FEASIBILITY ASSESSMENT OF IMPLEMENTING GSM OR DCS FREQUENCY BAND FOR 3G WIRELESS NETWORK IN BANGLADESH

By

Md. Maruf Hossain

A Thesis submitted to the Institute of Appropriate Technology (IAT), Bangladesh University of Engineering and Technology (BUET) in partial fulfillment of the requirement for the degree of
Master of Science in Management of Technology (MoT)

Institute of Appropriate Technology (IAT)

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

DHAKA-1000, BANGLADESH.

April 2019

CERTIFICATION OF APPROVAL

This thesis titled "**FEASIBILITY ASSESSMENT OF IMPLEMENTING GSM OR DCS FREQUENCY BAND FOR 3G WIRELESS NETWORK IN BANGLADESH**" is submitted by Md. Maruf Hossain, Student ID: 0413292005, Session: April, 2013 has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of Master of Science in Management of Technology (MoT) on 24th April 2019.

BOARD OF EXAMINERS

1. ______________________________

Dr. Mohammad Arif Hasan Mamun — Chairman
Professor
Department of ME, BUET, Dhaka.
And
Director, IAT, BUET, Dhaka.
(Supervisor)

2. ______________________________

Dr. Mohammad Arif Hasan Mamun — Member (Ex-Officio)
Director
Institute of Appropriate Technology,
BUET, Dhaka.

3. ______________________________

Dr. Iftekhar Uddin Bhuiyan — Member
Assistant Professor
Institute of Appropriate Technology, BUET, Dhaka – 1000.

4. ______________________________

Dr. Iftheker Ahmed Khan — Member
Assistant Professor
Institute of Appropriate Technology, BUET, Dhaka – 1000.

4. ______________________________

Dr. Md. Farhad Hossain — Member (External)
Professor
Department of EEE, BUET, Dhaka – 1000.

CANDIDATE'S DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Signature of the Candidate

....

Md. Maruf Hossain

Student ID: 0413292005

IAT, BUET

ACKNOWLEDGEMENT

It is my greatest pleasure to thanks and praise to Allah, the most beneficent and merciful creator, enabled me to complete this research work for the fulfillment of the requirements for the degree of Master of Science in Management of Technology (MoT).

I would like to express my heartfelt gratefulness, appreciation and deepest gratitude to my supervisor professor Dr. Mohammad Arif Hasan Mamun Director, Institute of Appropriate Technology (IAT), Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh, for his endless support, necessary supervision, active encouragement, valuable suggestions, constructive guidance, cordial behavior and constant effort throughout the progress of this work and preparation of thesis paper.

I am very much grateful to all the honorable teachers of Institute of Appropriate Technology (IAT), BUET, Dhaka, Bangladesh, for their worthwhile suggestions, and helpful guidance to complete my whole thesis works. I also like to thanks to all the stuffs of IAT who helped me in different dimension during my thesis activities.

I would like to express my sincere gratitude to Dr. Md. Farhad Hossain, Professor, Department of Electrical and Electronic Engineering, BUET, Dhaka, Bangladesh, for his throughout valuable advices, right directions, necessary suggestions and kind cooperation's for my thesis works up to complete the manuscript.

I wish to thