to Layer 1 (physical layer), whereas the combined voice and data traffic (*T*) relates to the Layer 3 (user level). In order to convert the busy hour traffic (*T*) to an appropriate Layer 1 figure, it is necessary to:
  - Add a signaling overhead (15%)
  - Apply a quality of service factor (50%) to ensure services can be supported with high quality and low delay.

  These values have not changed since developing the preliminary results.

1.3 Revised Spectrum Forecasts using GSMA Method Worldwide.

In this section, spectrum estimation based on the GSMA method for several countries is investigated [12]. The following country-specific data for each country of interest is required:

- Mobile data and voice traffic forecasts covering the period to 2020 supplied by CISCO and GSMA Intelligence respectively to drive the spectrum demand
- Population distribution data available from SEDAC, which is used to calculate area versus population coverage curves and to break the country into urban, suburban and rural areas
- Estimate of existing site numbers and densification over the period. These are critical in establishing a reliable spectrum estimate.

Experience has shown that it is not easy to obtain reliable or definitive estimates of site numbers. We require the number of macro-cell sites available to a single operator for national coverage, with the assumption that the total spectrum may be deployed at each site.

New information received since the preliminary results were prepared has resulted in some changes being made to estimated site numbers for Brazil, China and the USA, as documented below.

1.3.1 The UK

Revised results for the UK indicate a total spectrum of 2074 MHz will be required in 2020, assuming the number of macro-sites per operator to be 16,370. The increase in spectrum since the previous estimate arises from the attribution of a higher level of daily data traffic to the site busy hour as discussed in Section 1.2.

The increase in the total number of sites is due to the assumption of slightly higher densification rates in rural and suburban areas, although urban areas remain unchanged.

A graph of sites per operator versus total spectrum requirement is presented in Figure 1 – 2.

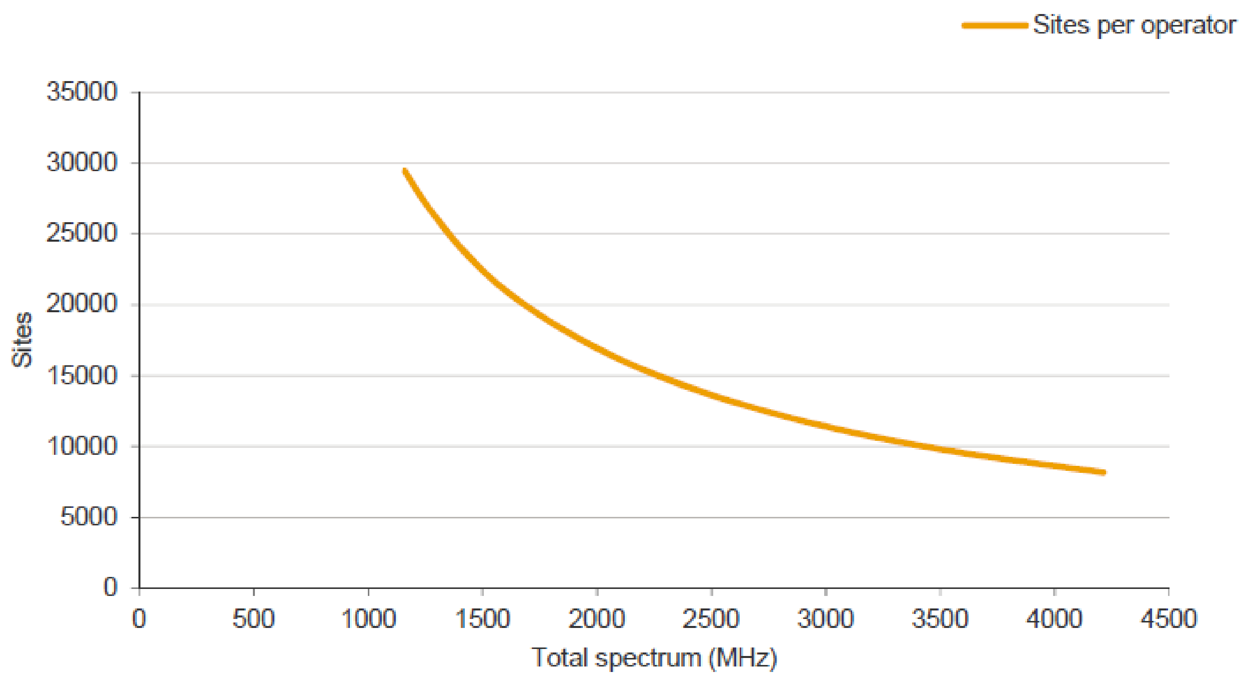

Figure 1 – 2: UK sites per operator versus total spectrum in 2020

1.3.2 Brazil

Revised results for Brazil indicate a total spectrum of 2080 MHz will be required in 2020 assuming a total of 22,850 macro-sites per operator.

The increase in spectrum since the previous estimate arises from the attribution of a higher level of daily traffic to the site busy hour as discussed in Section 2.2.2 and Appendix A. Initial site numbers have increased slightly following an analysis of data on the Brazilian Regulator, Anatel's website. At the same time, rates of densification in urban areas have been lowered, bringing the figure more in line with developed countries.

A graph of sites per operator versus total spectrum requirement is presented in Figure 1-3.

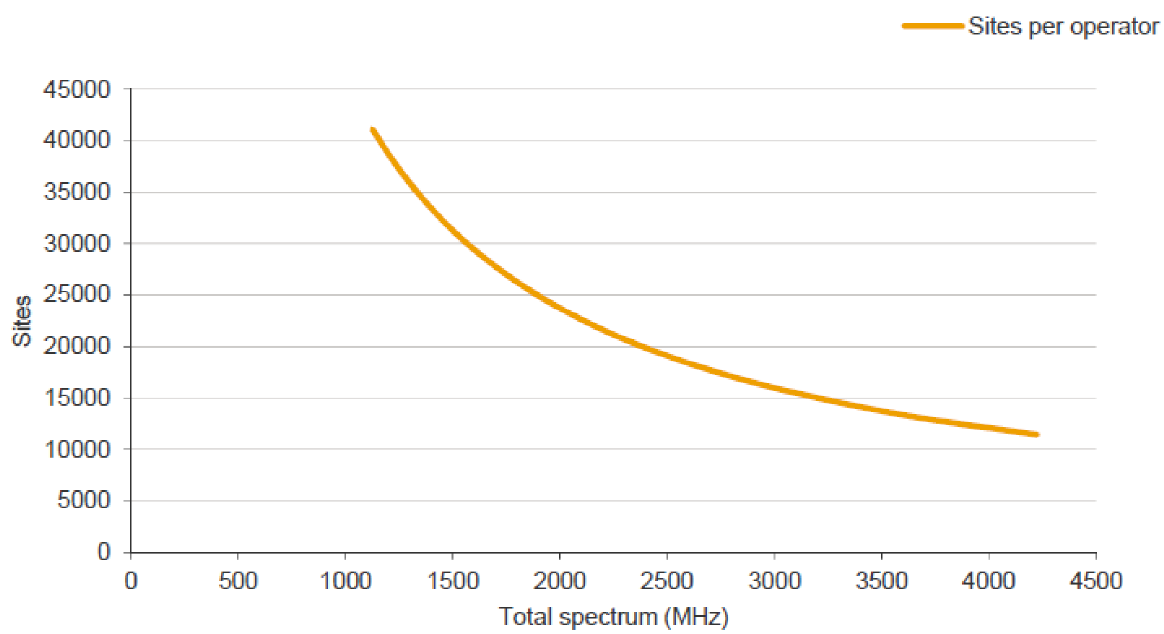

Figure 1 – 3: Brazil sites per operator versus total spectrum in 2020

1.3.3 China

Revised results for China indicate a total spectrum of 1844 MHz will be required in 2020 assuming a total of about 472,900 macro-sites per operator.

The result has changed little from the preliminary estimate, since the attribution of a higher level of daily traffic to the site busy hour is largely offset by an increase in site numbers.

Current site numbers were obtained from Chinese operators, involving some further assumptions. Rates of densification have been adjusted to give different values in urban, suburban and rural areas.

A graph of sites per operator versus total spectrum requirement is presented in Figure 1-4.

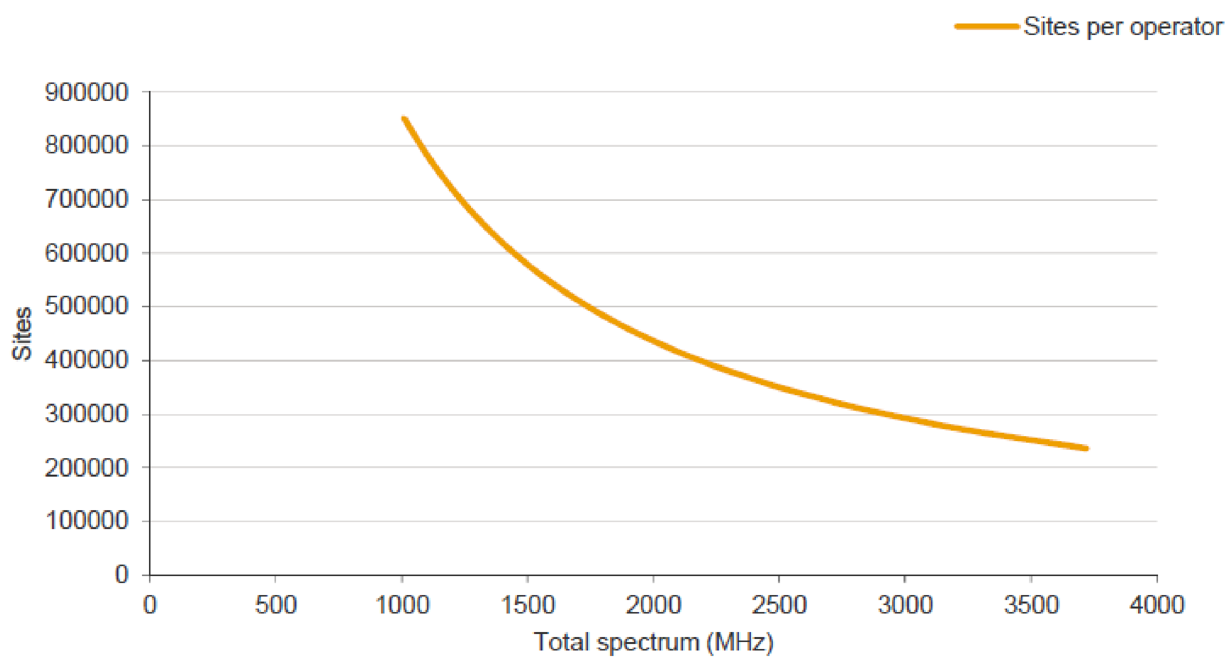

Figure 1-4: China sites per operator versus total spectrum in 2020

1.3.4 USA

Revised results for USA indicate a total spectrum of 1939 MHz will be required in 2020 assuming a total of about 84,420 macro-sites for a nation operator.

Overall site numbers have increased following a more detailed analysis of an earlier spectrum paper submitted to the ITU by the USA. This has resulted in a higher number of sites per operator for 2012. Overall rates of site densification are in line with trends identified in the USA, with lower rates in urban areas, in line with other developed countries.

A graph of sites per operator versus total spectrum requirement is presented in Figure 1-5.

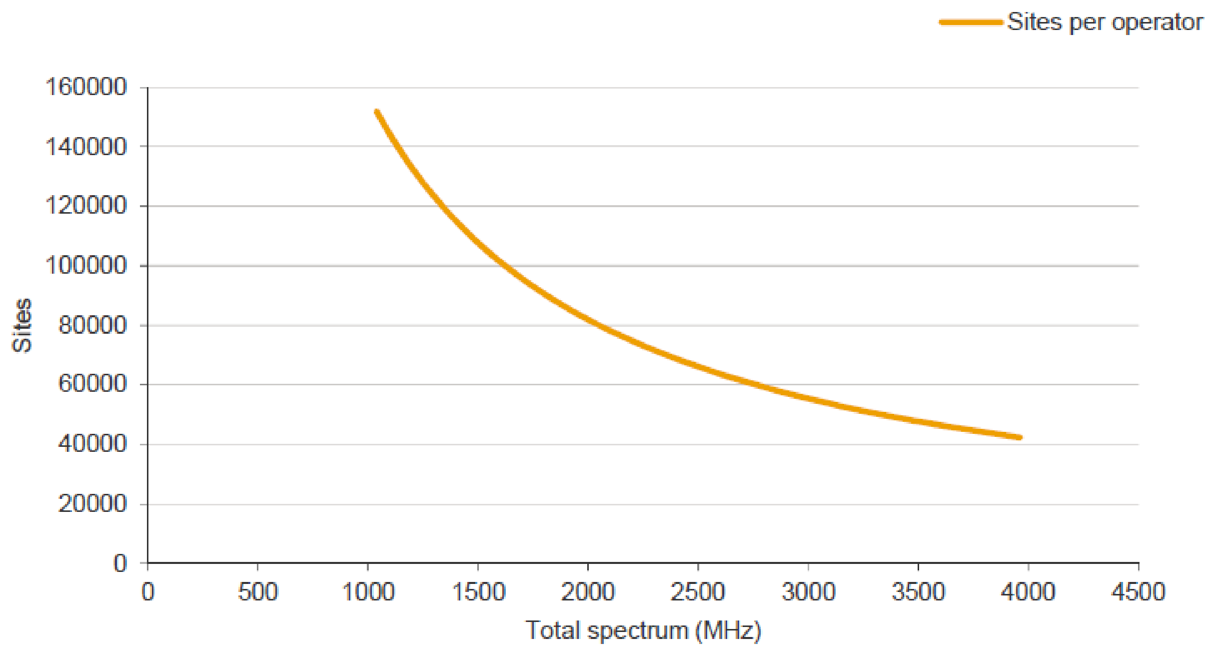

Figure 1 – 5: USA sites per operator versus total spectrum in 2020

1.4. Analysis of Data Input in Vietnam

Statistical data of major MNOs in Vietnam is used as input for this model.

1.4.1. Land Area Classification

According to GSO [1] of Vietnam, Vietnam is a Southeast Asian country with land area of 331,698 km^2 and total population of 88.7755 million people in 2012.

Because the model considers three scenarios across the full range of environments: urban, suburban, rural, we used SEDAC[2] population data on Vietnam in order to split the country into those 3 areas. The areas with population density of over 3000 pop/km^2 are classified as urban, areas with over 1000 pop/km^2 are classified as sub-urban, and areas below 1000 pop/km^2 are classified as rural. The classification is shown on the map in Figure 1-6.

This matches projection of UN[3] and World Bank[4], who estimated that by 2020, approx. 40 per cent of Vietnam's population of 100 million will live in urban areas/cities.

Table 1-1: Land Area and Population Density

Land Area (km^2)	331698
Population in 2012 (million)	88.7755
Urban threshold (pop/km2)	3000
Suburban threshold (pop/km2)	1000

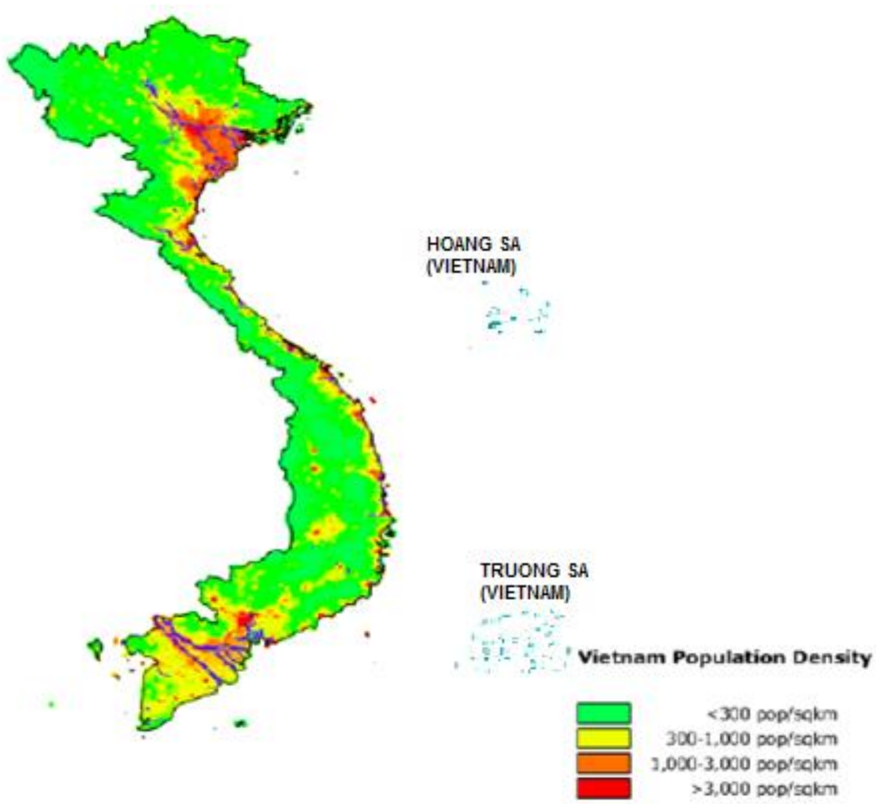

Figure 1-6: Area Classification

1.4.2. Subscriber Prediction

Figure 1-7 shows the statics of subscriber growth in recent years. In detail, analysis of subscriber growth is presented in Table 1-2.

Table 1-2: Prediction of Subscriber Increase

Year	Subscriber Total	Increase (million)	Growth Rate(%)
2012	42,690,919	N.A	N.A
2013	44,018,430	1,327,511	3.1
2014	47,276,461	3,258,031	7.4
2015	49,776,461	2,500,000	5.02
2016	51,544,000	1,767,539	3.6
2017	53,093,662	1,549,662	3

On average, the total number of subscribers has increased by 2 million annually. Then, we can estimate the range of subscriber number of 59 million by 2020.

Figure 1-7: Increase in subscribers by years

Furthermore, we assume that the percentage of population covered by the mobile network by 2020 is about 99%. Then, the subscriber distribution of each area category is summarized in the below table.

Table 1-3: Subscriber Distribution by 2020

Region	Subscriber Distribution	Land Area
Rural	58%	248,774 (75%)
Suburban	29%	19,902 (6%)
Urban	13%	1,659 (0.5%)
Uncovered Region	0%	63,023 (19%)

1.4.3. Data Traffic Prediction

3G services were launched in Vietnam in 2009. That resulted in a revolution in usage of mobile data. Figure 1-8 represents the growth of data traffic (traffic/user/month). For more detail, Table 1-4 provides the analysis of this parameter.

Table 1-4: Growth of Data Traffic per Year of the MNO

Year	Data Traffic (Data/User/month (MB))	Increase (MB)	Growth Rate
2012	324	N.A	
2013	675	350.36	108.1
2014	861.00	186.50	27.6

In detail, growth rate in 2013 is 108% compared to that in 2012. This rate reduces to 27.6% in 2014. It can be considered as a sign of saturation in the development of 3G in the Vietnam market.

As planned by Authority of Radio Frequency Management of Vietnam, 4G will be licensed early 2016. This technology promises a new revolution of mobile data in Vietnam. A report of Cisco[5]released at the beginning of 2015 states the average CAGR for data traffic in Asia is approximately 65% and range of data traffic is in 4 – 8 GB/user/month.

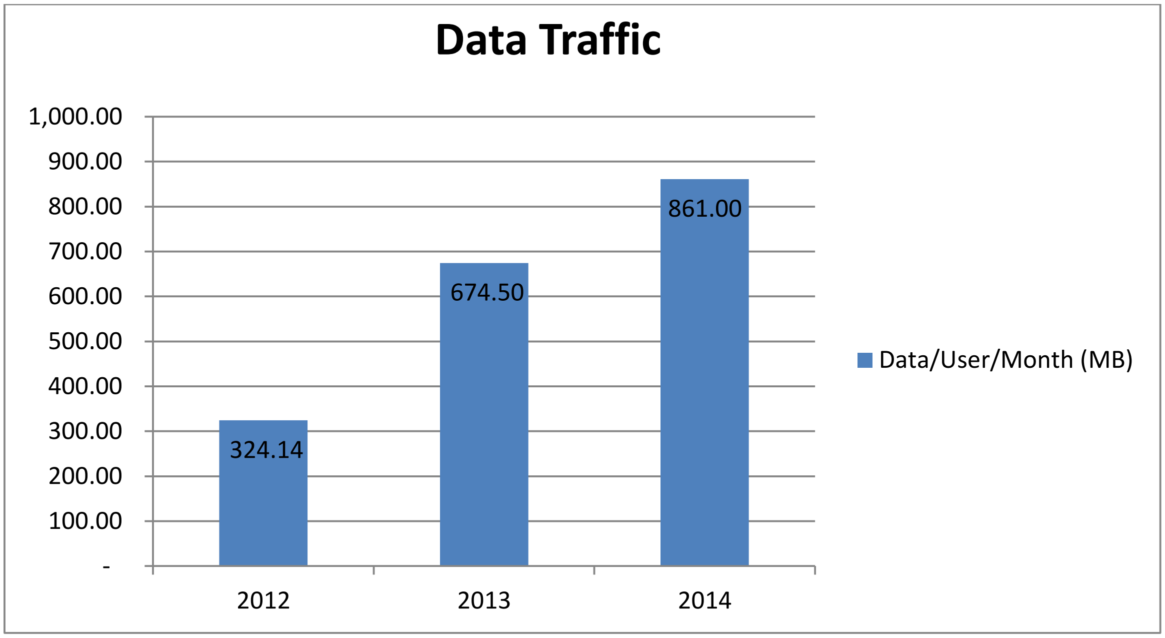

Figure 1-8: Growth of Data Traffic

With 861 MB/user/month in 2014, we will obtain estimated data traffic in 2020 with different CAGRs as shown in Table 1-5.

Table 1-5: Prediction of Data Traffic by 2020

Data Traffic in 2014(MB)	CAGR (%)	Data Traffic by 2020 (GB)
861	29.17	4
	38.21	6
	44.99	8

With the assumption of 59 million subscribers by 2020, we have total data traffic per month as shown in the Table 1-6.

The total data per month is calculated as follows:

total data / month = data traffic/user/month * subscriber total by 2020.

Table 1-6: Total Data per Month by 2020

Data Traffic Per User Per Month (GB)	Total Data / Month (PB)
4	236
6	354
8	472

1.4.4. Voice Traffic Prediction

Figure 1-9 depicts the growth of voice traffic in recent years. In detail, Table 1-7 provides an analysis of this parameter. As we can see, voice traffic seems not to increase from 2011 – 2013. In 2014, it increases by 18 minutes (increase at approximately 7.3% compared to that in 2013).

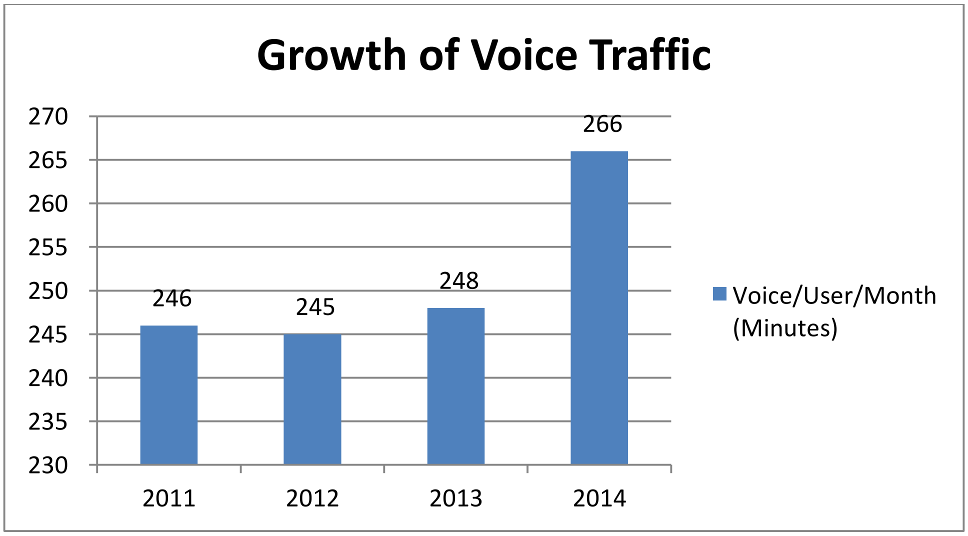

Figure 1-9: Growth of Voice Traffic

Table 1-7: Growth of Voice Traffic

Year	Voice traffic (Voice/User/Month)	Increase	Growth Rate (%)
2011	246	N.A	N.A
2012	245	-1	-0.4
2013	248	3	1.2
2014	266	18	7.3

Furthermore, nowadays, there are a lot of IP – based voice services such as: Skype, Viber, Zalo etc. We can predict that voice traffic will steady in forthcoming years. This is equivalent to voice traffic by 2020 at 266 minutes/user/month.

The total voice per month is equal to 15,694 million minutes.

1.4.5. Number of Operators

In Vietnam, currently, there are 5 mobile operators: Viettel, Mobifone, Vinaphone, Gtel and Vietnam Mobile. However, Viettel, Mobifone and Vinafone are the more dominant in terms of subscribers.

As shown in Figure 1-10, in 2011, Viettel and VNPT (consisting of Mobifone and Vinaphone) account for 40% and 48% of mobile communications in Vietnam, respectively. The rest operators comprise only 12%. In 2012, Viettel's market share increased to 41% while VNPT's rose to 48%. In the latest report of Information and Data on Information and Communication Technology of Ministry of Information and Communications, in 2013, Viettel's market share continued to increase to 43.48% while VNPT's increased to 49.23%. The other market players held a market share of only 7.29%.

From these statistics and the developing nature of the Vietnam market, it is envisioned that small operators may merge with the bigger ones.

Subsequently, we have analysed based on the number of operators by 2020 being in the region of 3.

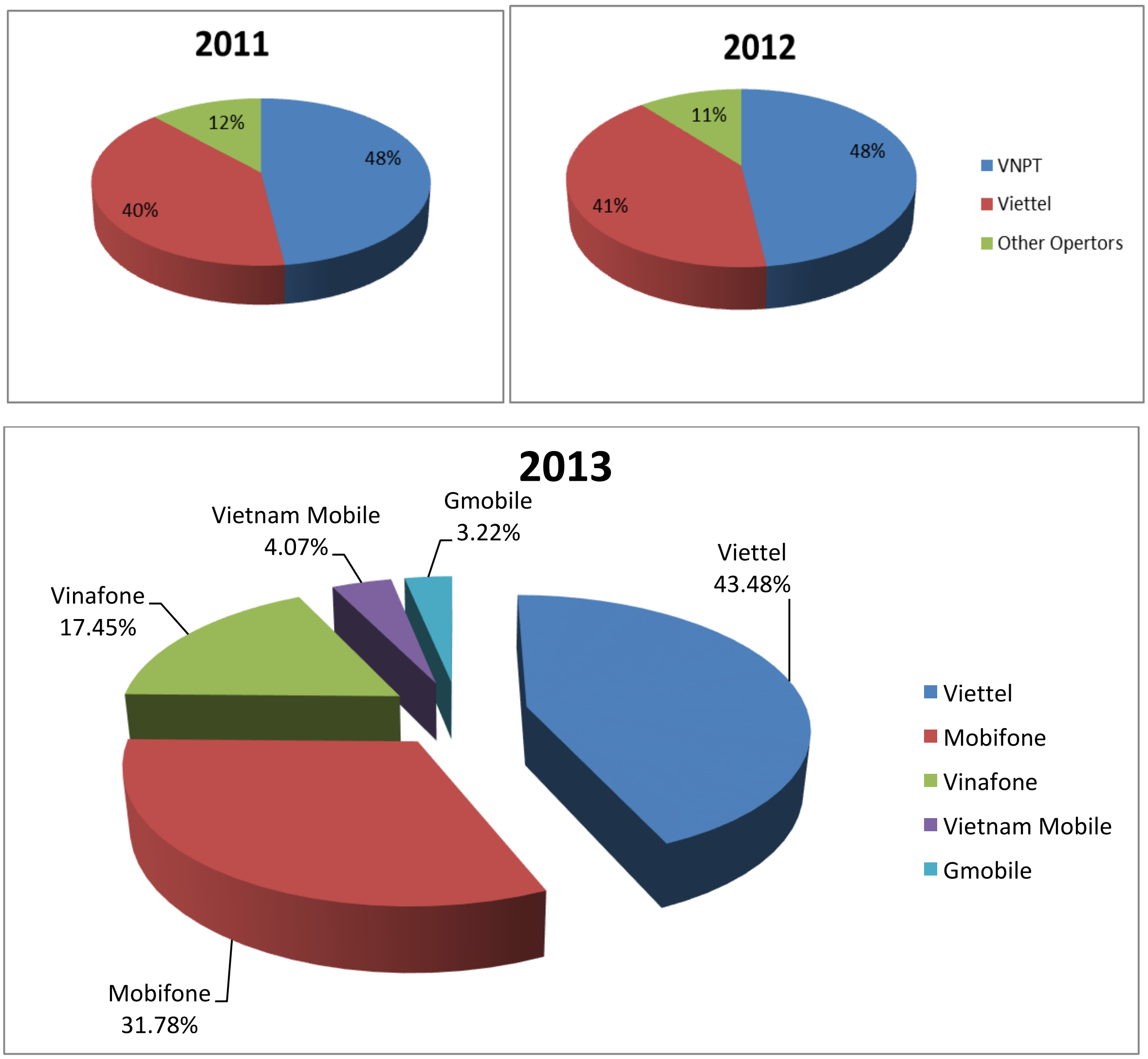

Figure 1-10: Mobile Communications Market Shares (by subscriber) in Vietnam by years

(Source: Report of the Authority of Radio Frequency Management in 2013 and Information and Data on Information and Communication Technology of MIC in 2014)

1.4.6. Spectrum Efficiency

Table 1-8 lists the ideal spectrum efficiency of different technologies.

Table 1-8: Macro Spectrum Efficiencies of different Technologies

Technology	Spectrum Efficiency (bps/Hz)
EDGE	0.1
WCDMA	0.24
HSDPA R5	0.48
HSPA R6	0.72
HSPA R7	1.29
LTE R8	1.5
LTE - Advanced	2.2

According to a report by Real Wireless[6], the following assumptions are introduced:

- LTE R8 will be utilized from 2015 to 2020.
- HSPA R7 will be utilized in 2017.

Based on the above assumptions, spectrum efficiency of macro sites could be estimated as Table 1-9 corresponding to 4 various assumptions about percentage of 2G, 3G and 4G from 2015 - 2020.

Table 1-9: Spectrum Efficiency Assumptions of the Macro Base sites (bps/Hz)

Combined Spectrum Efficiency	2015	2016	2017	2018	2019	2020
Case 1	0.66	0.89	1.21	1.395	1.505	1.82
Case 2	0.66	0.89	1.19	1.345	1.475	1.775
Case 3	0.66	0.89	1.19	1.395	1.565	1.91
Case 4	0.66	0.89	1.15	1.3	1.45	1.55

1.4.7. Other Assumptions

According to the report by the MNOs, in 2012, they deployed around 23,500 and 24,000 sites nationwide with few co-sites (2G & 3G). Investigating the development policy of BTSs in the MNO, we can assume that the site densifications of rural, suburban and urban by 2020 are 1.3, 1.2, and 1.1, respectively.

Table 1-10 provides fixed values of other parameters which are used in the GSMA Model.

Table 1-10: Fixed values of the rest parameters in GSMA Model

Parameter	**Unit**	**Amount**
DatainBH	%	12
VoiceinBH	%	12
AvgSecPerPico		1
BHMacroLoadQoS	%	50
BHPicoLoadQoS	%	50
MacroPicoSharing	%	50
EfficiencyPerMNO	%	95
GuardBandPerMNO	MHz	5
MinCarrier band	MHz	5
BHCellLoadQoS	%	100
MaxCarrierPerPico		2
MaxPicoPerMacro		3

1.5. Results

1.5.1. Spectrum Prediction Results

Using data from With 861 MB/user/month in 2014, we will obtain estimated data traffic in 2020 with different CAGRs as shown in Table 1-5.

Table 1-5 and table 1-9, we obtain the spectrum requirement by years as shown in Figure 1-11. In detail, table 1 -11 shows the spectrum forecast by years with different values of CAGRs and Spectrum Efficiency (SE).

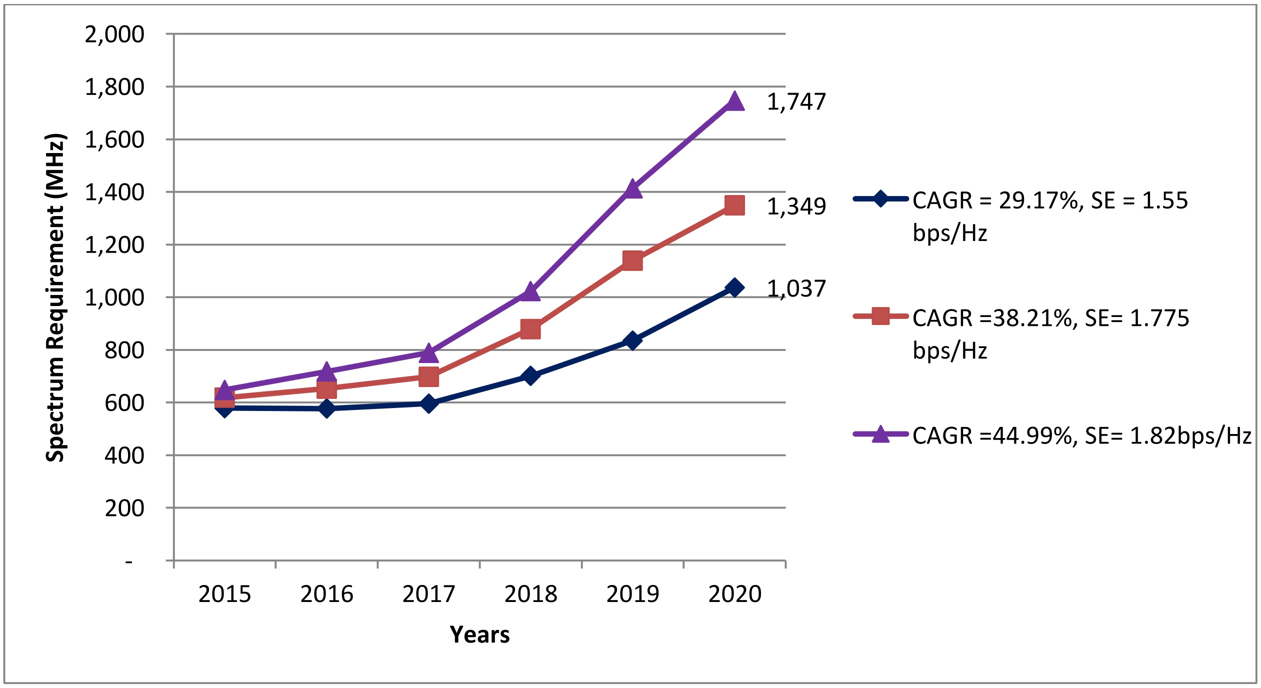

Figure 1-11: Spectrum forecast by years

Table 1-11: Spectrum Requirement by years (MHz)

	2015	2016	2017	2018	2019	2020
CAGR = 29.17%, SE = 1.55 bps/Hz	579	577	596	701	835	1,037
CAGR =38.21%, SE= 1.775 bps/Hz	618	653	698	879	1,139	1,349
CAGR = 44.99%, SE= 1.82bps/Hz	648	718	789	1,023	1,414	1,747

1.5.2. Sensitivity to Data Traffic Growth

Data traffic growth is a crucial factor to decide the spectrum requirement. As described in section 1.4.3, we estimate the range of data traffic from 4 – 8 GB/user/month by 2020. Figure 1-12 illustrates change of required spectrum over data traffic corresponding to 59 million subscribers and several of Macro Spectral Efficiencies.

Figure 1-12: Prediction of Spectrum Requirement vs. Data Traffic in 2020

1.5.3. Sensitivity to Number of Operators

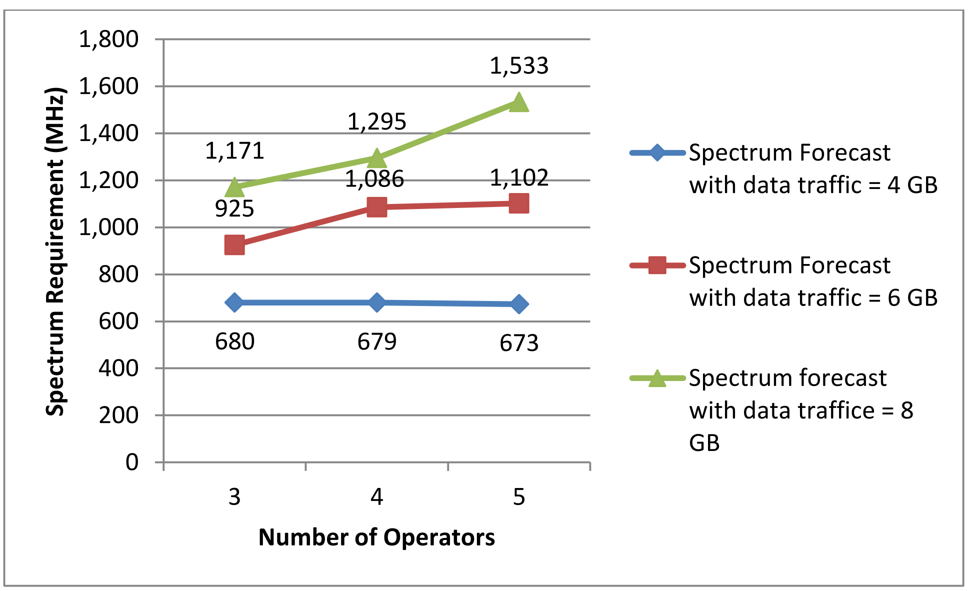

Figure *1-14* illustrates the dependence of calculated spectrum on the number of operators. In this scenario, we choose various values of data traffic by 2020 (equal to 4, 6 and 8 GB). As seen in the figure, the more operators there are, the more spectrums are needed except the case of data traffic equal to 4 GB.

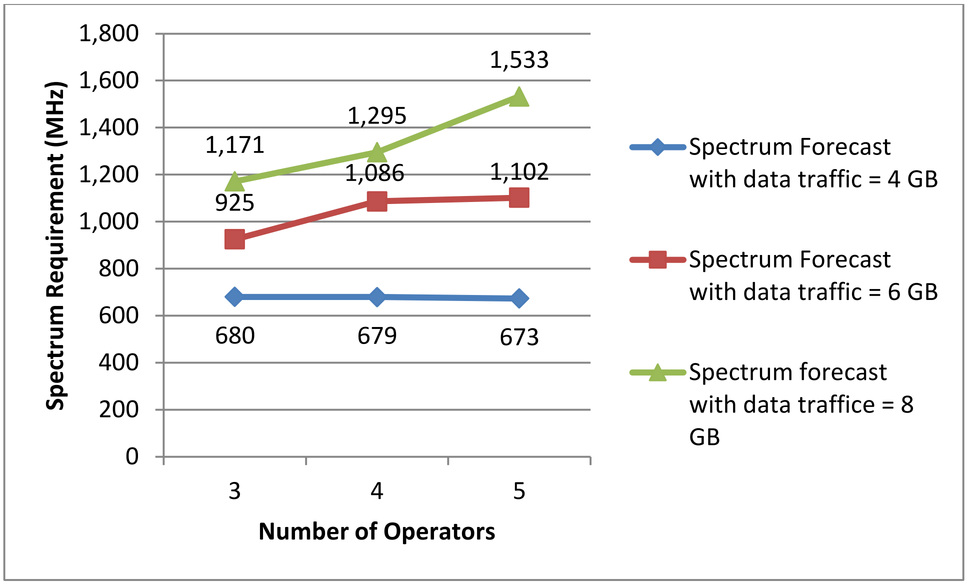

Figure 1-14: Prediction of Spectrum Requirement vs. Number of Operators.

1.5.4. Sensitivity to Number of BTS sites

Figure 1-15 illustrates spectrum requirement when we change the number of physical BTS sites in 2012. As shown in the figure, the more BTS sites we have the less spectrum requirement. However, in fact, the cost of deploying BTS sites is significant, trade-offs between the expense of BTS sites and spectrum requirement should be considered carefully.

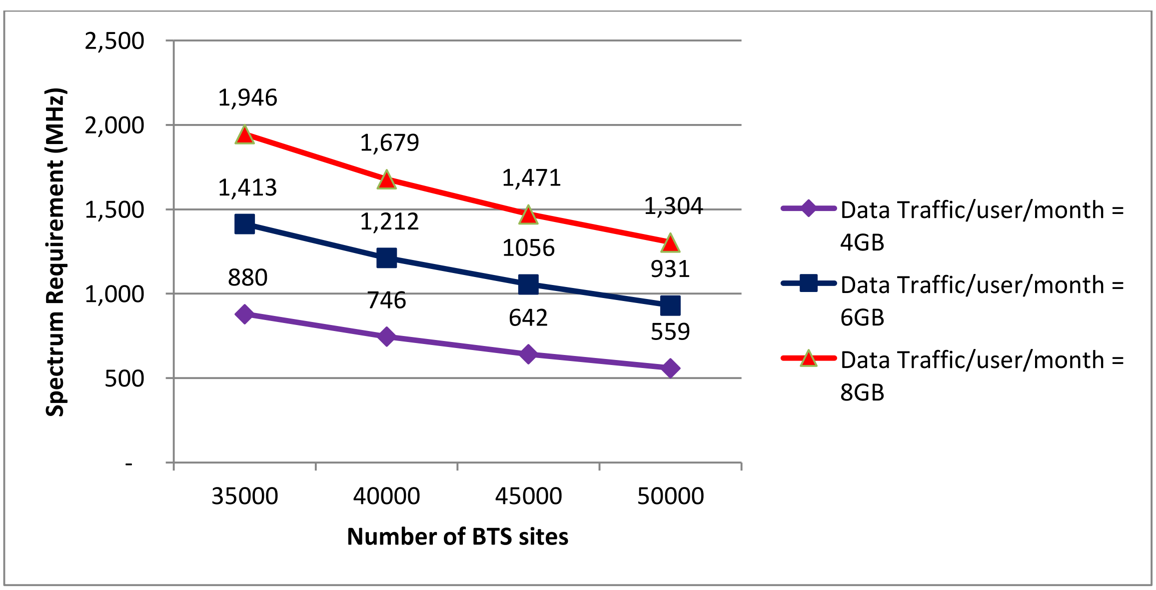

Figure 1-15: Prediction of Spectrum Requirement vs. Number of BTS sites

1.6. Conclusion

Based on obtained results, we estimate the range of spectrum required is between 1,037 MHz – 1,747 MHz.

Taking into account population and subscriber growth in Vietnam; we can forecast data traffic development within Vietnam is not expected to exceed 6 GB/ user/month by 2020. This is in line with the Cisco VNI prediction of the rest of APAC, which states mobile data usage per unique user to be approximately 6 GB/Month in 2019.

We can choose the average of min and max scenarios corresponding to data traffic of 4 GB and 8 GB. That means the spectrum requirement is approximately 1,392 GHz.

2 - ITU-R Method

2.1. Methodology Overview

The methodology used in this report was recommended by ITU-R for the calculation of terrestrial spectrum requirement estimation for International Mobile Telecommunications (IMT). It provides a systematic approach that incorporates service categories (a combination of service type and traffic class), service environments (a combination of service usage pattern and teledensity), radio environments, market data analysis and traffic estimation by using these categories and environments, traffic distribution among radio access technique groups (RATGs), required system capacity calculation and resultant spectrum requirement determination. The methodology is applicable to packet switch-based traffic and can accommodate multiple services. It can also accommodate circuit switched emulation traffic using a reservation based concept [7].

This methodology takes into account the total terrestrial communication market that will be provided by various communication means in terms of services and networks according to Recommendations ITU-R M.1645, ITU-R M.1457 and ITU-R M.2012. There are a number of RATGs which can be identified. The present methodology distributes the total traffic forecasted for the total terrestrial communication market to the identified RATGs, which are:

Group 1: Pre-IMT systems, IMT-2000 and its enhancements.

This group covers the digital cellular mobile systems, IMT-2000 systems and their enhancements.

Group 2: IMT-Advanced systems as described in Recommendation ITU R M.2012.

Group 3: Existing radio LANs and their enhancements.

Group 4: Digital mobile broadcasting systems and their enhancements.

The technical process of estimating spectrum requirements for mobile communications has to be based on four essential issues:

- Definition of services
- Market expectations
- Technical and operational framework
- Spectrum calculation algorithm

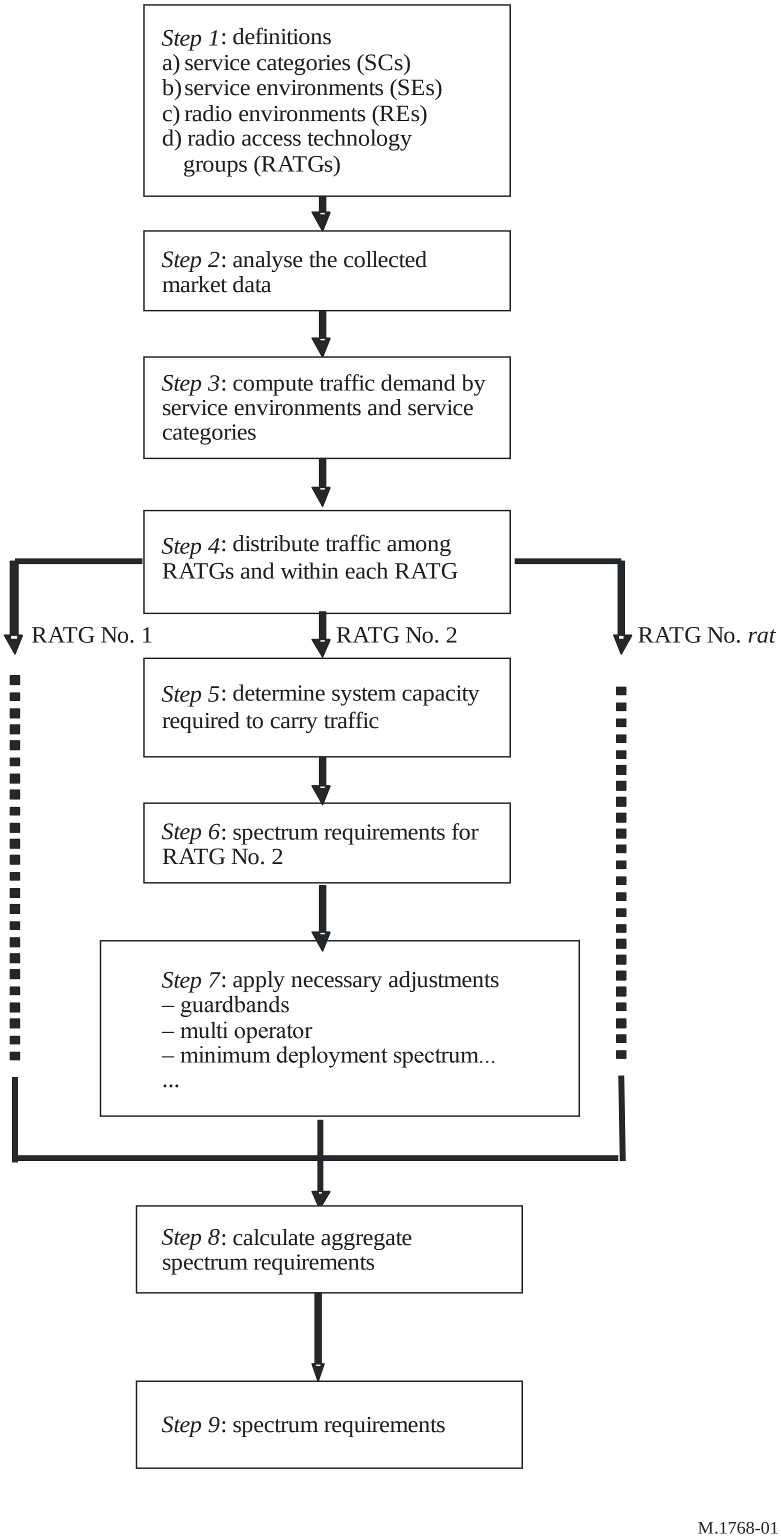

Figure 2-1: Flow chart for a generic spectrum calculation methodology

2.2. Input parameter definitions

2.2.1. Service categories

In this method, services are divided in 20 specific categories regarded as service category (SC), the classification is based on the combination of service type and traffic class as shown in Table 2-1.

Table 2-1: Service Categories (SCs)

Traffic class / **Service type**	**Conversational**	**Streaming**	**Interactive**	**Background**
Super-highMultiMedia	SC1	SC6	SC11	SC16
High MultiMedia	SC2	SC7	SC12	SC17
Medium MultiMedia	SC3	SC8	SC13	SC18
Low rate data and low multimedia	SC4	SC9	SC14	SC19
Verylow rate data(1)	SC5	SC10	SC15	SC20

(1) This includes speech and SMS.

- **Service type**

The service types are classified corresponding to the peak bit rates. The different services are divided into five service types as shown in Table 2-2

Table 2-2: Service types and their peak bit rates

Service type	**Peak bit rate**
Very low rate data	< 16 kbit/s
Low rate data and low multimedia	< 144 kbit/s
Medium MultiMedia	< 2 Mbit/s
High MultiMedia	< 30 Mbit/s
Super-high MultiMedia	30 Mbit/s to 100 Mbit/s/1 Gbit/s

a) *Very low rate data*

This service type requires a peak bit rates up to 16 kbit/s. The services in this type may include very low data rate applications of speech and simple message service, some applications in the field of sensor communication and/or low bit rate data telemetry.

b) Low rate data and low multimedia

This service type supports data rates of up to 144 kbit/s. This service type takes into account of pre IMT-2000 data communication applications.

c) Medium multimedia

This service type supports a peak bit rate of up to 2 Mbit/s. This type would be required to sustain the compatibility with the IMT-2000 applications.

d) High multimedia

This service type accommodates high data rate applications, including multimedia video streaming services, which are provided with xDSL service in fixed wired communication systems.

e) Super-high multimedia

This service type accommodates super-high data rates multimedia applications, which are currently provided with fiber-to-the-home (FTTH) services in case of wired communication systems.

- **Traffic classes**

This factor used in the ITU-R M.1768 is the result taken out from Recommendation ITU-R M.1079, which defines four qualities of service (QoS) classes for IMT-2000 from the user perspective:

- Conversational class of service
- Interactive class of service
- Streaming class of service
- Background class of service

For more details, please refer to Recommendation ITU-R M.1079.

2.2.2. Service categories parameters

Each service category is characterized with parameters which are obtained either from market studies or from other sources [7].

- User density (user/km^2)
- Session arrival rate per user (session/(s/.user))
- Mean service bit rate (bit/s)

- Mean session duration (s/session)
- Mobility ratio

The first four parameters characterize the demand of different service categories, while the mobility parameter is used in traffic distribution. Terminal mobility is closely related to application usage scenarios. Recommendation ITU-R M.1390 defines mobility as:

- In-building;
- Pedestrian;
- Vehicular.

The requirements depend upon the speed of the mobile stations. In market studies in Report ITU R M.2072, the mobility classes are categorized as follows:

- Stationary (0 km/h)
- Low (> 0 km/h and < 4 km/h)
- High (> 4 km/h and < 100 km/h)
- Super-high (>100 km/h and < 250 km/h).

The range limits of the categories should be related to typical characteristics of cellular radio networks. For small cells the minimum time a user stays in a cell between handovers needs to be significantly longer than the handover initiation and execution time. Therefore for small cells the cell size limits the maximum supported velocity. For this reason, pico cells are typically limited to support up to pedestrian velocities (up to 3-10 km/h), micro cells up to urban vehicular speeds of 50 km/h and macro cells of mobile cellular radio networks cover the remaining range of user velocity. For application of the mobility classes in the methodology, the mobility classes from market studies are re-interpreted as follows:

- Stationary/Pedestrian (0-4 km/h)
- Low (> 4 km/h and < 50 km/h)
- High (> 50 km/h).

The traffic of the "high" mobility class obtained from market studies is split into the "low" and "high" mobility classes for the methodology.

2.2.3. Service Environment

Service Environment (SE) is defined as a combination of ***service usage pattern*** and ***teledensity***.

- ***Service usage pattern***

This factor is classified in accordance with an area where users exploit similar services and expect similar quality of service. The following service usage patterns are used in the report [7]:

- Home
- Office
- Public area

- ***Teledensity***

As defined in Recommendation ITU-R M.1390, population density and the number of devices per person are also important factors when considering service environments. The teledensity includes three parameters which are characterized by population density and communication device density as follows:

- Dense urban
- Suburban
- Rural

Hence, there are 6 service environments used in the report corresponding to each teledensity and service usage pattern as shown in the Table 2-3:

Table 2-3: The identification of service environments

<table>
<tr><th>Teledensity
Service
usage pattern</th><th>Dense urban</th><th>Suburban</th><th>Rural</th></tr>
<tr><td>Home</td><td>SE1</td><td>SE4</td><td rowspan="3">SE6</td></tr>
<tr><td>Office</td><td>SE2</td><td rowspan="2">SE5</td></tr>
<tr><td>Public area</td><td>SE3</td></tr>
</table>

Table 2-4: Examples of user groups and applications of service environments

	Usergroups	**Applications**
SE1	Private user, business user	Voice, Internet access, games, e-commerce, remoteeducation, multimedia applications
SE2	Business user, small and medium size enterprise	Voice, Internet access, video conferencing, e-commerce, mobile business applications
SE3	Private user, business user, public service user (e.g. bus driver, emergency service), tourist, sales people	Voice, Internet access, videoconferencing, mobile business applications, tourist information, e-commerce
SE4	Private user, business user	Voice, Internet access, games, e-commerce, multimedia applications, remoteeducation
SE5	Business user, enterprise	Voice, Internet access, e-commerce, video conferencing, mobile business applications
SE6	Private user, farm, public service user	Voice, information application

Spectrum requirements shall first be calculated separately for each teledensity. The final spectrum requirement is calculated by taking the maximum value among spectrum requirements for the three teledensity areas (dense urban, suburban and rural).

2.2.4. Radio Environment

Radio Environments (RE) are defined by the cell layers in a network consisting of hierarchical cell layers, i.e. macro, micro, pico and hot-spot cells. Methodology uses the cell area of the different radio environments as input to the calculations. The cell area has a direct impact on the traffic volume dependent spectrum requirement [7].

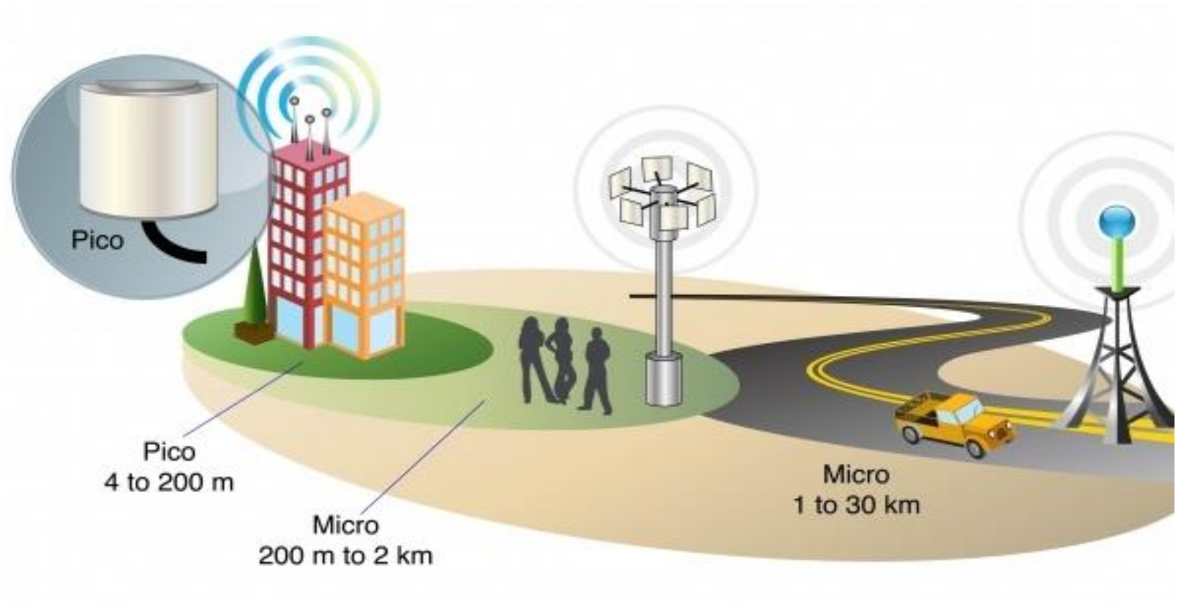

Figure 2-2: Radio Environments

2.2.5. Distribution Ratio

The Distribution Ratio (DR) is defined as distribution traffic between RATGs. The RATGs distribution ratio depends on the available RATGs in each RE and SE.

The example of distribution ratio is shown in Table 2-5.

Table 2-5: Distribution ratios among available RATGs

AvailableRATGs	Distribution ratio (%)			
	RATG1	RATG2	RATG3	RATG4
1	100	–	–	–
2	–	100	–	–
3	–	–	100	
4	–	–	–	100
1, 2	20	80	–	
1, 3	20	–	80	
1, 4	10	–	–	90
2, 3	–	20	80	
2, 4	–	10	–	90
3, 4	–	–	10	90
1, 2, 3	20	20	60	

1, 2, 4	10	10	–	80
1, 3, 4	10	–	10	80
2, 3, 4	–	10	10	80
1, 2, 3, 4	10	10	10	70

2.2.6. Spectral Efficiency

According to Recommendation ITU-R M. 2078, the theoretical limit of the channel capacity for communication systems is given by the Shannon channel capacity in the sense of information theory [9]. The Shannon channel capacity is given by:

$$\frac{C_s}{W} = \log_2\left(1 + \frac{c}{I+N}\right)$$

With

Cs: Shannon channel capacity

W: system carrier bandwidth

c: carrier power

I: interference power

N: noise power

The Shannon bound describes the link level in terms of spectral efficiency versus CIR = C/(I+N).

The spectral efficiency for the feasible radio interface follows as:

$$\varepsilon = \frac{T}{W} = \log_2\left(1 + \frac{CIR}{\Delta CIR}\right) for \varepsilon \leq \varepsilon_{max} and CIR \leq CIR'$$

$$\varepsilon = \frac{T}{W} = \varepsilon_{max} = const for CIR > CIR'$$

2.2.7. Relationship among SEs, RATGs, and REs

Service environments and radio environments should be separately considered in the spectrum calculation such that traffic demands are forecasted over service environments only, while total spectrum requirements are calculated with different RATGs and their possible radio environments. Spectrum requirements are calculated within each teledensity but final spectrum requirements need to be chosen as the maximum among spectrum requirements of all teledensities. Therefore, traffic in service environments should be accumulated with their corresponding teledensity first [7].

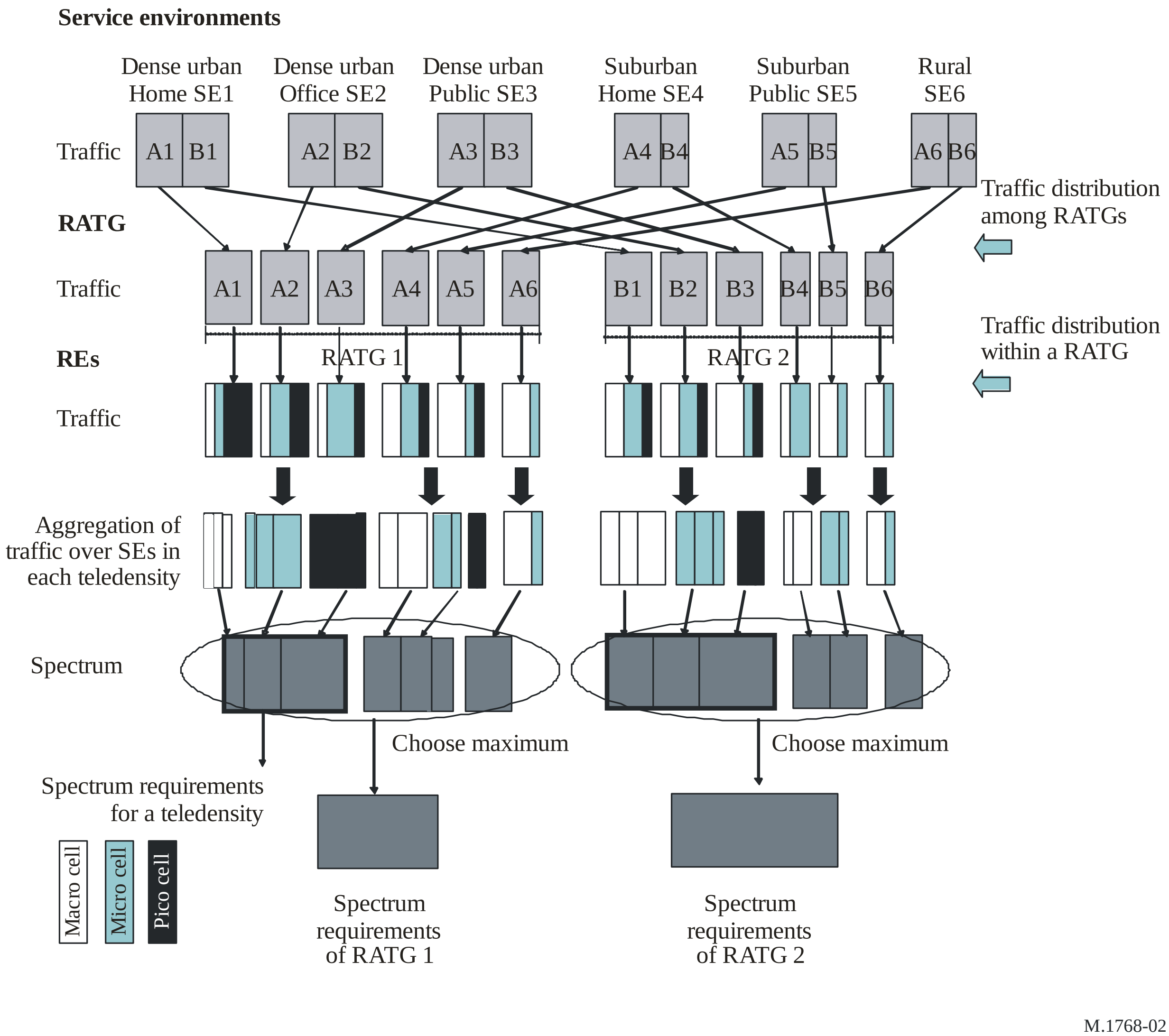

Figure 2-3: Traffic distributions among SEs, RATGs, and REs

2.3. Analyzing Vietnam's Market

2.3.1. Population Density

In this method, population density is a crucial factor that directly impacts the estimation. The spectrum requirement is assumed as proper value if it meets the demands of the most crowded city in Vietnam. Hence, Ho Chi Minh City is taken as a reference in the consideration of population density in this report.

According to the annual report of Ho Chi Minh City's Statistical Office of Vietnam in 2011 [8], the population density of the whole city is approximately 3590 person/sq.km; this is about 12449 person/sq.km in urban districts and 857 person/sq.km for rural districts.

Table 2-6: HCM's Population by urban and rural over years

	2001	2003	2005	2007	2009	2011
Whole city	5489122	5846086	6291055	6778867	7201550	7521138
Urban	4605922	5115324	5330757	5658597	5992278	6250963
Rural	883200	886854	960298	1120270	1209272	1270175

The average population growth rate is nearly 5.87%. The population of the whole city can be predicted using this rate. Figure 2-4 forecasts the population of HCM up to 2020.

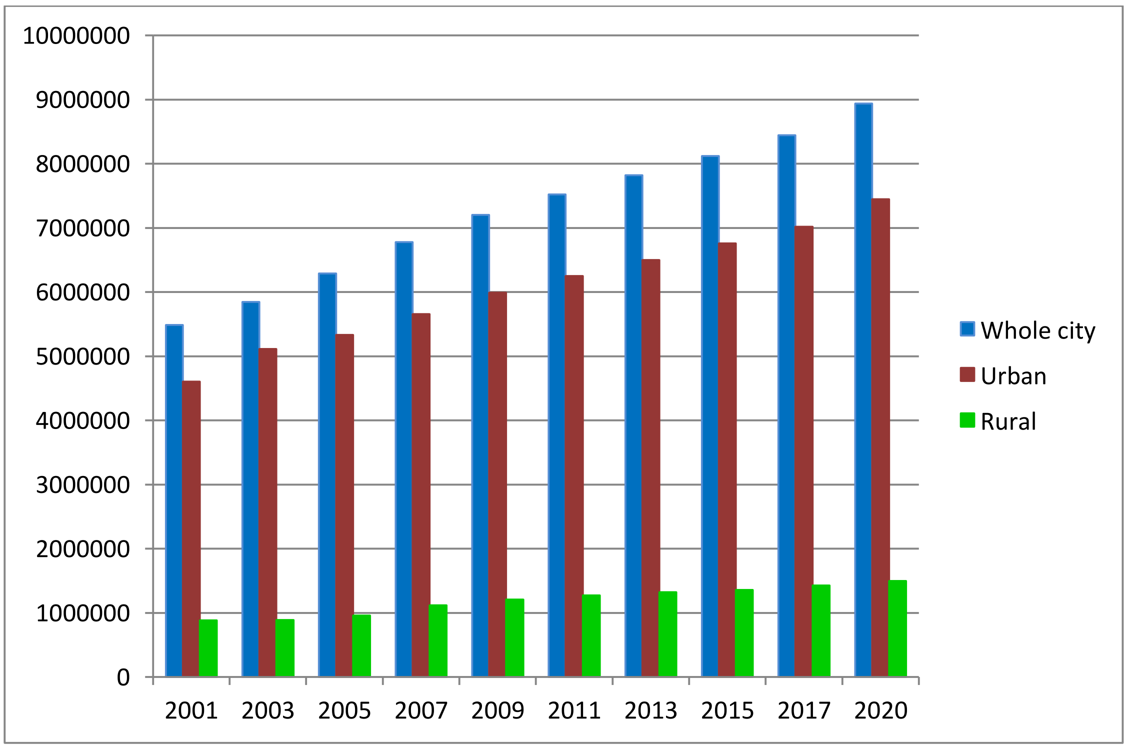

Figure 2-4: The forecasted population of HCM City

Ho Chi Minh City has an area of 2095.01 square kilometers. The population density in HCM city, therefore, can be calculated from its area and population. The population density of Ho Chi Minh City is shown in figure 2.5.

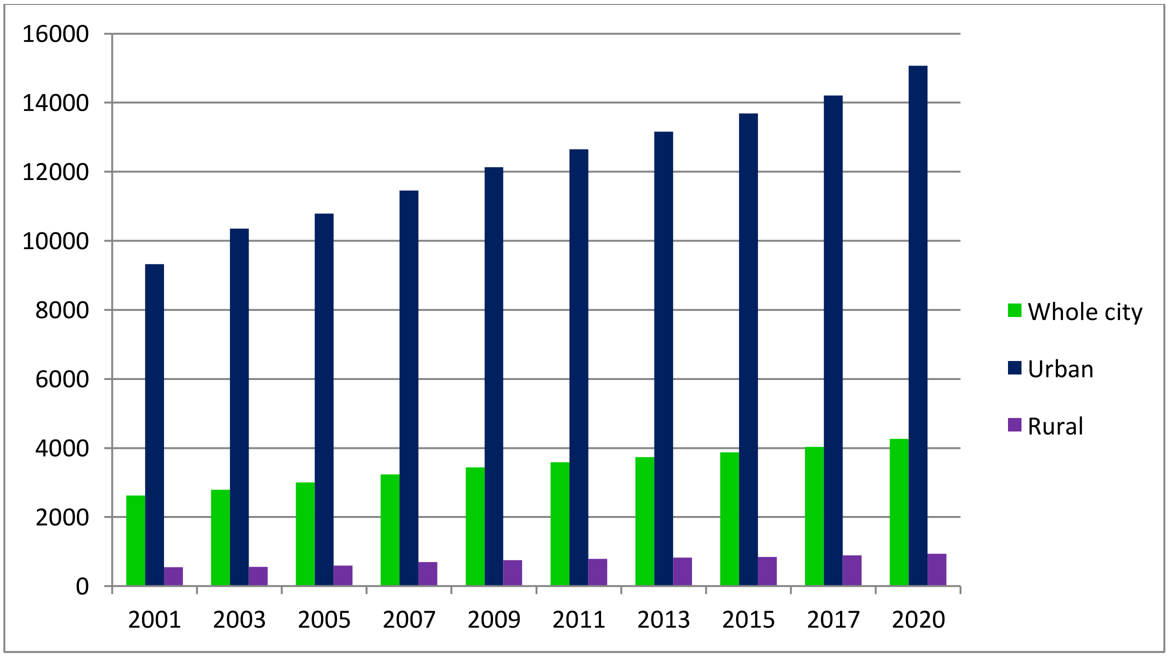

Figure 2-5: Population density of Ho Chi Minh City over years

2.3.2. Subscriber Distribution

In 2009, Vietnam's network operators deployed 3G networks. During this time, 3G users has gone up steadily with the average growth rate of 50% each year, while 2G at first occupied the most market with approximate 95% of subscribers. However, this number decreased 10% each year. Therefore, tendency of using mobile phone services in Vietnam in next 5 years might be forecasted as shown in the Figure 2-6.

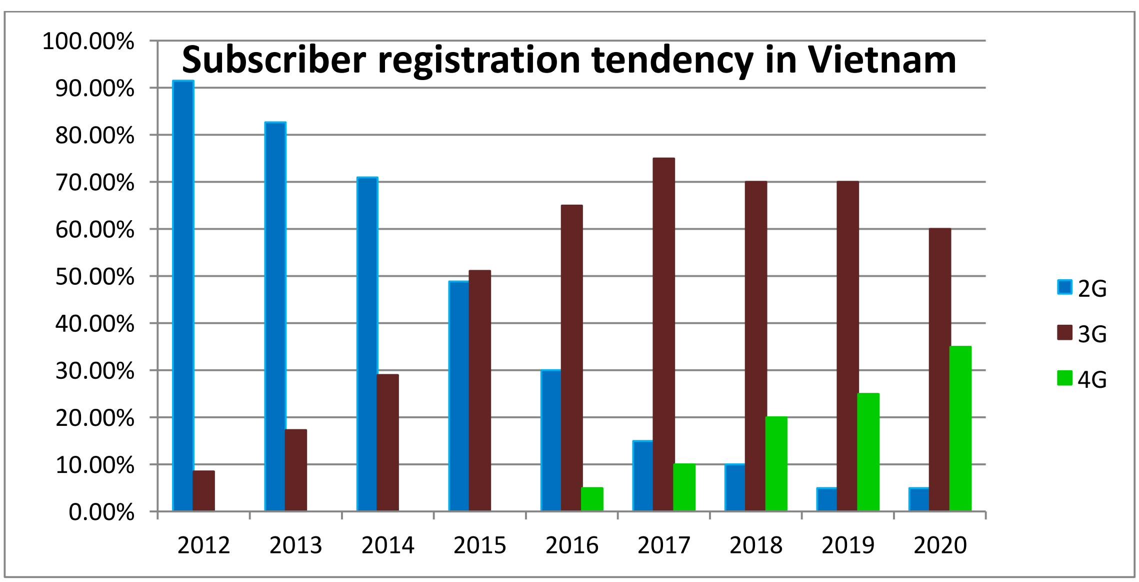

Figure 2-6: 2G, 3G and 4G distribution forecasting

In accordance with the data provided by a network operator, the number of 2G and 3G subscribers in HCM City from 2011 to 2013 is shown in figure 2.7. There are apparently an increasing number of 3G subscribers in Ho Chi Minh City, as 2G services become less popular.

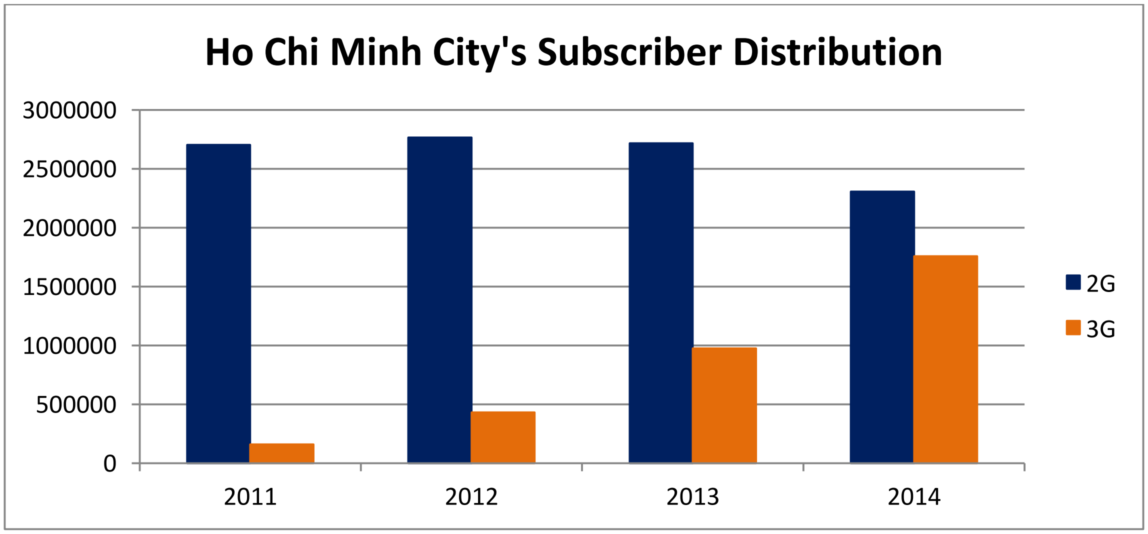

Figure 2-7: 2G and 3G subscriber in HCM City

2.4. Input Parameters

According to data selected and forecasted from Vietnam market, some input parameter values have been changed to be suitable for Vietnam.

2.4.1. Sector Area

The size of cell coverage areas are adjusted according to the data provided by network operators in Vietnam. The updated values are demonstrated in Table 2-7.

Table 2-7: Cell coverage areas

SECTOR AREA [km^2]

Radio environment	Teledensity		
	DU	SU	RU
Macro cell	0.0625	2.25	25
Micro cell	0.07	0.1	0.15
Pico cell	1.00E-04	1.00E-04	1.00E-04
Hot spot	6.50E-05	6.50E-05	6.50E-05

2.4.2. Distribution Ratio

This factor represents the distribution of traffic between RATGs. It depends on the available RATGs in each RE and SE. The data obtained from the market shows that the data traffic is primarily from 3G services contributing about 95% on average.

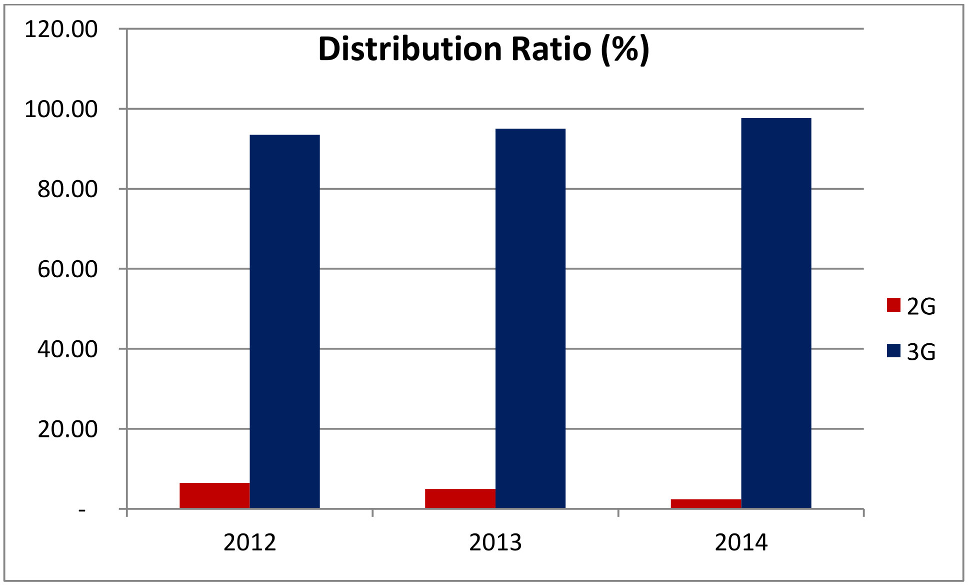

Figure 2-8: Distribution ratio between 2G and 3G

As a plan, 4G will be licensed and deployed by the end of this year or the beginning of next year 2016. Hence, the distribution between RATG#1 and RATG#2 might be the same as between 2G and 3G. In this report, we mainly consider RATG#1 and RATG#2, and in accordance with the selected data, the distribution ratio forecasting up to 2020 in Vietnam is given as the following Table 2-8.

Table 2-8: Distribution ratio for 2020

Available RAT groups	**Distribution ratio [%]**			
	RATG#1	RATG#2	RATG#3	RATG#4
#1	100	-	-	-
#2	-	100	-	-
#3	-	0	0	-
#4	-	-	-	100
#1,#2	10	90	-	-
#1,#3	0	-	0	-

#1,#4	100	-	-	100
#2,#3	-	0	0	-
#2,#4	-	100	-	100
#3,#4	-	-	100	100
#1,#2,#3	0	0	0	-
#1,#2,#4	100	100	-	100
#1,#3,#4	100	-	100	100
#2,#3,#4	-	100	100	100
#1,#2,#3,#4	100	100	100	100

2.4.3. Radio related input parameters

Most factors in this section are unchanged in comparison with values provided by ITU. However, the maximum supported velocity is adjusted to meet with the limited velocity of vehicles in Vietnam. According to official dispatch of Ministry of Transportation, the maximum velocity of vehicle is adjusted from 100 km/h to 120 km/h. After 2020, Vietnam will have a bullet train having maximum velocity of 200 km/h. Consequently, the maximum supported velocity in the report is adjusted to 150 km/h to be suitable for the Vietnam market. The details are shown in the Table 2-9.

Table 2-9: Required radio parameters for each RATGs

Required Radio Parameters for RATG #1

Attribute	Unit	Value			
		Macro cell	Micro cell	Pico cell	Hot spot
Application data rate	[kbit/s]	20000	40000	40000	1000000
Maximum supported velocity	[km/h]	150	50	4	4
Guard band between operators	[MHz]	0			
Minimum deployment per operator and radio environment	[MHz]	20	20	20	20

Number of overlapping network deployment	#	1			
Support for multicast (yes=1, no=0)		1			
granularity for spectrum allocation	[MHz]	20	20	20	20

Required Radio Parameters for RATG #2

Attribute	Unit	Value			
		Macro cell	Micro cell	Pico cell	Hot spot
Application data rate	[kbit/s]	50000	100000	1000000	1000000
Maximum supported velocity	[km/h]	150	50	4	4
Guard band between operators	[MHz]	0			
Minimum deployment per operator and radio environment	[MHz]	20	20	120	120
Number of overlapping network deployment	#	1			
Support for multicast (yes=1, no=0)		1			
granularity for spectrum allocation	[MHz]	20	20	20	20

2.4.4. Spectral Efficiency

Based on the report for Ofcom 4G capacity Gains [6], the spectral efficiency forecasted for Vietnam market up to 2020 has been proposed. The adjusted values for Vietnam market in 2020 are shown in the

Table 2-10.

Table 2-10: Spectral efficiency of VN in 2020

RATG #1				
Teledensity	**Radio Deployment Environments**			
	Macro cell	**Micro cell**	**Pico cell**	**Hot Spot**
Dense Urban	0.8	1.6	1.6	1.6
Sub Urban	0.8	1.6	1.6	1.6
Rural	0.8	1.6	1.6	1.6
2020				
RATG #2				
Teledensity	**Radio Deployment Environments**			
	Macro cell	**Micro cell**	**Pico cell**	**Hot Spot**
Dense Urban	1.91	2.9	3.92	4.5
Sub Urban	1.91	2.9	3.92	4.5
Rural	1.91	2.9	3.92	4.5

2.4.5. Market Input 2020 – User density

In this section, the minimum and maximum user density in 2020 are calculated and proposed for each service category corresponding to each service environment. As mentioned in the previous section, Ho Chi Minh City is taken into account as a reference.

This methodology has been used for calculating the spectrum requirement in China. The user density could be deduced from the proportion of population density between Vietnam and China. By comparing population of HCM City, the biggest city in Vietnam and Shenzhen, one of five biggest cities in China, the calculation could be done.

According to [10] and [11], Shenzhen, the fifth largest city in China, has the area of 1991.4 km^2; the population in 2001 was 7,245,700 and was 10,467,400 in 2011. The average population growth rate is about 3.2%. Hence, the proposed values for next 5 years are given and shown in the Figure 2-9.

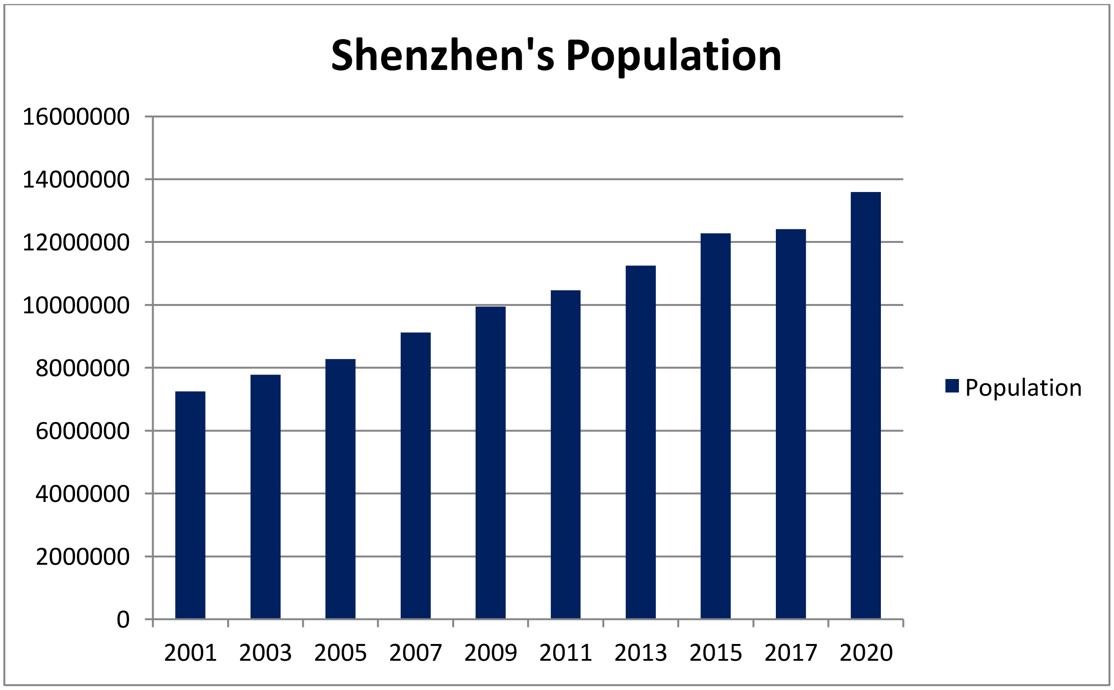

Figure 2-9: Historical and forecasted population in Shenzhen

The population density of Shenzhen, therefore, is certainly deduced and compared to Ho Chi Minh City.

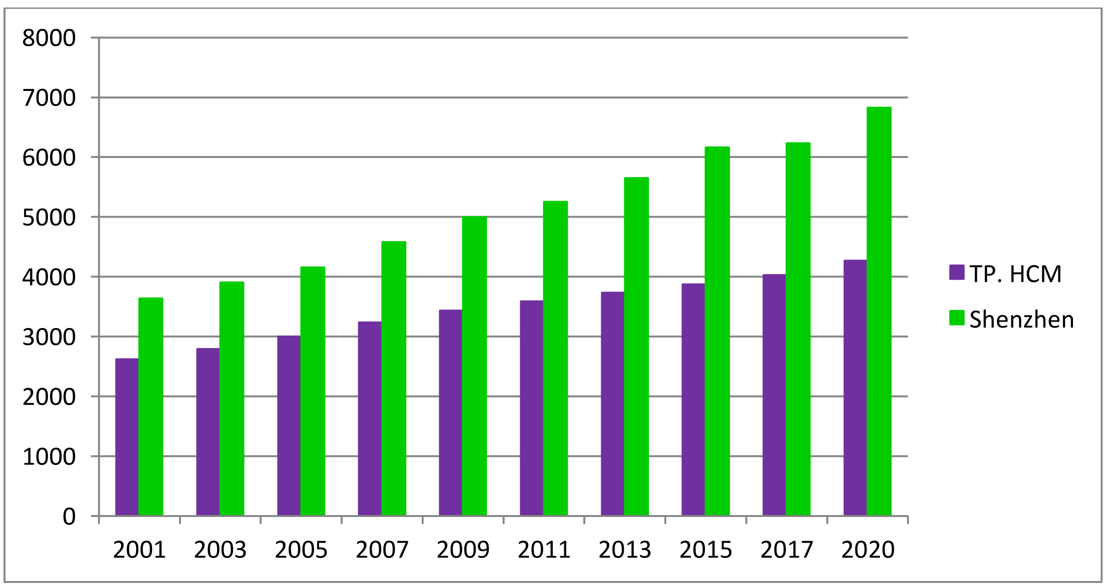

Figure 2-10: Comparison of population density between HCM and Shenzhen

The population density of HCM city is approximately 75% of that in Shenzhen. For these reasons, the user density is proposed as follows.

Table 2-11: User density in 2020 – Down Link

SC(n)	SE(m)	User density (users/km^2) [current value]	SC(n)	SE(m)	User density (users/km^2) [current value]
1	1	0	11	1	19.15
1	2	0	11	2	19.15
1	3	0	11	3	12967.69
1	4	0	11	4	0
1	5	0	11	5	958.69
1	6	0	11	6	17.97
2	1	3263.7	12	1	24322.99
2	2	11749.32	12	2	83479.36
2	3	7049.56	12	3	56742.89
2	4	195.82	12	4	7280.33
2	5	522.19	12	5	4220.93
2	6	9.79	12	6	84.44
3	1	12556.24	13	1	9930.77
3	2	24619.78	13	2	9908.87
3	3	18144.38	13	3	12122.86
3	4	621.22	13	4	31.49
3	5	881.7	13	5	78.73
3	6	22.1175	13	6	17.44
4	1	9033.1	14	1	10774.53
4	2	9078.41	14	2	10774.53
4	3	12020.96	14	3	17966.54
4	4	12	14	4	25.55
4	5	10.5	14	5	856.02
4	6	13	14	6	15.76

5	1	26352.21	15	1	9135.95
5	2	47106.42	15	2	28421.45
5	3	31468.17	15	3	17674.15
5	4	3024.84	15	4	556.63
5	5	1265.64	15	5	1330.26
5	6	38.84	15	6	29.69
6	1	601.34	16	1	0
6	2	601.34	16	2	17.94
6	3	801.78	16	3	0
6	4	0	16	4	0
6	5	0	16	5	3.45
6	6	0	16	6	0
7	1	3505.55	17	1	3100.34
7	2	9445.91	17	2	11208.67
7	3	2050.51	17	3	2048.96
7	4	126.55	17	4	180.75
7	5	31.23	17	5	291.47
7	6	6.45	17	6	18.11
8	1	10891.1	18	1	546.93
8	2	10943.41	18	2	1185.015
8	3	5881.72	18	3	18.59
8	4	18.59	18	4	91.16
8	5	68.79	18	5	63.72
8	6	5.6	18	6	8.85
9	1	273.47	19	1	455.76
9	2	364.62	19	2	911.55
9	3	46.02	19	3	46.02
9	4	46.02	19	4	46.02
9	5	91.16	19	5	46.02
9	6	8.85	19	6	8.85

10	1	182.31	20	1	911.55
10	2	273.47	20	2	911.55
10	3	46.02	20	3	911.55
10	4	46.02	20	4	911.55
10	5	46.02	20	5	46.02
10	6	8.85	20	6	8.85

Table 2-12: User density in 2020 - Up link

SC(n)	SE(m)	User density (users/km2) [current value]	SC(n)	SE(m)	User density (users/km2) [current value]
1	1	0	11	1	19.15
1	2	0	11	2	19.15
1	3	0	11	3	10.21
1	4	0	11	4	0
1	5	0	11	5	0.23
1	6	0	11	6	0
2	1	52	12	1	15231.9
2	2	57	12	2	54124.35
2	3	0	12	3	32614.63
2	4	21	12	4	925.11
2	5	10	12	5	2420.59
2	6	1	12	6	47.6
3	1	12496.3	13	1	10963.01
3	2	24869.8	13	2	9908.87
3	3	18177.86	13	3	12122.86
3	4	906.84	13	4	195.282
3	5	3672.48	13	5	78.735
3	6	23.36	13	6	26.277
4	1	9033.1	14	1	10774.53
4	2	9060.64	14	2	10774.53

4	3	12020.96	14	3	17966.54
4	4	10.62	14	4	19.16
4	5	18.585	14	5	455.82
4	6	11.505	14	6	15.759
5	1	25973.61	15	1	22590.95
5	2	47106.42	15	2	76859.45
5	3	31468.17	15	3	45595.005
5	4	738.456	15	4	1363.965
5	5	1265.64	15	5	3398.463
5	6	21.6933	15	6	2564565
6	1	601.34	16	1	0
6	2	601.34	16	2	23.92
6	3	801.78	16	3	0
6	4	0	16	4	0
6	5	0	16	5	4.6
6	6	0	16	6	0
7	1	7843.06	17	1	218.21254
7	2	24737.86	17	2	509.7
7	3	15974.54	17	3	378.29
7	4	386.78	17	4	25.99
7	5	1051.05	17	5	69.685
7	6	19.47	17	6	5.52
8	1	10891.1	18	1	404.79
8	2	10946.41	18	2	877.045
8	3	14711.12	18	3	13.755
8	4	18.585	18	4	67.465
8	5	68.79	18	5	47.16
8	6	9.95	18	6	6.55
9	1	273.46	19	1	337.325
9	2	364.62	19	2	674.65

9	3	46.02	19	3	34.06
9	4	46.02	19	4	34.06
9	5	91.16	19	5	34.06
9	6	8.85	19	6	6.55
10	1	2029.44	20	1	674.65
10	2	7072.38	20	2	674.65
10	3	4171.36	20	3	577.26
10	4	143.172	20	4	91.155
10	5	334.99	20	5	86.04
10	6	28.41	20	6	9.45

2.5. Output Results

After adjusting, the spectrum requirement estimated for 2020 is obtained as shown in the Table 2-13.

Table 2-13: Spectrum requirement for 2020

Spectrum requirement in MHz			
Spectrum for	year 2010	year 2015	year 2020
RAT Group #1	-	-	**300**
RAT Group #2	-	-	**1060**

The spectrum requirement for recent years might be deduced using on the socio-economic growth rate in Vietnam. As mentioned above, the population growth rate of HCM City is approximately 4% and the subscriber growth rate is about 3%. Hence, the user density for each year has been proposed. The forecasted values have been done for a period of time from 2015 to 2020.

Table 2-14: Spectrum requirement estimation from 2015 to2020

	2015	2016	2017	2018	2019	2020
RATG#1	**420**	**260**	**220**	**260**	**280**	**300**
RATG#2		**360**	**460**	**620**	**820**	**1060**
Spectrum Requirement	**420**	**620**	**680**	**880**	**1100**	**1360**

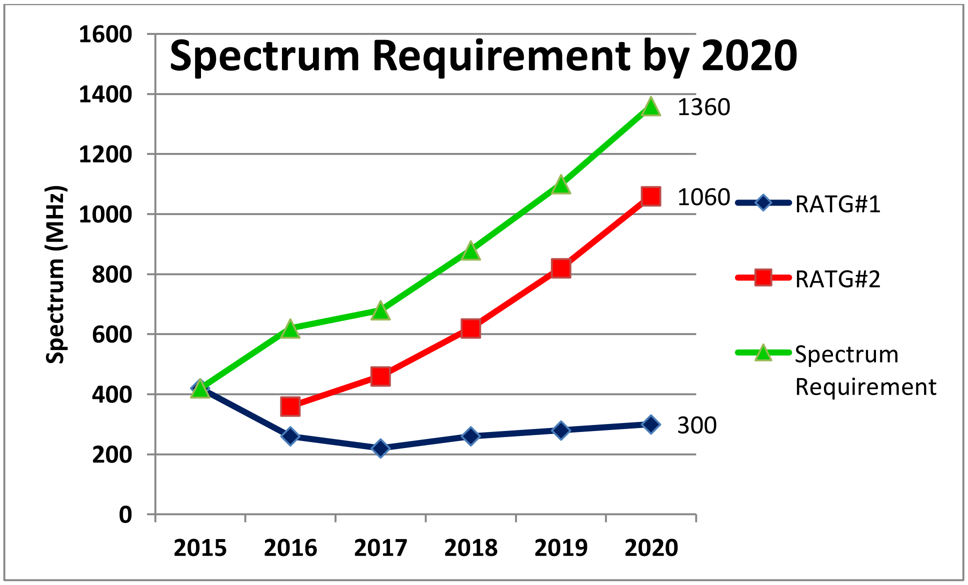

Figure 2-11: Spectrum requirement estimation for VN market

The comparison between result of ITU method and that of GSMA method is shown in the Figure 2 – 12:

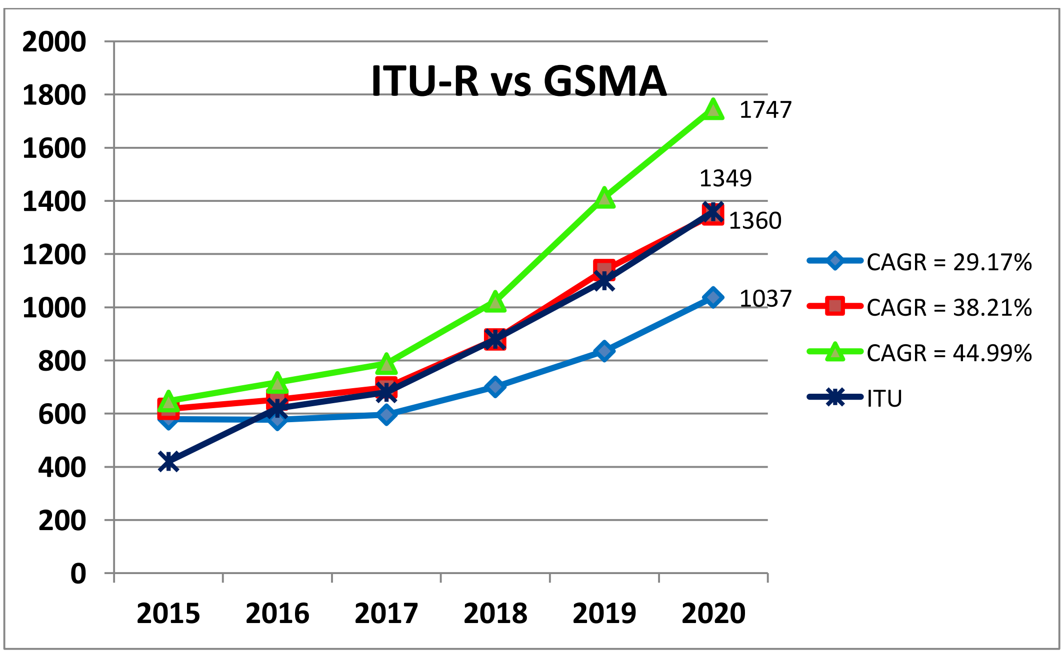

Figure 2-12: Comparison with GSMA method

2.6. The National Spectrum Requirements in other countries

The figures for some countries which utilize ITU method to calculate spectrum requirement are provided in R-REP-M.2290. The table below summarizes these results as provided by some member states and one sector member at the time of approval of the report. It should be noted that these national spectrum requirements have differences in the methodology used and assumptions made (e.g. differences in traffic/radio-aspects related parameters, differences in estimation year, differences in estimates based on whether the spectrum requirements are total or additional, etc.).

Table 2-15: The National Spectrum Requirment in other countries

Source	**US**	**Australia**	**Russia**	**China**	**GSMA6**	**India**	**UK**
Estimation year	**Until 2014**	**Until 2020**	**2020**	**2015, 2020**	**2020**	**2017, 2020**	**2020**
Spectrum requirements	Additional requirement of 275 MHz by 2014	Total requirement of 1 081 MHz (Additional requirement of 300 MHz by 2020)	Total requirement of 1 065 MHz (Additional requirement of 385 MHz by 2020)	Total requirement of 570-690 MHz (by 2015) Total requirement of 1 490-1 810 MHz (by 2020)	Total requirement of 1 600-1 800 MHz for some countries	Additional requirement of 300 MHz by 2017 Additional requirement of another 200 MHz by 2020	Total requirement of 775-1 080 MHz for the low demand setting Total requirement of 2 230-2 770 MHz for the high demand setting
Methodology	Using an original methodology	Using an original methodology	Using an original methodology	Using the methodology in Rec. ITU-R M.1768-1	Using a new methodology to complement the methodology in Rec. ITU-R M.1768-1	Using an original methodology	Using the methodology in Rec. ITU-R M.1768-1

2.7. Conclusions

By comparing the above results of other countries, the spectrum requirement given in the report is definitely suitable for Vietnam market.

PART II

THE SOCIO-ECONOMIC IMPACT OF ALLOCATING SPECTRUMFOR MOBILE BROADBAND SERVICES IN VIETNAM

3 - The Total Impact on Economic Growth of Spectrum

As the contribution by spectrum is difficult to break down into different components, it thus becomes difficult to analyze its economic impact. This study is for the case of Vietnam, where the spectrum allocation is not perfectly market-based mechanism. In order to render our economic analysis of spectrum as objective and accurate as possible, we have devised a five-step framework to calculate its value, as shown in the following figure.

3.1. The main framework

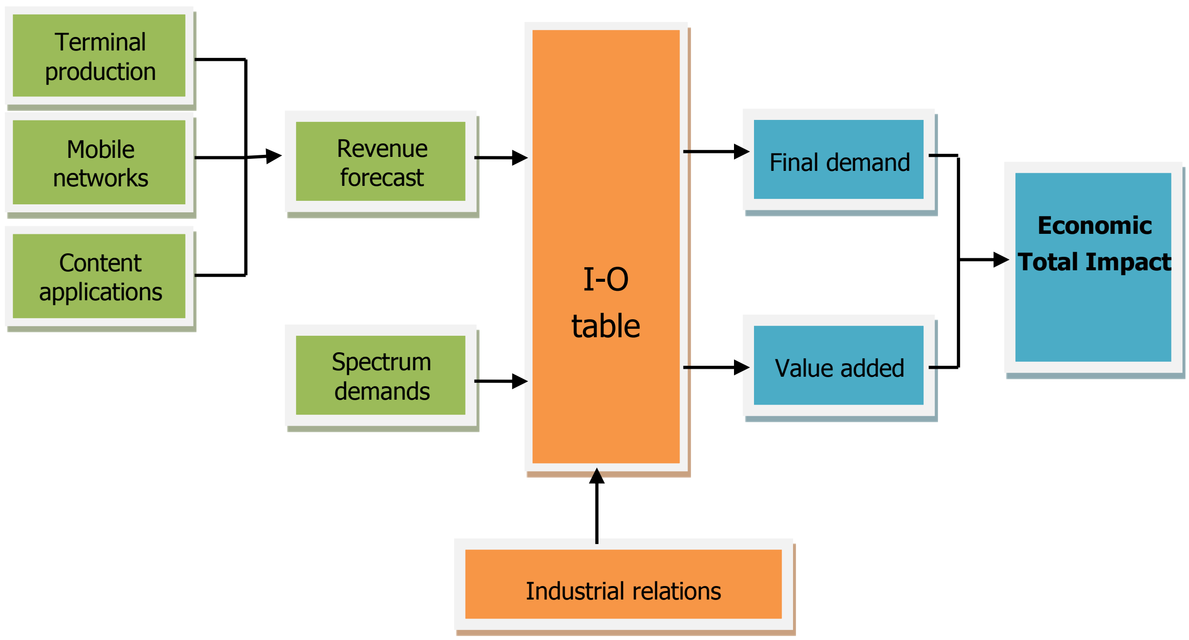

Figure 3-1: The main framework to estimate economic contribution

The analysis and economic impact assessment model of spectrum includes 5 processing steps as follows:

Step 1: Identify services related to use of bandwidth and important proportion occupation of the economy to forecast sales of the industry. For the mobile sector, in order to calculate and forecast service revenue in the future, we focus on the factors including Terminal production, Mobile network and Content applications.

Step 2: Enter the input parameters of the sectors related to forecast revenue and spectrum demand.

This step is to estimate future information demand through revenue and spectrum demand, of which information demand is the function of traffic information demand and spectrum. We believe that in constructing the two elements for information demand, data traffic or revenue and spectrum demand are both indispensable and irreplaceable.

Step 3: Analysis of data by Input Output table, compare and balance with the other service sectors in the national economic system.

This step is to analyze the increase on economic flow caused by spectrum input, through the analysis of the increase revenue caused by data traffic and through industrial relations.

Step 4: Determine the value of Final Demand (Final Consumption) and Value added of the sectors, then compare.

In the industrial system of national economy, when certain industrial sector experiences change, this will cause changes in other industrial sectors directly related to it through different industrial relations. The changes in the latter will again cause further changes in more sectors directly related to them. The transmission of such influence will gradually diminish. This whole process is the direct industrial relation

Step 5: Assess the overall impact of spectrum to the development of the economy by the calculation index.

The economic contribution of spectrum as measured through industrial relations can be divided into three kinds of effect: multiplier effect, feedback effect and spill-over effect.

- Multiplier effect. The change in the level of production caused by the unit of final demand within an industry is the influence of internal demand upon itself for the industry, with its effect to be seen in the industrial capacity of development and self-correction.
- Feedback effect. After the unit of final demand in a certain industry has influenced upon other sectors, this influence will in its turn produce a feedback effect upon the very industry.
- Spill-over effect. The spill-over effect can be defined as the sum of both direct and indirect influence of the unit of final demand in a certain industry upon the output of other sectors. This effect is a single-directional effect, reflecting the industry's impact capacity.

3.2. The Revenue Forecast

According to estimates by the provider of mobile communication[1], by the end of 2020, the world will have 9.2 billion mobile subscribers, of which 80% will be mobile broadband subscribers. Also, the broadband data development speed also increase rapidly, it is predicted that until 2018, the data usage level will increase 61% compared to 2013, in which data growth in Asia Pacific will account for 42.4%, highest in the regions. Therefore, Vietnam has set policies to develop broadband, which will enhance the use of bands, including the bands were not licensed and licensed.

The study analyses the income of various services relying on radio spectrum, on the basis of which to further distinguish and evaluate whether these services income fall in the economic contribution of radio spectrum in the sectors: Mobile (MS); Radio, Television (RT); Civil Aviation (CA); Satellite (SS) and other sectors. The service income for the telecom sector mainly includes the following seven categories: fixed local call network, long-distance call network, data communications, mobile communications network, satellite communications network.

We calculate revenue forecast by S-shaped curve:

$$\mathbf{y = L/(1+a*e^{-bt})}$$

- L: A "scale" parameter which scales the function "up and down". Scale parameter L is specified by trial and error, L is found which minimizes the standard deviation of errors.
- a, b: Estimated values of forecasts for y at time t are obtained by using the equation defined
- e: the base of the natural logarithm, approximately equal to 2.71828
- t: Period

(See Annex for details)

3.2.1. Mobile Revenue Forecast

According to the different functions along the industrial chain, the mobile Internet system can be divided into the three parts: terminal, network and application, which is commonly referred to as "terminal, pipe and cloud", the three of which are closely related

with functional complementary, thus building the base for the existence of the mobile Internet. To measure the economic contribution of the mobile Internet, first of all we need to forecast

[1]Report by Ericsson in 2014

the future growth of the above-mentioned three aspects. Based on the representativeness and availability of data, for the "terminal" part we select smart terminal (ST) as the index, for the "duct" part mobile data traffic cost, while for the "cloud" part software revenue related to the mobile Internet.

ST, MN and AI are estimated based on S-shaped curve method. Using the S-shaped curve and on the basis of related parameters estimated by the growth trend in the past seven years from 2007 to 2013, we have forecasted the revenue in the seven-year period from 2014 to 2020[2].

Table 3-1: MS revenue (million US dollar)

Year	**Mobile Revenue**	**Year**	**Mobile Revenue**
2007	2,844	2014	7,526
2008	3,308	2015	8,474
2009	3,834	2016	9,482
2010	4,428	2017	10,538
2011	5,093	2018	11,629
2012	5,832	2019	12,742
2013	6,643	2020	13,859

[2]Using S-shaped curve function with data taken from 2007 to 2013 to forecast

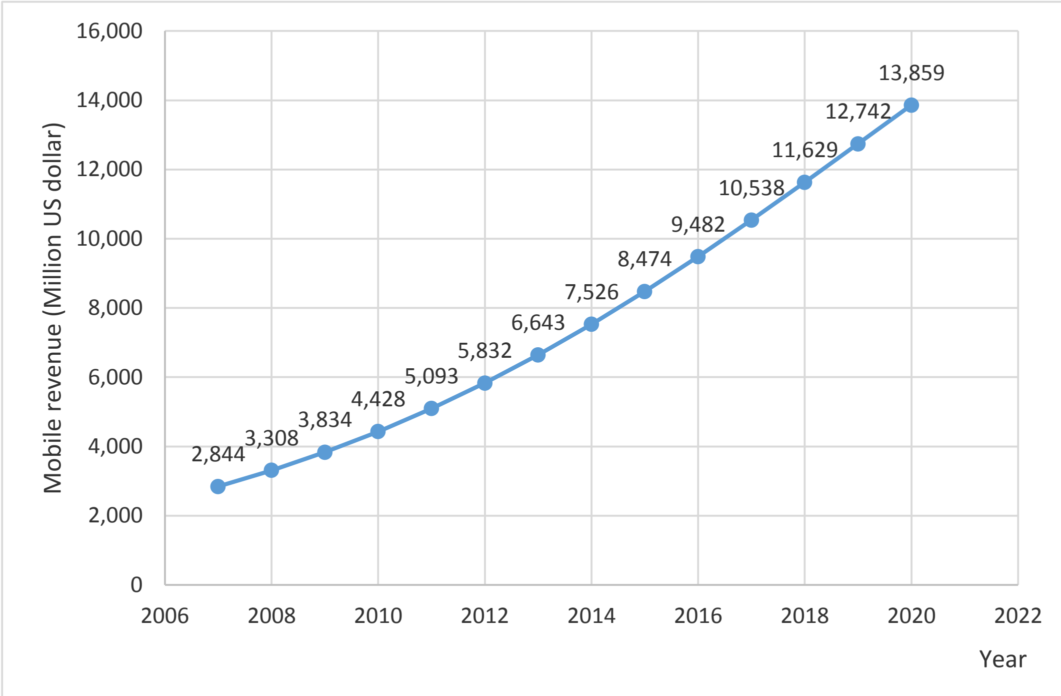

Figure 3-2: MS revenue growth rate

3.2.2. Radio, Television Revenue Forecast

Reallocation of broadcasting and television spectrum is the general trend taken across the world. In 2007, the ITU decided to release the 698 to 806 MHz. In principle it is up to each and every country to decide its own pace of promoting this programme in accordance with the demands of their domestic mobile communication and the digitalization of broadcasting and television. According to this plan, the US has auctioned twice, where out of the 800 MHz band, 100 MHz broadband was released to ensure that mobile broadband acquire sufficient spectrum resources.

Advertisement revenue is the most direct manifestation of the economic value of radio technology being applied to the radio broadcasting sector, for which reason the advertisement revenue of broadcasting can be used to calculate the contribution to GDP by radio spectrum in the radio broadcasting sector. RT revenue is calculated by television services, terrestrial broadcast, satellite digital television and advertising revenues.

3.2.3. Civil Aviation Revenue Forecast

With the rapid development of the civil aviation sector all over the world, new radio technology, services and equipment have been increasingly applied to the civil aviation sector, especially in such aspects as communications, navigation, surveillance and metrology. It plays an important role in improving flight security and advancing its steady, coordinated and sustainable development. With the rapid development of the civil aviation sector in Vietnam and a continuous increase in the number of civil aircrafts, airports, airway and regulatory sectors, there is a tremendous increase in the demand of frequencies for aviation communications by airports. Currently, the radio spectrum for aviation is on VHF communication and navigation frequency.

CA revenue referred in this study includes meteorological monitoring equipment system, new air traffic control radio, navigation radio DVOR/DME, precision landing equipment (ILS).

3.2.4. Satellite Revenue Forecast

VINASAT is the national satellite program of Vietnam. The project aims to bring independence in satellite communications for Vietnam, besides other benefits such as enhancing national security, opening new economic opportunities, Vinasat-1 is the first Vietnamese satellite to be placed in orbit. It was launched at 22:17 GMT on 18 April, 2008. The satellite has 12 Ku band transponders and 8 C band transponders.

The Vinasat-2 is the second Vietnamese satellite to be placed in orbit. It was launched at 5.13am on May 16, 2012. The Vinasat-1 and 2 at 132^0 East orbital position and $131,8^0$ East have extensive coverage in Asia, Australia and Hawaii.

The Revenue is calculated on the basic services provided play/recording, broadcast television services to every household (DTH) service, providing VSAT (DAMA, TDM/TDMA, PAMA), providing private network customers and other services.

The revenue of satellite may increase in the future depending on the number of satellites in orbit and diversity of services.

3.3. The Economic Impact of Spectrum

3.3.1. The Economic Impact of Mobile

International experiences have testified that the mobile Internet can contribute to economic growth. Of course, this is not just due to the need of production input to build networks and sell mobile phones, but more importantly, due to the fact that the mobile Internet can advance the spread of information, improve productivity and efficiency, and enable individuals to explore new market and services in the whole economy.

In 2020, the total revenue of mobile services in Vietnam is forecasted by 13,859 million US dollars. Based on that, the final demand is calculated based on Input-Output Table 1shown in the Table 3-2 below.

Table 3-2: MS Model inputs (million US dollar)

Year	MS Revenue	Final Demand
2014	7,526	1,937
2015	8,474	2,181
2016	9,482	2,440
2017	10,538	2,712
2018	11,629	2,993
2019	12,742	3,279
2020	13,859	3,567

Based on the input-output method, the mobile product value is calculated with the condition of fully-allocated spectrum for all sectors on demand from 2014 to 2020.In order to see the impact of mobile on GDP, which is an added value of the whole economy, added value of mobile should be calculated (Net Added Value of Mobile = Product value of Mobile * added value rate of Mobile). From Vietnamese Input-Output table, added value rate of mobile is 44% and the Net Value Added from 2014 to 2020 is listed below.

Table 3-3: MS Model outputs (Million US dollar)

Year	MS Product Value	Net Value Added
2014	4,459	1,974
2015	5,021	2,223.
2016	5,618	2,488
2017	6,243	2,765
2018	6,890	3,051
2019	7,549	3,343
2020	8,211	3,636

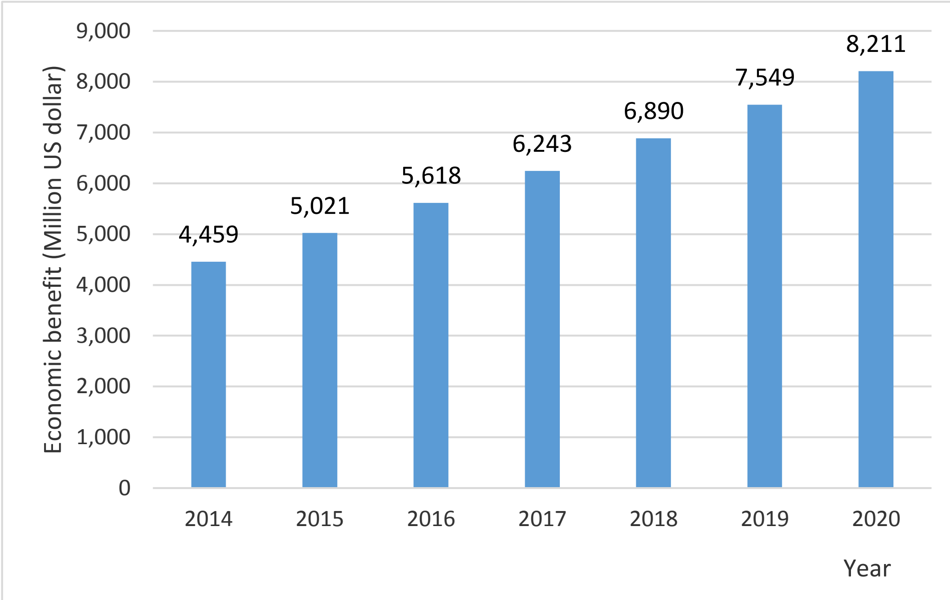

Figure 3-3: Economic benefit of MS

Basing on our forecast of revenue of mobile, we can estimate the value added and total economic impact of mobile in 2020, in which they will reach respectively 3,636 and 8,211 million US dollars.

The contribution rate to the general national economy by the Mobile sector can be seen in the following figure.

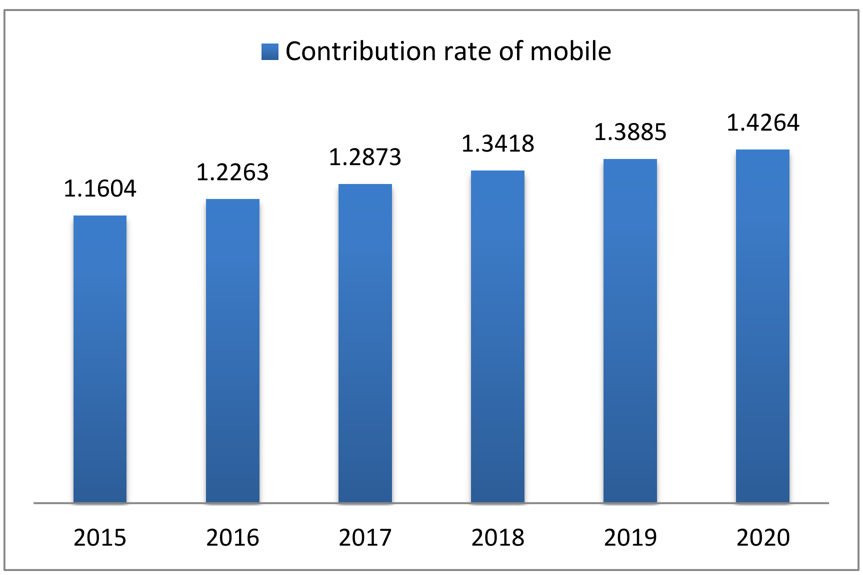

Figure 3-4: Contribution rate of Mobile

From this figure, it can be seen that the rate of economic contribution by the Mobile sector will rise from 1.16 % of GDP growth in 2015 to 1.43% in 2020, such a relatively stable growth rate.

3.3.2. The Economic Impact of Other sectors

The only way to solve the problem of shortage of the spectrum resources is to increase the overall supply and efficiency of the use of spectrum. Based on the accuracy and availability of data, our analysis of the economic impact of other sectors is mainly focused on RT, CA and SS.

(a) The Economic Impact of Radio, Television

According the same method used to calculate the economic contribution by Mobile sector, we have calculated the value added economic contribution by RT sector, as can be seen in the following table:

Table 3-4: Net Value added of RT (Million US dollar)

Year	Value added
2014	26.43
2015	30.62
2016	34.36
2017	37.48
2018	39.97
2019	41.87
2020	43.27

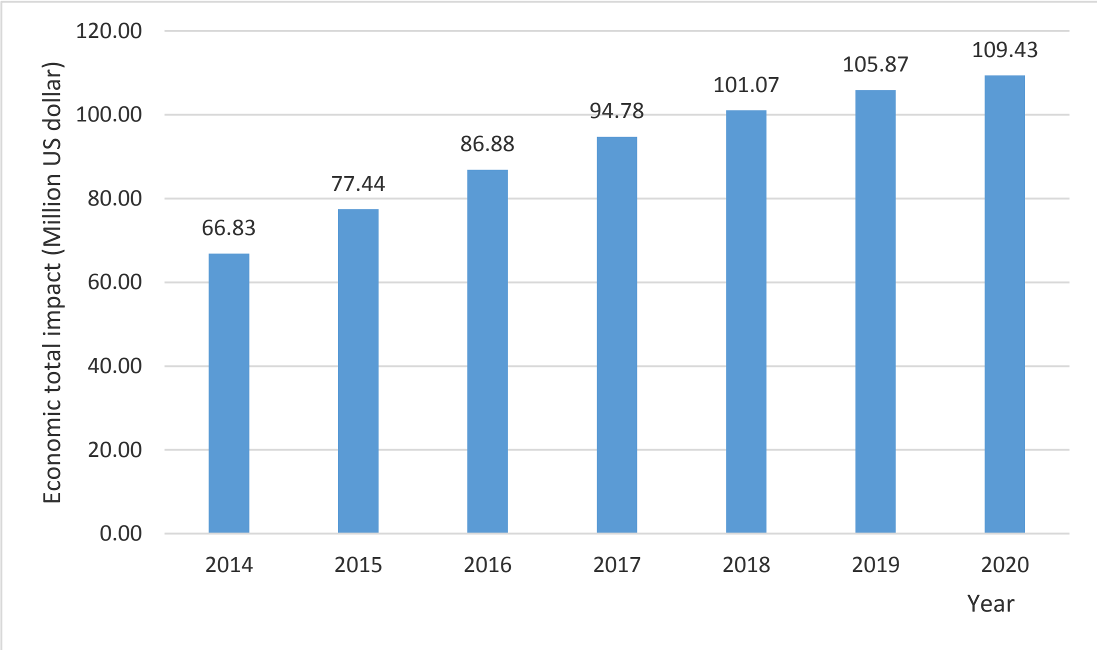

Figure 3-5: Economic total impact of Radio, Television

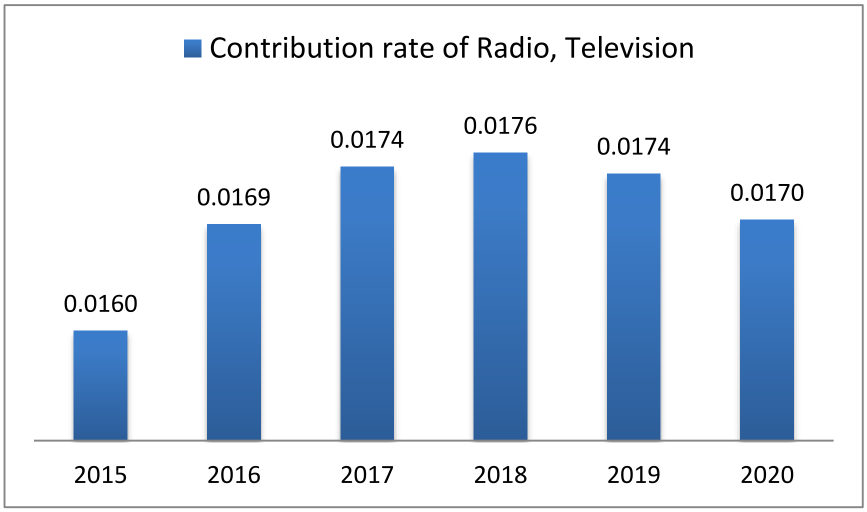

Figure 3-6: The contribution rate of Radio, Television

From the above figure, it can be seen that the rate of economic contribution by the RT sector will rise from 0.016% in 2015 to 0.017 % of GDP growth in 2020.

(b) The Economic Impact of Civil Aviation

Currently, the radio spectrum for aviation in Vietnam has almost covered all spectrum bands from long wave to microwave, the increase in the demand of frequencies for aviation communications by airports, the radio frequency resources in civil aviation is mainly concentrated on VHF communication and navigation frequency. These services are application-band FM radio, promotional information, communication between the aircraft-aircraft and aircraft-ground. Information ground mobile and maritime radio and amateur radio weather…

According the same method used to calculate the economic contribution by Mobile sector, we have calculated the added value economic contribution by the CA sectors, as can be seen in the following table:

Table 3-5: Net Value added of CA (million US dollar)

Year	Net Value added
2014	354,38
2015	392,78
2016	429,38
2017	463,34
2018	494,08
2019	521,29
2020	544,89

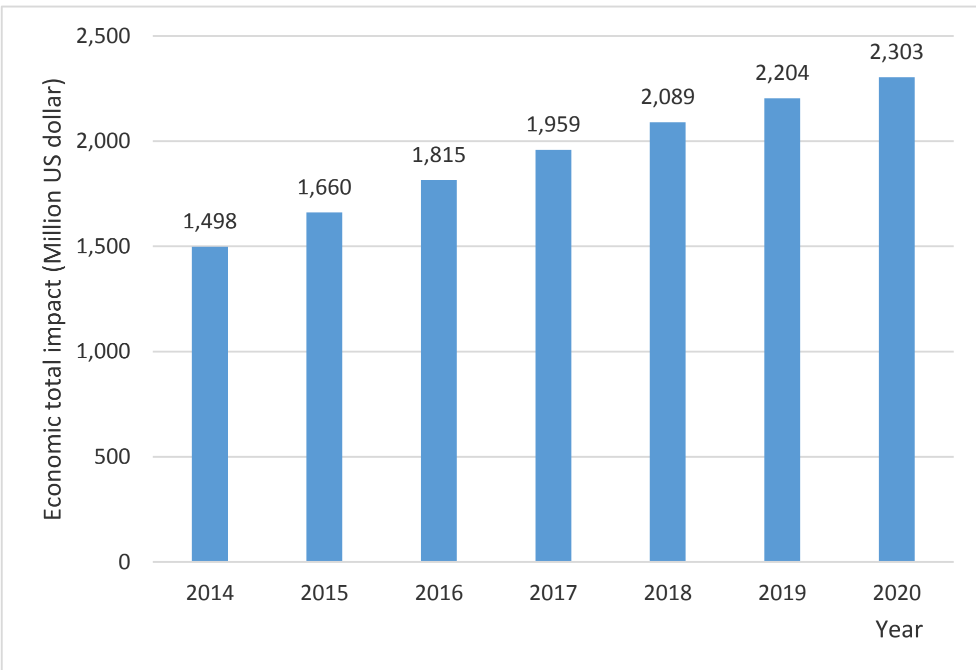

Figure 3-7: Economic total impact of CA

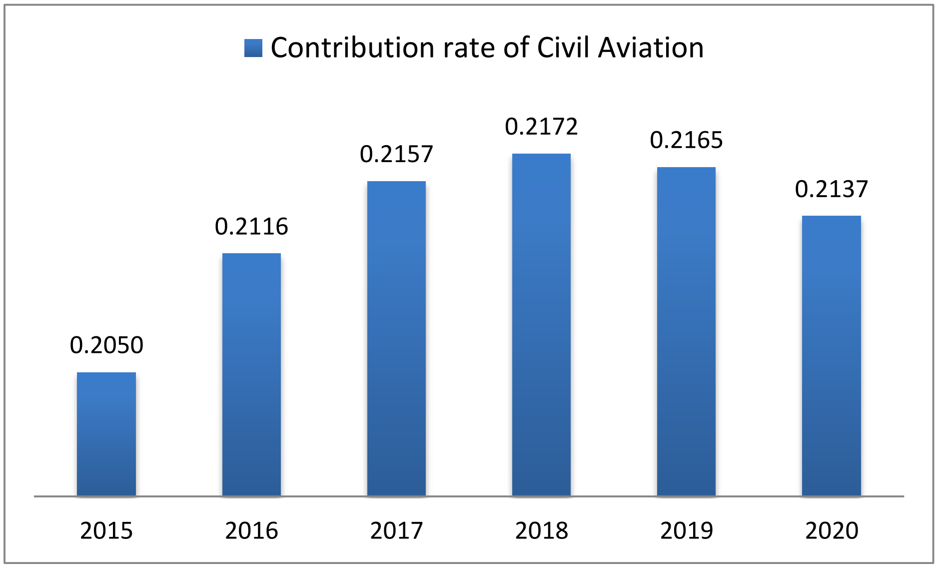

Figure 3-8: The contribution rate of Civil Aviation

(c) The Economic Impact of Satellite

Vietnam has successfully launched two telecommunication satellites Vinasat-1 and Vinasat-2. Vinasat-1, using the platform model A2100, has 20 transponders, including 12 Ku-band and 8 C-band transponders with a bandwidth of 36 MHz.

Coverage areas of satellite for Ku band beams covers the Vietnam, Laos, Cambodia, Thailand and Myanmar part with high radiation power levels up to 55 dBW that is very suitable for promotion services. Coverage areas of satellite for Ku band beams covers the Vietnam, Laos, Cambodia, Southeast Asia, eastern China, Korea, India, Japan, Australia and the Hawaiian Islands with radiation power levels up to 44dBW that quality assurance transmission for telecommunications networks.

Vinasat-2 consist of 30 transponders in which 24 transponders are bringing into market, others are the redundancy. Transmission capacity of the satellite is equivalent of 13,000 Voice, Internet, data communication channels or equivalent 150 TV channels.

According the same method used to calculate the economic contribution by Mobile sector, we have calculated the added value and economic contribution by the Satellite sector, as can be seen in the following figures:

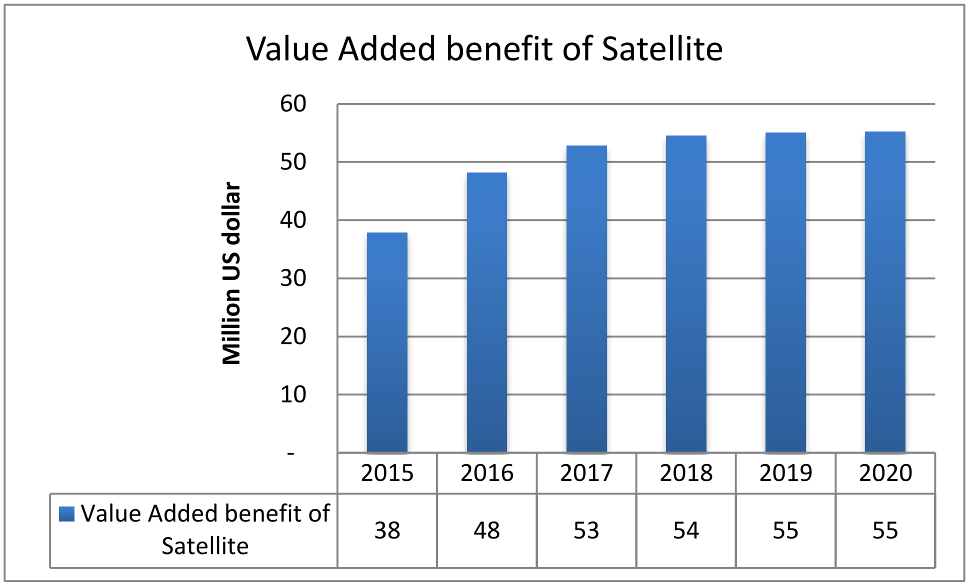

Figure 3-9: Value added benefit of Satellite

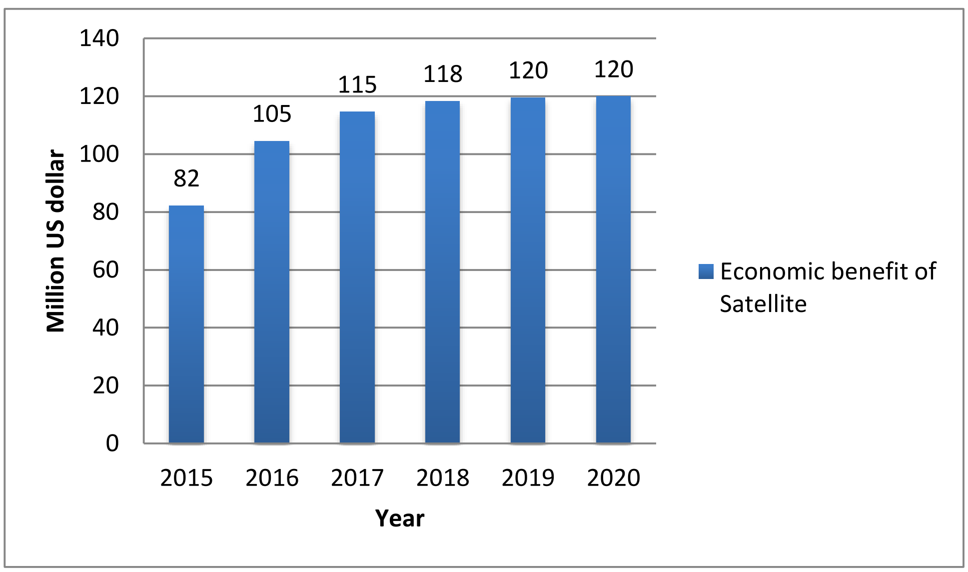

Figure 3-10: Economic benefit of Satellite

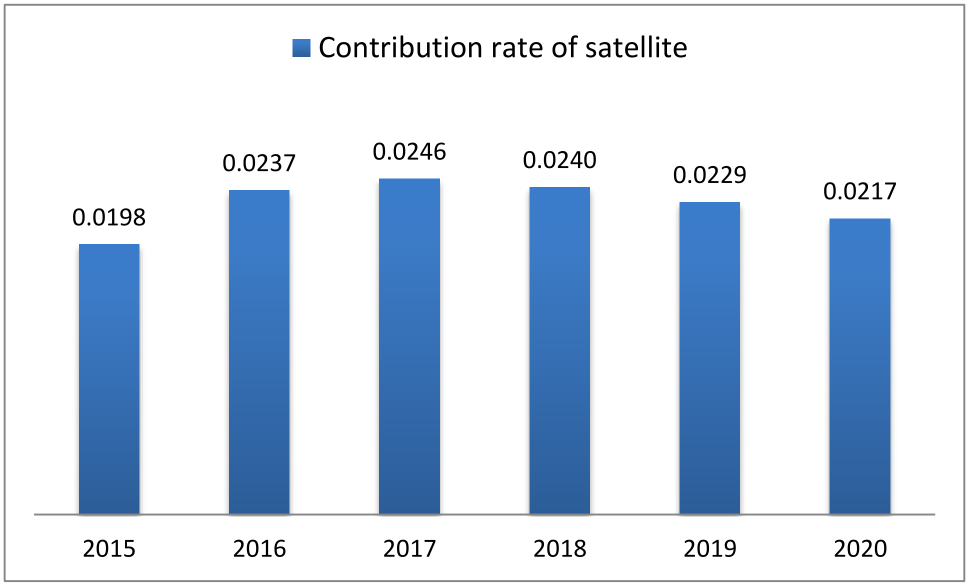

Figure 3-11: Contribution rate of SS

According to the analyzed results, the economic impact of the Mobile sector and other sectors, we can see the difference contribution between the sectors shown in the following table:

Table 3-6: Comparison of contribution rate to GDP (%)

Year	Mobile	Radio, Television	Civil Aviation	Satellite
2015	1,1600	0,0160	0,2050	0,0198
2016	1,2300	0,0169	0,2116	0,0237
2017	1,2900	0,0174	0,2157	0,0246
2018	1,3400	0,0176	0,2172	0,0204
2019	1,3900	0,0174	0,2165	0,0229
2020	1,4300	0,0170	0,2137	0,0217

3.3.3. Total Impact of Mobile

As far as the differentiation of industrial relation is concerned, of the three effects, the spill-over effect is the most prominent, the multiplier one in the second while the feedback effect the least prominent. In particular, every increase of one million US dollar in final demand will produce a total impact effect of 2.30205 million US dollars, of which the multiplier effect will contribute 1.00517 million US dollars, while the feedback effect 99.757 and the spill-over effects 1.29443 million US dollars.

Table 3-7: Differentiation of the effect of industrial relation

Multiplier Effect	**Feedback Effect**	**Spill-over Effect**	**Total Effect**
1.00517	0.99757	1.29443	2.30205

4 - The Economic Benefits of Spectrum

Although the spectrum is an important natural and strategic resource, the economic contribution by spectrum does not exist independently and its economic impact is possible only after it is combined with other productive input. However, due to the limited availability of data, it is impossible to calculate the marginal contribution of spectrum. As a substitute, we can see the important role of spectrum indirectly through the economic benefits of those sectors using spectrum and their contribution to the whole national economy.

4.1. Spectrum Allocation and Demand in Vietnam

Radio spectrum is an important natural and strategic resource to a nation. The enormous economic value of radio frequency becomes a publicly-known fact. The direct contradiction between the have and have not, abundance and shortage, high and low efficiency of use of the spectrum resource between different sectors has become all the more salient. On the one hand, certain units and agencies possess some spectrum band, which is kept idle and unused for long; while on the other hand, over used spectrum band, with the development of new technology and an increase in the number of users and service load, becomes so crowded that it can no longer meet the needs of further development.

The studies for allocating spectrum for the IMT system designed by ITU-R WP5D is used not only as reference for spectrum planning by regulatory bodies across nations around the world, but also as industrial guidance for manufacturers, for purpose of achieving economy of scale and reducing barriers for international roaming by means of global or regional integration. At the moment, the spectrum allocated for mobile communication systems can, in principle, be used for the deployment of any technology in the future, albeit with a consideration of the status quo of service applications on current frequency bands, the issue of interference with services on neighboring bands, and the strategy of spectrum re allocation.

New frequency bands have been allocated for the IMT service at the following three conferences, namely WARC-92, WRC-2000, and WRC-07. Such frequency bands include 450-470 MHz, 698-960 MHz, 1710-2025 MHz, 2110-2200 MHz, 2500-2690 MHz, 2300-2400 MHz, and 3400-3600 MHz, of which 698-960 MHz and 3400-3600 MHz are not global frequency bands, which is annotated in the form of footnote by certain regions.

In order to advance the global or regional integration of spectrum planning and use by mobile communication systems, to reduce inter-system interference, and to provide regulatory bodies all over the world with reference on spectrum allocation for mobile communication systems, ITU-R has carried out research on the planning and use of these spectrum. By the same token, it has drafted some technical recommendation M.1036, namely “Programme for Spectrum Allocation for the IMT System”.

Table 4-1: Spectrum Allocation in Vietnam

Sector	**Spectrum band**	**Spectrum range (MHz)**
Mobile	463.08-467.37 MHz; 453.08-457.37 MHz 824 - 835 MHz; 869 - 880 MHz; 880 - 915 MHz; 925 - 960 MHz; 1710 - 1780 MHz; 1805 - 1880 MHz; 806 - 824 MHz; 835 - 869 MHz; 1427 - 1525 MHz; 1920 - 1980 MHz; 2110 - 2170 MHz; 2300 - 2390 MHz; 2500 - 2690 MHz;	~685
Satellite	3400 – 3600 MHz; 3600 – 3900 MHz; 3900 – 4200 MHz;	~800
Broadcasting	470 – 806 MHz	~336
Civil Aviation	960 – 1215 MHz; 1300 – 1350 MHz; 2700 – 2900 MHz; 4200 – 4400 MHz;	~705

(*) Other sectors as the Radar, National Defense… which we cannot get data of spectrum are not in this table.

Currently, the total spectrum resource possessed by the Mobile sector in Vietnam is around 630 MHz (800 MHz, 900 MHz, 1800 MHz, 2.3-2.4GHz, 2.5-2.96GHz).Although a large portion of this was only made available recently and with some restrictions in some bands. Because of the international nature of the Mobile industry and the need for low cost, mass produced devices, it is important that the bands selected for consideration in Vietnam match up with what is under consideration in current the ITU/WRC global harmonization process.

The Table 4-1 above shows the current use of Mobile candidate frequency bands in Vietnam, according to forecast done in Part I, in the year 2020, the total spectrum demand of the Mobile sector will be 1349 MHz.

Table 4-2: Spectrum Demand Forecasting for Mobile (MHz)

Year	2015	2016	2017	2018	2019	2020
Spectrum demand	618	653	698	879	1,139	1,349

4.2. Scenarios for Alternative Use of Released Spectrum

In order to be able to estimate the economic benefits for each industry in our following scenarios, we assumed that spectrum necessary to Mobile will be taken proportionally from the available bandwidth from each of these candidate bands. Ideally one would need to optimize this, rather than take just spectrum proportionally. For example in figure 1.3, one can see that in 2020 the economic impact of Satellite is very low compared to the other services (some 120 for Satellite vs 8,211 for Mobile). Yet SS has 300 MHz of spectrum. That would imply that the economic value generated by SS (per MHz) would be around 26 times less than Mobile, in the year 2020.

Although the transfer of spectrum between different sectors (e.g. CA, RT etc.) will incur significant costs, overall it is likely to generate better economic benefits overall for Vietnam. This is consistent with modern economic theory that suggests scarce resources should flow from low value uses to higher value ones, to maximize economic efficiency. We need to consider two scenarios below to illustrate this problem.

(a) Spectrum not re-allocated – the baseline scenario, in which spectrum owners in all sectors remain the status quo, MS will only have 685 MHz currently identified.

(b) Spectrum re-allocated to meet MS spectrum demand – a scenario in which spectrum is allocated for mobile from storage and transferred from other sectors to satisfy MS demands. In this case, we should consider the costs of alternative uses.

Before 2018, there will be no shortage of spectrum in the MS, for this reason the key area for our analysis is the scenario after 2018. We can classify scenario (b) into the following few circumstances:

- (b1) Annually allocate spectrum for Mobile as its demand giving a total of 885 MHz.
- (b2) Annually allocate spectrum for Mobile as its demand giving a total of 997 MHz by getting 92 MHz from broadcast sector (700 MHz band).

- (b3) Annually allocate spectrum for Mobile as its demand giving a total of 1117 MHz by getting more 140 MHz from L-band in comparison with scenario b2.
- (b4) Annually allocate spectrum for Mobile as its demand giving a total of 1,267 MHz by getting more 150 MHz (of which 100 MHz from 2.7-2.9 GHz band and the other 50 MHz from other band of civil aviation, except C band) in comparison with scenario b3.
- (b5) Annually allocate spectrum for Mobile as its demand giving a total of 1,367 MHz by getting more 100 MHz from broadcast sector in comparison with scenario b4.
- (b6) Annually allocate spectrum for Mobile as its demand giving a total of 1467 MHz by getting more 50 MHz from broadcast and 50 MHz from other band of civil aviation, except C band, in comparison with scenario b5.

Under different scenarios, we analyze several economic indices below, including Final Demand, Economic Benefit and Net Value Added in the next sections.

4.3. Economic Benefit

In order to estimate the economic benefits for each industry in our following scenarios, we assumed that spectrum necessary to Mobile will be taken proportionally from the available bandwidth from each of these candidate bands. Ideally one would need to optimize this, rather than take just spectrum proportionally.

If we assume that all the spectrum demand in the Mobile sector can be satisfied and there is no loss to the other services (RT, SS, CA) in allocating more spectrums to Mobile, then we can first of all have an estimate of the economic benefits for the Mobile, as can be seen in the following figure. We can see that in 2020 the economic benefit of Satellite is very low compared to the other services (some 60.00 for Satellite vs. 8,211 for Mobile).

From the below figure, it can be seen that under the assumption that all Mobile spectrum needs can be satisfied, the efficiency of using spectrum in the Mobile sector exhibits a large increase, In 2015, the contribution of spectrum in the Mobile sector to the whole national economy reached some 5,021 million US dollars, it will reach some 8,211 million US dollars in 2020.

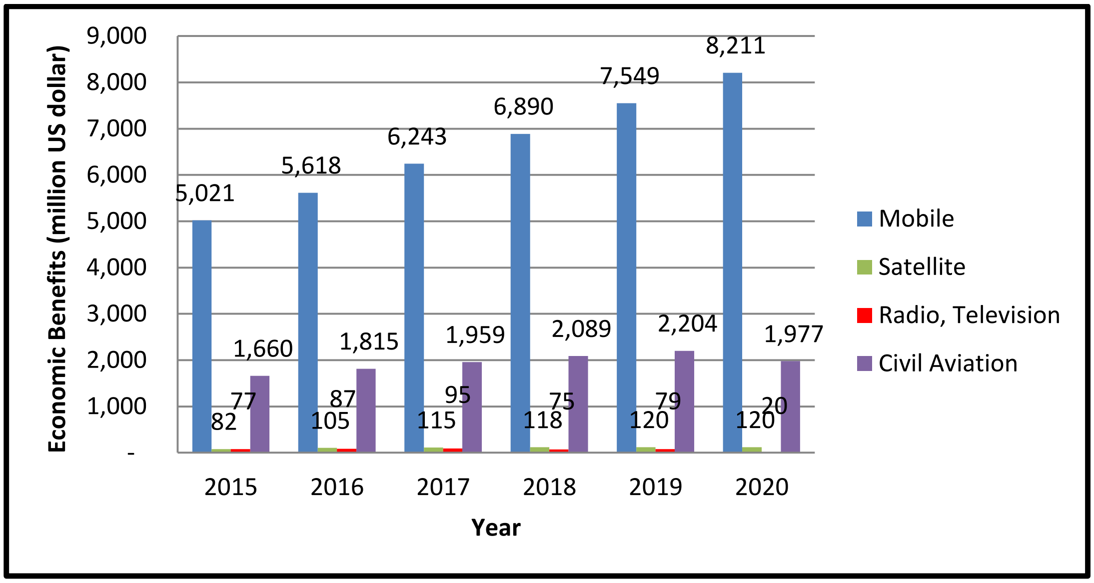

Figure 4-1: Economic benefit of each sector

4.4. Net Economic Benefit

In the case that spectrum is allocated sufficiently to all sectors, we calculate the economic total impact of each sector in the figure 4-1 above.

In order to analyze the impact of spectrum re-allocation on national economy, we will analyze Scenario (a) and (b1-b6) from the perspective of total volume of net economic benefits.

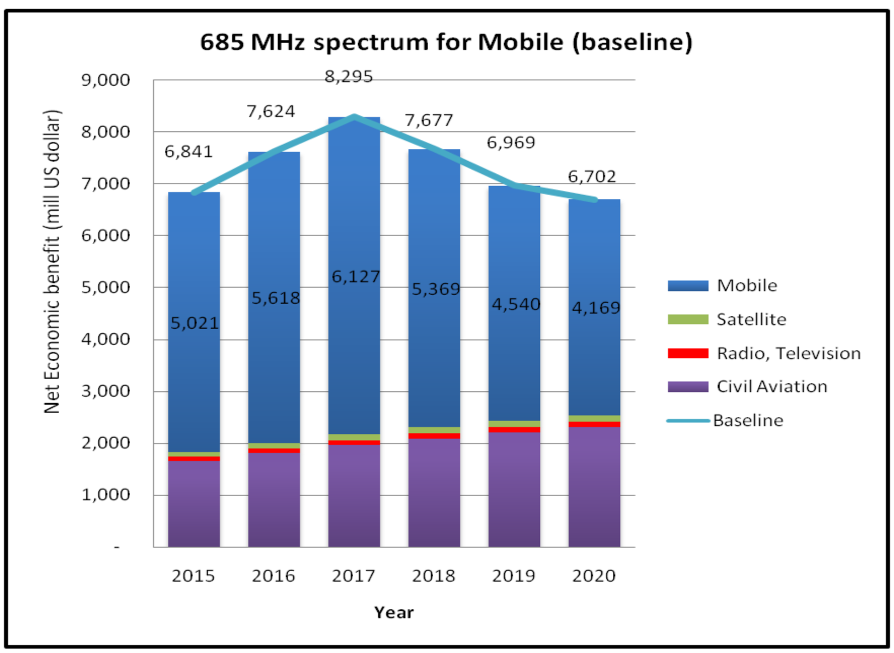

Figure 4-2: Net economic benefit of 4 sectors in case of scenario (a)

If we assume that spectrum is an indispensable resource for the sectors using spectrum, then in Scenario (a) – the status quo, the economic benefits for the total of the 4 industries can be seen in the following figure. There is no more frequency for Mobile since 2015, giving total of 685 MHz. From the figure, the Net economic benefit of mobile is gradually dropped from 2018 to 2020 because of frequency shortage and still decreasing even if the spectrum allocation is fixed 685 MHz as the decreasing rate of economic benefit per 1 MHz of mobile since 2018 to 2020. In such situation the mobile network quality cannot compete with alternative such as satellite communication or fixed line infrastructure, and therefore mobile customers use much less data than they would have to if they had quality network, resulting to less revenue for operators, and less associated economic benefits.

With the Net Economic Benefit and Net Value Added of Mobile in case of scenario (a) above, the contribution rate from 2014-2020 in this case can be seen as follows. The figures show that the contribution rate of MS to GDP is gradually declined as of spectrum shortage.

Table 4-3: Contribution rate to GDP of MS (a)

Year	2015	2016	2017	2018	2019	2020
Contribution rate to GDP (%)	1.16	1.23	1.26	1.05	0.84	0.72

In fact, it is impossible to allocate spectrum sufficiently to all sectors due to its limited resource. Thus, we analyze the scenarios b (from b1 to b6) in which we will allocate spectrum to Mobile in such a way that Economic benefit will reach a maximum value. In order to analyze the impact of spectrum re-allocation on national economy, we will analyze scenarios from the perspective of total volume of total impact. We analyze the result of each scenario (from b1 to b6) by the following figures.

In **scenario b1**, we can see the total economic impact of each sector in the Figure 4-3 below.

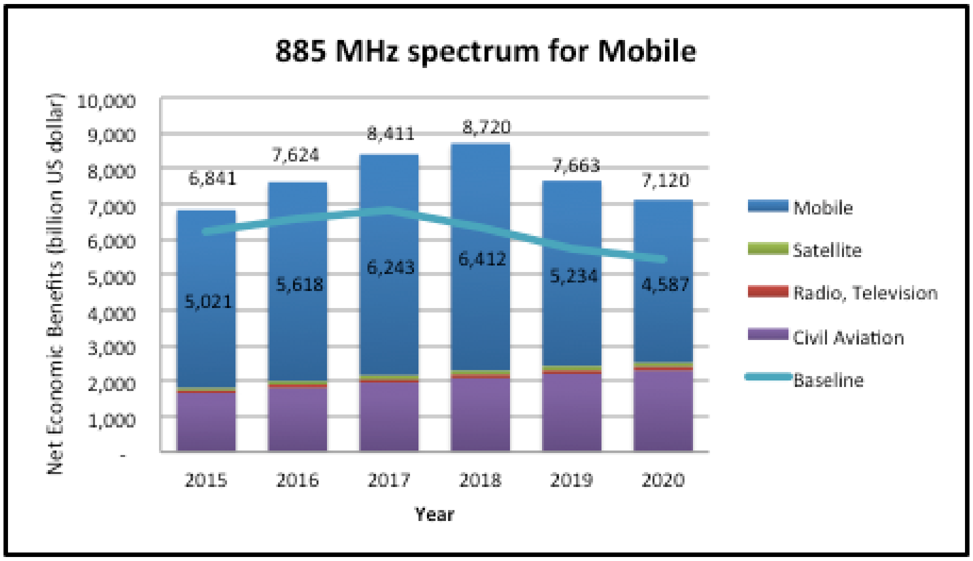

Figure 4-3: Economic benefit of Mobile (scenario b1)

Also, we can see the statistical Table 4-4 below on spectrum allocation status to see how insufficient spectrum allocation impact of Mobile in particular and all sectors as well to GDP.

Table 4-4: Spectrum allocation status statistics (b1)

Year / Sector	2015	2016	2017	2018	2019	2020
Mobile	X	X	X	X	254	464
Satellite	X	X	X	X	X	X
Radio, Television	X	X	X	X	X	X
Civil Aviation	X	X	X	X	X	X

X: sufficiently allocated spectrum; Unit: MHz

According to this scenario b1, spectrum is sufficiently allocated to all sectors from 2015-2020, while it is not sufficiently allocated to Mobile from 2019 and 2020 by respectively 254 and 464 MHz respectively. Due to this insufficient spectrum allocation, GDP loss caused by Mobile is 2,824 million US dollars in 2020 and this number also shows the GDP loss from the 4 sectors in this same year.

With the Economic Benefit and Net Value Added of Mobile in case of scenario (b1) above, the contribution rate from 2015-2020 in this case can be seen as follows. The figures show that the contribution rate of MS to GDP is increased from 2015 to 2017, and then gradually declined as of spectrum shortage in 2018, 2019 and 2020.

Table 4-5: Contribution rate to GDP of MS (b1)

Year	2015	2016	2017	2018	2019	2020
Contribution rate to GDP (%)	1.16	1.23	1.29	1.34	1.08	0.94

In **scenario b2**, through analysis from scenario b1 in which spectrum allocation is considered under economic perspective, we would analysis this scenario b2 in which spectrum is allocated to mobile industry of 977 MHz

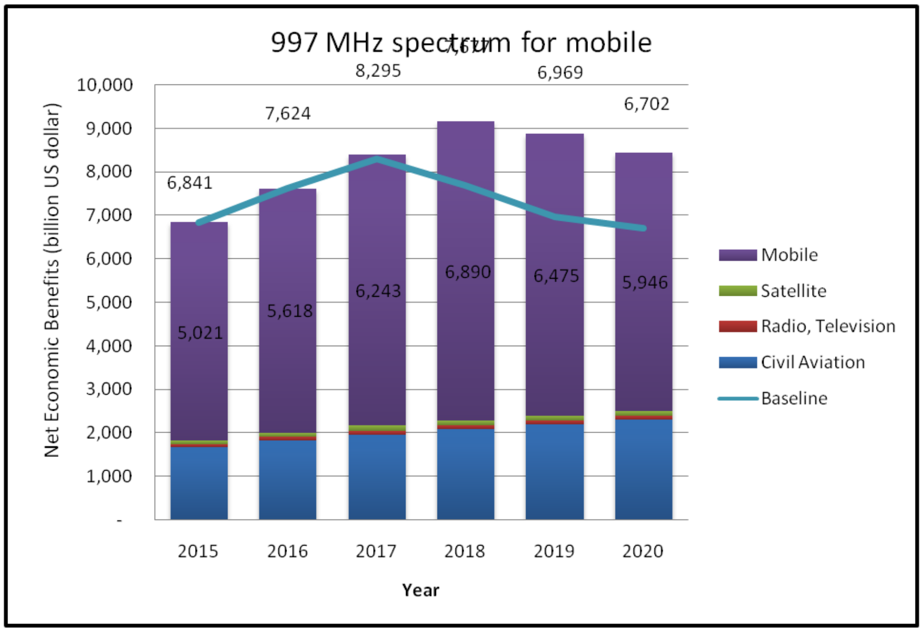

Figure 4-4: Economic benefit of Mobile (scenario b2)

We can see the statistical Table 4-6 below on spectrum allocation status to see how insufficient spectrum allocation impact of the sectors to GDP.

Table 4-6: Spectrum allocation status statistics (b2)

Year / **Sector**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Mobile	X	X	X	X	162	372
Satellite	X	X	X	X	X	X
Radio, Television	X	X	X	92	92	92
Civil Aviation	X	X	X	X	X	X

X: sufficiently allocated spectrum; Unit: MHz

According to this case in scenario b2, spectrum is sufficiently allocated to SS and CA, except for RT (in 2018-2020) and MS (in 2019 and 2020). According to the figures in the table 4-6, there will be total of 162 MHz and 372 MHz of spectrum shortage to MS in 2019 and 2020 respectively. This shortage spectrum by MS results in GDP loss of some 2,264 million US dollars in 2020.

The contribution rate of MS to GDP from 2015-2020 in this case can be seen as follows.

Table 4-7: Contribution rate to GDP of MS (scenario b2)

Year	2015	2016	2017	2018	2019	2020
Contribution rate to GDP (%)	1.16	1.23	1.29	1.34	1.19	1.03

The contribution rate of MS/GDP increases by 0.11% in 2019 and 0.09% in 2020 in comparison with the scenario b1 where 92 MHz is not added. This increase results in the decrease of GDP loss by 1,798 and 3,174, million US dollars in 2019 and 2020 respectively.

In **scenario b3**, through analysis from scenario b2 in which spectrum allocation is considered under economic perspective, we would analysis this scenario b3 in which spectrum is allocated to mobile industry of 1117 MHz.

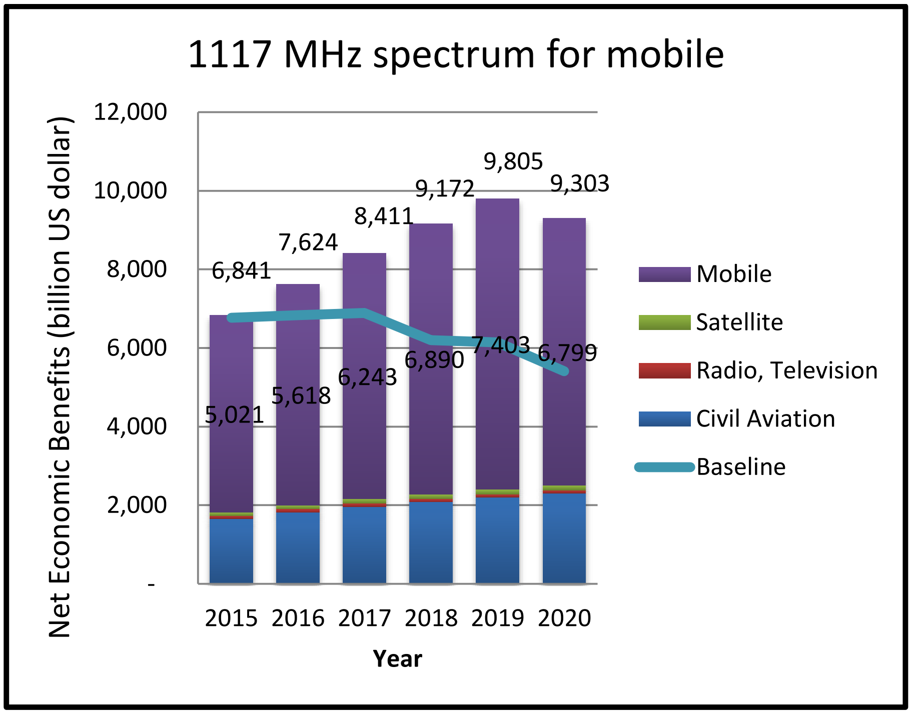

Figure 4-5: Economic benefit of Mobile (scenario b3)

We can see the statistical Table 4-8 below on spectrum allocation status to see how insufficient spectrum allocation impact of the sectors to GDP.

Table 4-8: Spectrum allocation status statistics (scenario b3)

Sector \ **Year**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Mobile	X	X	X	X	22	232
Satellite	X	X	X	X	X	X
Radio, Television	X	X	X	92	92	92
Civil Aviation	X	X	X	X	X	X

X: sufficiently allocated spectrum; Unit: MHz

According to this case in scenario b3, spectrum is sufficiently allocated to Satellite and Civil Aviation, except for Radio, Television (in 2018-2020) and Mobile (in 2019 and 2020). There will be 22 and 232 MHz of spectrum shortage to Mobile. This shortage spectrum by Mobile results in GDP loss some 1,412 million US dollars in 2020.

The contribution rate of MS to GDP from 2015-2020 in this case can be seen as follows.

Table 4-9: Contribution rate to GDP of MS (scenario b3)

Year	2015	2016	2017	2018	2019	2020
Contribution rate to GDP (%)	1.16	1.23	1.29	1.34	1.36	1.18

The contribution rate of MS to GDP significantly increases in comparison with the above scenarios. It is about 0.17% in 2019 and 0.15% in 2020 in comparison with the scenario b2 when getting more spectrums of 100 MHz from 2.7-2.9 band and 50 MHz from other band of civil aviation. This increase results in the decrease of GDP loss by 145 and 1,412 million US dollars in 2019 and 2020 respectively.

In **scenario b4**, through analysis from scenario b3 in which spectrum allocation is considered under economic perspective, we would analysis this scenario b4 in which spectrum is allocated to mobile industry of 1,267 MHz.

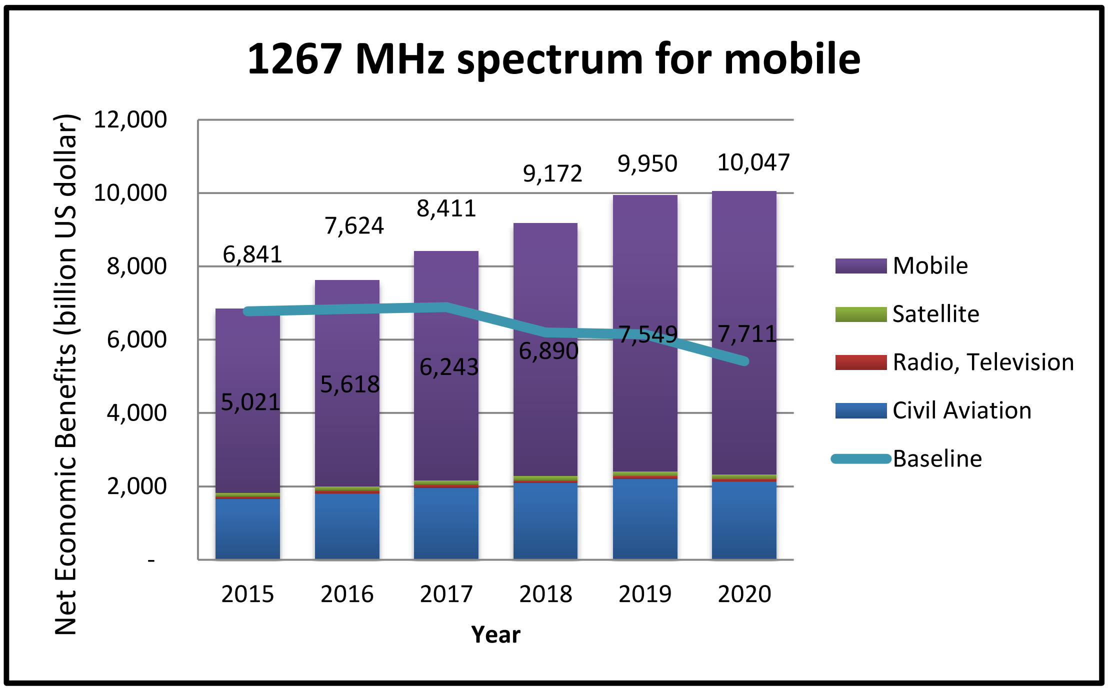

Figure 4-6: Economic benefit of Mobile (scenario b4)

We can see the statistical Table 4-10 below on spectrum allocation status to see how insufficient spectrum allocation impact of the sectors to GDP.

Table 4-10: Spectrum allocation status statistics (scenario b4)

Year / Sector	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Mobile	X	X	X	X	X	82
Satellite	X	X	X	X	X	X
Radio, Television	X	X	X	92	92	92
Civil Aviation	X	X	X	X	X	50

X: sufficiently allocated spectrum; Unit: MHz

According to this case in scenario b4, spectrum is sufficiently allocated to SS except for RT (in 2018-2020), MS and CA (in 2020). In 2020, there will be 82 MHz of spectrum shortage to MS. This shortage spectrum by MS results in GDP loss some 499 million US dollars in 2020.

The contribution rate of MS to GDP from 2015-2020 in this case can be seen as follows.

Table 4-11: Contribution rate to GDP of MS (b4)

Year	2015	2016	2017	2018	2019	2020
Contribution rate to GDP (%)	1.16	1.23	1.29	1.34	1.39	1.34

The contribution rate of MS to GDP significantly increases in comparison with the above scenarios. It is about 0.03% in 2019 and 0.16% in 2020 in comparison with the scenario b3 when getting more spectrums of 100 MHz from 2.7-2.9 band and 50 MHz from other band of civil aviation.

In **scenario b5**, through analysis from scenario b4 in which spectrum allocation is considered under economic perspective, we would analysis this scenario b5 in which spectrum is allocated to mobile industry of 1,367 MHz.

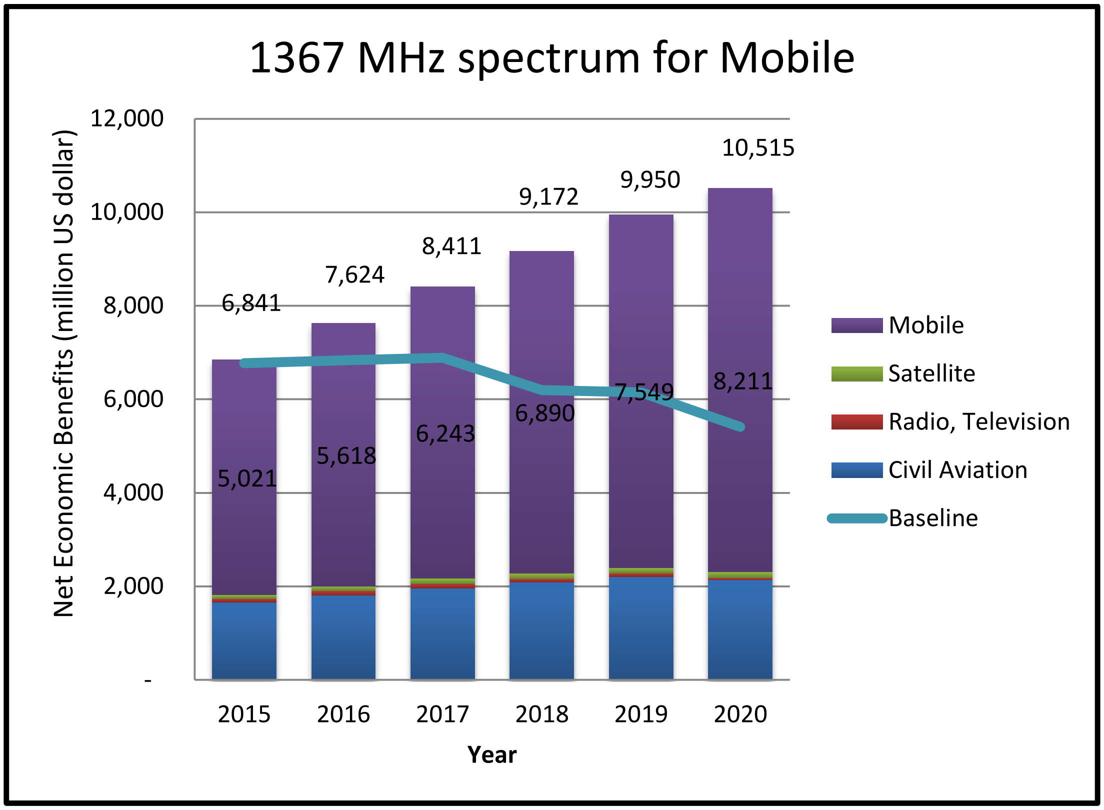

Figure 4-7: Economic benefit of Mobile (scenario b5)

We can see the statistical Table 4-12 below on spectrum allocation status to see how insufficient spectrum allocation impact of the sectors to GDP.

Table 4-12: Spectrum allocation status statistics (scenario b5)

Year / Sector	2015	2016	2017	2018	2019	2020
Mobile	X	X	X	X	X	X
Satellite	X	X	X	X	X	X
Radio, Television	X	X	X	92	92	92
Civil Aviation	X	X	X	X	X	50

X: sufficiently allocated spectrum; Unit: MHz

According to this case in scenario b5, spectrum is sufficiently allocated to MS and SS except for RT (in 2018-2020) and CA (in 2020). In 2020, the sufficient allocation spectrum to MS will result in no loss to GDP.

The contribution rate of MS to GDP from 2015-2020 in this case can be seen as follows.

Table 4-13: Contribution rate to GDP of MS (scenario b5)

Year	2015	2016	2017	2018	2019	2020
Contribution rate to GDP (%)	1.16	1.23	1.29	1.34	1.39	1.43

The contribution rate of MS to GDP increases in comparison with the above scenarios. It is about 0.09% in 2020 in comparison with the scenario b4 when getting more spectrums of 100 MHz from broadcast band.

In **scenario b6**, through analysis from scenario b5 in which spectrum allocation is considered under economic perspective, we would analysis this scenario b5 in which spectrum is allocated to mobile industry of 1,467 MHz.

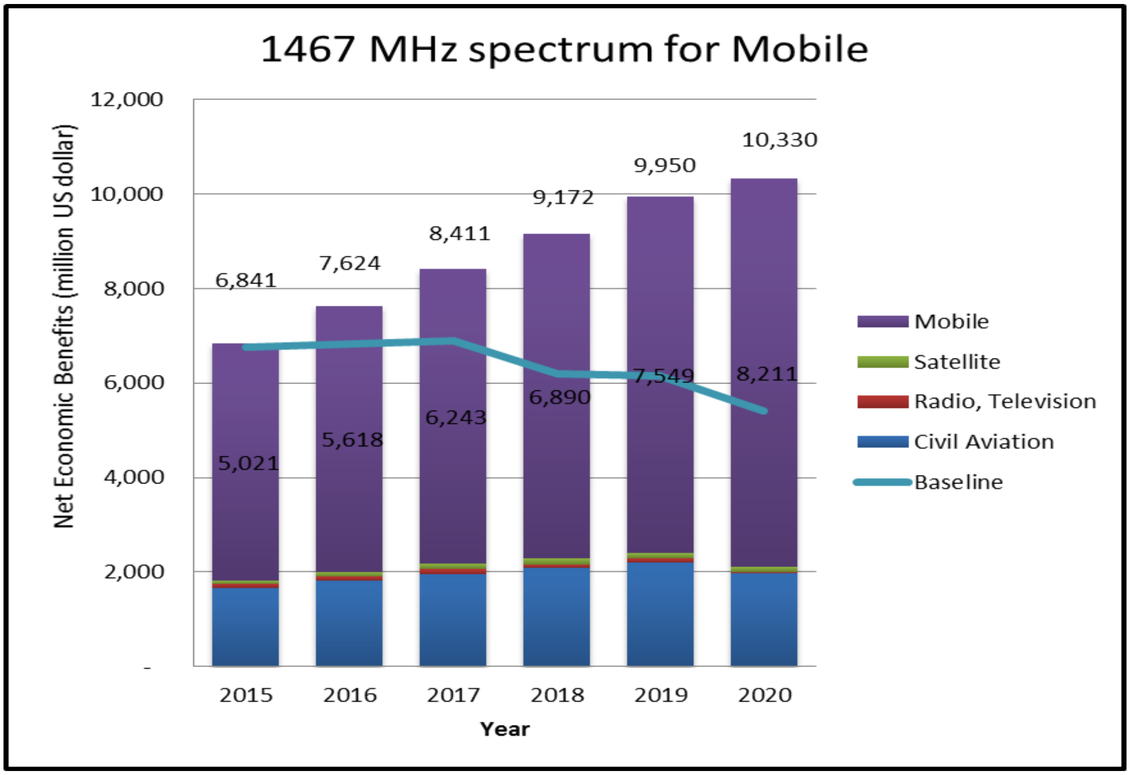

Figure 4-8: Economic benefit of Mobile (scenario b6)

We can see the statistical Table 4-14 below on spectrum allocation status to see how insufficient spectrum allocation impact of the sectors to GDP.

Table 4-14: Spectrum allocation status statistics (scenario b6)

Sector \ Year	2015	2016	2017	2018	2019	2020
Mobile	X	X	X	X	X	X
Satellite	X	X	X	X	X	X
Radio, Television	X	X	X	92	92	242
Civil Aviation	X	X	X	X	X	100

X: sufficiently allocated spectrum; Unit: MHz

According to this case in scenario b6, spectrum is sufficiently allocated to Mobile and Satellite except for Radio, Television and Civil Aviation of 100 MHz. This spectrum allocation results in no loss of GDP from Mobile in 2020.

The contribution rate of MS to GDP from 2015-2020 in this case can be seen as follows.

Table 4-15: Contribution rate to GDP of MS (b6)

Year	2015	2016	2017	2018	2019	2020
Contribution rate to GDP (%)	1.16	1.23	1.29	1.34	1.39	1.43

The contribution rate of MS to GDP remains the status quo in comparison with the scenario b5 when getting more spectrums of 100 MHz.

A comparison of the 7 scenarios above for year 2020 is summarized in the following graph.

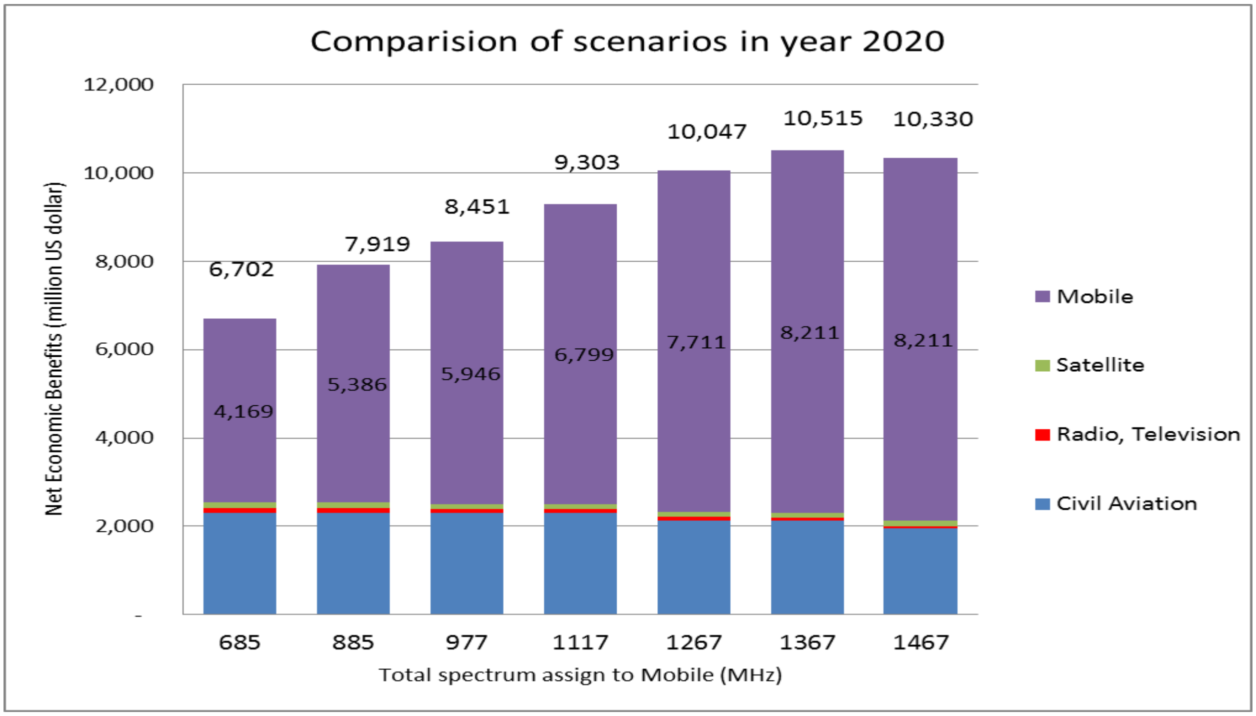

Figure 4-9: Net economic benefit of 4 sectors with different scenarios in 2020

We can see that the overall economic benefit from the 4 industries in 2020 is maximized when 1,106 MHz is allocated for Mobile, giving it a total of 1,367 MHz. The economic benefit for Vietnamese economy will be 8,221 million US dollars compared to 4,169 million US dollars if no extra spectrum is given to Mobile.

Contribution to GDP

Economic benefit of spectrum will be 8411 million US dollar in 2017. Using a Value added ratio of 0.44, the Net Value Added is 3318 million US dollar. The proportion of spectrum benefit to GDP is then 1.54%. The above scenarios, based on the input-output model, the economic impact of spectrum is shown in the following table.

Table 4-16 Value Added under different scenarios (million US dollar)

Scenario	Economic benefit	Net Value Added
(a).	6,702	2,949
(b1). 200 MHz	7,919	3,484
(b2). 292 MHz	8,451	3,718
(b3). 432 MHz	9,303	4,093
(b4). 582 MHz	10,047	4,421
(b5). 682 MHz	10,515	4,627
(b6). 782 MHz	10,330	4,545

(*) Note: Net Value Ratio is 0.44%

From Table 4-16 above, economic benefits of spectrum are 6,702; 7,919; 8,451; 9,303; 10,047; 10,515 and 10,330 million US dollars. Net Value Added will be 2,949; 3,484; 3,718; 4,093; 4,421; 4,627 and 4,545 million US dollars. Assuming the GDP of 2020 is 254,938 million US dollars, the Net Value added of spectrum to GDP will be 1.16%, 1.37%, 1.46%, 1.61%, 1.73%, 1.81% and 1.78%, respectively. Comparing scenario (b6) to scenario (a), the re-allocation of spectrum will induce an increment of 3,628 million US dollar or 0.7% of GDP in 2020.

FOR THE SUMMARY SECTION

Sectors	Economic benefit in 2015		Projected Economic benefit in 2020 with 1,367 MHzfor Mobile	
	Value (*)	%	Value (*)	%
Mobile	5,021	73.39	8,211	78.08
Satellite	82	1.20	120	1.14
Radio, Television	77	1.13	50	0.48
Civil Aviation	1,660	24.27	2,134	20.29
Total	6,841	100	10,515	100

(*). Million US dollar

5 - The Social Benefits of Spectrum

With radio spectrum being extensively used all over the world for new generation information technology such as LTE, it has not only profoundly influenced our economic structure and efficiency, but also our social culture and spiritual civilization. New communication technology has been widely used by governments to implement social management and public services, thus becoming the new vehicle of improving social welfare. Radio application has penetrated in such aspects as national economy, social life and national defence. It can help to improve the living standard and make our life more convenient and efficient.

The spectrum resource brings wider benefits to individuals, communities and nations besides the pure economic benefits outlined already in this report. Many of the cultural and social benefits that come from using spectrum in the economic estimates given in Section 3 do not take into account the improvements in the quality of life which cannot be measured with simple GDP estimates. This section discusses these less tangible benefits in qualitative terms, giving examples of the benefits that may be delivered by services using spectrum in Vietnam.

5.1. Improving the Service Quality of Social Enterprise

Social enterprise is concerned with the improvement of people's welfare, as well acting as an important guarantor of social harmony and stability. The wide application of radio IMT to social enterprise can continuously improve the level of digitalisation in such areas as education, research and health care.

When it comes to education, mobile broadband enables a rich and dynamic classroom experience with virtual classrooms that can be accessed via webcams, tablets and electronic whiteboards. As well as expanding access to education, this also increases interaction and collaboration among schools across the world. Moreover, broadband Internet can improve the quality of education by expanding the range of synchronous and asynchronous learning opportunities through online services and applications. These include email, discussion boards, live webcasts, podcasts, wikis, blogs, and customized course management that provide lesson plans and teaching material for teachers. An increase in Internet availability means education will become more accessible and affordable and help Vietnam close the gap with the rest of the world as regards the provision of education.

As well as education, the Internet can enhance academic and scientific research. For example, the Internet can improve communication, and the exchange of expertise, between researchers and research centres, as well as facilitate ‘virtual laboratories’ and ‘webinars’ meaning that Vietnamese academics no longer need to travel to overseas universities to take part in leading research and to collaborate with eminent academics. There is also the potential for large-scale collaborative projects involving specialist researchers and ordinary citizens.

Vietnam can also use mobile broadband to build upon this and improve healthcare outcomes further. While broadband alone cannot substitute for doctors, nurses and healthcare workers, the potential benefits of Internet applications for healthcare are large. Appropriate mobile solutions can not only provide healthcare for more people, but also improve the quality of life for patients, increase the efficiency of healthcare delivery models and reduce costs for healthcare providers.

Mobile broadband will allow patients and healthcare workers to access medical health records more efficiently to distribute them better, thus cutting bureaucracy and treatment times. Tele-consultations in which healthcare workers talk to patients remotely, increase efficiency and allow patients in rural areas access to good healthcare. Such consultations may use video services – vital for good patient care. Recent developments in healthcare applications may allow healthcare workers to monitor patient blood pressure, pulse and weight, potentially at remote distance.

Counterfeit drugs are a common problem in developing markets, so the ability to verify legitimate medicine via a mobile phone will be a very helpful for the population of Vietnam. This is already starting to be done in some countries, including India and Kenya, using SMS, but the advent of broadband would increase its popularity and ensure its use.

Where broadband is common, public health agencies are increasingly turning to social media as an efficient way of reaching the population. Social media, such as Face book, is an important driver of mobile broadband take-up and, as such, is a highly effective way of communicating important public health messages. By targeting through social media, campaigns can reach and educate the population within a short timescale. The nature of communication through social media is that it can be very quick to get a message out; making it a valuable tool for public health crisis management.

5.2. The importance of an all-round increase of digitalized applications in urban services

Utilizing IMT services, government and public administrations can help to deepen the application of e-governance, improve the capacity of public services and innovate using social media. Through using such technologies as sensing, transmitting, smart computing and treatment, early warning systems for disasters can improve security and their prevention and transportation management can also be built upon and improved, to create ‘smart cities’ with higher levels of connectivity. For instance, the new public service system can integrate data and processes into one integrated platform, data and processes that are originally administered separately in such functional departments as civil affairs, social security, police and taxation. A uniform process can be established to offer an integrated administration of systems and data and this will provide greater convenience and a highly-efficient “one-stop” service to the public. Through sensors that can be installed everywhere, it can help to collect real-time information on traffic and assist the monitoring and controlling of road traffic.

In finance, there are two levels of control over personal finance that mobile broadband brings. Firstly, the cost to an individual of running a bank account or other financial service is much lower when they are able to do so without travelling to a bank branch for every transaction. The second level of control over personal finance that mobile broadband brings allows people to transfer money and, in addition, gives them bank accounts that enable them to plan for the future. Mobile banking over broadband will allow people to save money; for investments, for adversity or for retirement. Saving for investment will provide a boost to SMEs, which may lack access to capital markets. Saving for hard times will help communities become self-sufficient and thus cope with famine, drought or disease. Saving for retirement will reduce the burden on future generations.

Mobile banking over broadband will give savers the opportunity to search for the best returns on investment; it will also give borrowers, including SMEs, the opportunity to find the cheapest capital; in that way it will provide significant competition in the financial services industry. Mobile banking will also enable people to transfer money between countries with lower transaction costs opening the possibility of international investment.

5.3. Serving the modernization of rural communities

Low cost high-speed mobile internet access—which is ideal for rural areas with poor fixed infrastructure—could pave the way for substantial improvements in education and healthcare. Mobile broadband allows children access to information anytime and anywhere.

Concerning agriculture, IMT plays an important role in restructuring agricultural development and improving the quality of life among rural residents. By making a host of services available to increase yields and quality, these services include agricultural information, data collection, trading, financing and even education and training.

Collectively they can make a significant contribution to the income and welfare of the farmers. It can also consolidate the rural information infrastructure and be used to promote R&D and the application of IMT in agriculture, advance the development, integration and comprehensive use of agriculture-related information resources, provide service to large-scale, sophisticated agricultural production, and reduce the digital gap between rural and urban areas.

5.4. Other Benefits

Beside the above benefits, spectrum resource also brings many alternative benefits for the society of Vietnam as follow.

Mobile broadband will help government agencies protect the environment against climate change and irresponsible behaviour; it will also help farmers increase their efficiency. Also, through mobile broadband, government agencies will be able to accurately monitor changes in climate, such as rising sea levels, and thus be better prepared to deal with such potential threats. Overall, mobile broadband will aid the collection of environmental data and the development of environmentally friendly agriculture and industry.

Mobile broadband can also help government agencies in the fight against poaching and monitoring natural environment. For example, rangers have started using unmanned drones to observe and protect national parks from poaching. Similar technology can also be used to assist in the fight against other criminal activities, such as weapons trafficking.

In addition, mobile broadband enables consumers to access e-commerce; the buying and selling of goods, as well as the paying of bills and taxes, over the Internet. This brings:

- New distribution channels for existing products and services (such as digital music, video or software).
- More efficient search mechanisms for locating and weather information or better availability of assessment of consumer goods, which could lead to lower business risk.
- New ways of addressing consumers’ needs online, often at very minimal cost (such as email, mobile marketing).
- Better communication between consumers about firms and products.
- Communication with distant family members will be enhanced – for example through video communication – and it will be easier to keep in contact through online social networks.

In conclusion, the spectrum resource could bring about significant social benefits for Vietnam, with social justice dividends including improved wealth distribution and cultural diversity, developmental benefits such as access to education and healthcare and improved food security, as well as increasing innovation and infrastructure, all of that can only lead to an improved business environment.

CONCLUSIONS

This report has been carried out to highlight the importance of IMT to the economy. Due to the significant contribution of IMT to the Vietnam's socio-economy, it is needed to quantify the role of its contribution.

The report has given key answers to the IMT spectrum management:

- *IMT spectrum estimation demand*: It is expected that the demand for IMT spectrum is continue to rise in the near future. Applying the most two famous methods, the report has given demand estimation for IMT in the year 2020 to be 1,349 MHz
- *Socio-economic impact of IMT*: Based on the IMT spectrum estimation, the report has employed I-O model to quantify the contribution of IMT to the economy as a whole. To address the spectrum shortage, 6 different spectrum re-allocation strategies have been considered and evaluated in detail. The re-allocations will impact other industry sectors – satellite, broadcasting, aviation. These impacts are also evaluated.

Under the current situation of spectrum usage in Vietnam, the total spectrum available for IMT is nearly 800 MHz. This study suggests potential ways to address the shortfall of future demand IMT spectrums and tries to quantify the advantage and disadvantage of each scenario. The results clearly demonstrate that, although the spectrum reallocations will affect other sectors to some degree, there is a significant contribution of IMT to the economy in all scenarios. This contribution is highest when all IMT spectrum demand is satisfied, i.e. in scenarios around 1,349 MHz.

Due to difficulties in spectrum refarming from other sectors and the long overhead time for spectrum planning, it is recommended that the regulator should first considers already available bands such as 2.3 GHz and 2.6 GHz bands to address the shortfall of IMT spectrum. The authors are well aware of the difficulties in spectrum reallocation. The civil aviation bands are not easily re-farmed due to existing essential equipment. It is also hard to reduce the satellite spectrum usage because the operation of Vinasat-1 satellite. Spectrum from digital dividend in broadcasting sector will be the most viable way to address the shortfall of IMT spectrum in the short term. Therefore, reallocating spectrum from broadcasting sector is considered first in our research.

We suggest that further studies in spectrum re-allocation strategies should be conducted to have a comprehensive view in the harmonized benefit of all spectrum usage sectors.

We believe that this is the first socio-economic research conducted to quantify the impact of IMT spectrum allocation to the Vietnam's economy. Although the research is not done in an exhaustive way, we do hope that these results will assist the regulation in developing future spectrum usage policies to maximize the benefit to the whole society.

Appendix- GSMA Method Tabulated Table of Calculating Spectrum Requirement by 2020

Topsite Perc	0.5%	0.5%	0.5%	0.5%
Predict Year	2020	2020	2020	2020
Rural				
Site Densitification	1.3	1.3	1.3	1.3
Suburban				
Site Densitification	1.2	1.2	1.2	1.2
Urban				
Site Densitification	1.1	1.1	1.1	1.1
Forecast for 2020				
Subscribers (million)	58	58	58	58
Data per User per Month (GB)	4	6	8	10
Voice per User per month (min)	234	234	234	234
Data In BH (%)	12	12	12	12
Voice In BH (%)	12	12	12	12
Voice data rate (kbps)	12	12	12	12
Total Data (PB/month)	236	354	472	590
Total Voice (m min/month)	10296	10296	10296	10296
Rural				
Subsc Percent (%)	58	58	58	58
Suburban				
Subsc Percent (%)	29	29	29	29
Urban				
Subsc Percent (%)	13	13	13	13

Quick Spectral Efficiency Estimate 2020				
Macro Site Spectrum Efficiency	1.82	1.82	1.82	1.82
Avg Sec per Pico	1	1	1	1
BH Macro Load QoS (%)	50	50	50	50
BH pico Load QoS (%)	50	50	50	50
Macro Pico Sharing(%)	50	50	50	50
Efficiency per MNO (%)	95	95	95	95
Guard Band per MNO (MHz)	5	5	5	5
Macro Cells				
BH Cell Load QoS (%)	100	100	100	100
Min Carrier bandwidth (MHz)	5	5	5	5
Pico Cells				
BH Cell Load QoS (%)	100	100	100	100
Max Carrier Per Pico Cell	2	2	2	2
Max Pico Cell Per Macro	3	3	3	3
Results				
Spectrum Required (MHz)	673	1,102	1,533	1,700

Annex 1 - S-Shaped Curve

As mentioned in the model of estimating the impact of spectrum, industry revenue is input parameter to determine the final consumption demand based on technical matrix (Leontief). Identifying and forecasting revenues is a complex task, however, due to data conditions, revenue figures are predicted by interpolation methods directly from the revenue figures in the past.

In this evaluation model, revenue in future years is estimated and projected through the prediction function "S-shaped curve". This is a classic forecasting function commonly used in estimating and forecasting the pace of change in technology, improvement rate of speed of technological change and market penetration rate of turnover .

S-shaped curve is determined by the equation:

$Y = L/(1+ a*\exp(-bt))$ (1)

Perform mathematical transformations, (1) is deployed by the followings

$a*\exp(-bt) = L/Y$ (2)

$a*\exp(-bt) = L/Y-1$ (3)

$\ln(a*\exp(-bt)) = \ln(L/Y-1)$ (4)

$\ln(a) + \ln(\exp(-bt)) = \ln(L/Y-1)$ (5)

$\ln(a) – bt = \ln(L/Y-1)$ (6)

If

$\varphi = \ln(a)$

$\beta = -b$

$Y' = \ln(L/y-1)$

Then (6) is transformed into

$Y' = \varphi - \beta t$ (7)

Meanwhile, the calculation and forecast by S-shaped curve (6) is converted to the calculation and forecast task by straight line (7) as shown above.

There is an input parameter L must be determined. This parameter will determine the rise and fall of the curve. The determination of the parameter L will rely on the determination on the basis that the error number and the standard deviation must be the smallest values.

Whereas

The following formula is used to determine the standard deviation:

$$\sqrt{\frac{\sum (x-\bar{x})^2}{n}}$$

Where x is the average value AVERAGE (number1, number2...) and n is the sample size.

Standard error formula:

$$\sqrt{\frac{1}{(n-2)}\left[\sum (y-\bar{y})^2 - \frac{\left[\sum (x-\bar{x})(y-\bar{y})\right]^2}{\sum (x-\bar{x})^2}\right]}$$

Annex 2 - Total Impact (Leontief)

The impact calculation is based on interdisciplinary balance table I/O 2007 in Vietnam. This national Table I/O was set up with 138 industries, with competitive and non-competitive format. This table was developed by the Department of National Accounts System – General Statistics Office of Vietnam (GSO). Based on the I/O Table 2007, 138 branches is switched to the I/O table calculating the 7 sectors including Mobile; Satellite; Broadcasting; Aviation; Agriculture, Forestry, Aquaculture; Industry and Construction, Services of all kinds.[3]

A sectoral balance table including the value of production of each branch (Xi) and final consumption value of the sector (Fi) is represented by the following equation:

$X_1 = X_{11} + X_{12} + X_{13} + \ldots + X_{1n} + F_1$

$X_2 = X_{21} + X_{22} + X_{23} + \ldots + X_{2n} + F_2$

……………………………………. (1)

$X_i = X_{i1} + X_{i2} + X_{i3} + \ldots + X_{in} + F_i$

…………………………………….

$X_n = X_{n1} + X_{n2} + X_{n3} + \ldots + X_{nn} + F_n$

It can be seen that, the industries have close relationships with one another through the purchase of inputs from the sectors as well as providing outputs for intermediate consumption sectors. An industry with development condition will lead to the development of other sectors, in turn, other industries having facilities to expand their production capacity will make very pervasive impact on the whole economy.

To analyse pervasive impact, we use the direct intermediate coefficient cost. This coefficient says how much production value of other sectors needed to create a unit of production value of a certain sector. The direct intermediate coefficient cost is noted as aij and determined as follows:

$a_{ij} = X_{ij} / X_j$ (2)

Or $X_{ij} = a_{ij} * X_j$ (3)

---

[3]In 1941,WassilyLeotieffirstmodelpresentsinterdisciplinarybalance(I/O) inthe"Structure the USeconomy" Today themodelI/Ousedin analyzing andforecastingtheeconomicimpactofa countryoraregionon the basis ofconsiderationofinter-sectorallinkagesinthe economy.

Substitute (3) to (1), we have:

$X_1 = a_{11}*X_1 + a_{12}*X_2 + \ldots + a_{1n}*X_n + F_1$

$X_2 = a_{21}*X_1 + a_{22}*X_2 + \ldots + a_{2n}*X_n + F_2$

……………………………………….. (4)

$X_i = a_{i1}*X_1 + a_{i2}*X_2 + \ldots + a_{in}*X_n + F_i$

………………………………………

$X_n = a_{n1}*X_1 + a_{n2}*X_2 + \ldots + a_{nn}*X_n + F_n$

Transform (4), we have:

$(1-a_{11}) X_1 - a_{12}X_2 - \ldots - a_{1j}X_j - \ldots - a_{1n}X_n = F_1$

$a_{21} X_1 - (1-a_{22}) X_2 - \ldots - a_{2j}X_j - \ldots - a_{2n}X_n = F_2$

…………………………………………………. (5)

$a_{i1} X_1 - a_{i2}X_2 - \ldots (1 - aij)Xj - \ldots - ai_nX_n = F_i$

………………………………………………..

$a_{n1} X_1 - a_{n2}X_2 - \ldots - a_{nj}X_j - \ldots (1 - ann)Xn = F_n$

Mathematically, the equation (5) can be represented as follows:

$(1-A)*X=F$ (6)

Whereas A is the direct intermediate coefficient (Annex C (A)), I is the unit vector (AnnexD (I)) and F is the final consumption vector.

$A = (a_{ij})$;

$F = (F_i)$;

$X = (X_i)$.

Formula (6) represents the most fundamental relationship of I/O Table, this formula is used to measure the change of production value of each sector as well as the total change of the production value of the whole economy under the impact of the change on final consumption by each sector's products.

$\Delta X = (I-A)^1 * \Delta F$ (7)

Matrix (I-A)^1 is the full cost coefficient matrix or Leontief inverse matrix. This matrix shows the total cost to produce a unit of final use of a certain sector.

ΔX reflects the total impact on the economy when final consumption of a sector is equivalent to a unit.

In the calculation model, ΔX is determined by the formula (7).

ΔF of a sector determined by the final consumption coefficient is determined by (1).

$\Delta F = v_{fi} * X_i$

Whereas $v_{fi} = F_i/X_i$

Annex 3- The Other Basic Factors

* Backward linkage (BL)

Besides the way to assess the impact on the economy, another way to assess is using the indicator BL. This indicator determines the extent of spread of a sector to the economy. The meaning of this indicator is the reflection that when the final consumption of a sector increases by 1 unit, this will represent how the production value of this sector and other sectors will be affected. This is a relative indicator determined by comparing the output known as numerator of each sector with an average output numerator of all sectors by the following formula:

$BL = O_j/((1/n)*\sum O_j))$

Whereas

$O_j = \Sigma \varphi_{ij}$ with i ranging from 1 – n

φ_{ij}: the ij^{th} element of the Leontief inverse matrix.

* Forward Linkage (FL)

Similarly, we have FL indicator. FL value reflects the relative degree of economic dependence of other sectors with a sector of the economy and is determined by the formula:

$FL = O_i/((1/n)*\sum O_i))$

Whereas

$O_i = \Sigma \varphi_{ij}$ with i ranging from 1 – n

φ_{ij}: the ij^{th}element of the Leontief inverse matrix.

* Multiplier Effect

This is a coefficient reflecting the spread degree to other sectors when the sector increases by 1 unit of output. FL is determined by the formula as below:

$ME_i = 1/(1-a_{ii})$

Where, a_{ii} is the production value of the sector using itself in creating one unit of output.

* Feedback Effect

This is a coefficient reflecting a received part when other sectors increased by the impact of the industry over the other sectors

$FB_i = ME/\varphi_{ii}$

Whereas φ_{ii} is the element ii^{th} of the Leontief inverse matrix

* Indirect Impact or Spill Over is the impact value to other sectors when the sector increased final consumption by one unit

$II = \sum \varphi_{ij} - \varphi_{ii}$ with j ranging from 1 – n

φ_{ij}: ij^{th} element of the Leontief inverse matrix

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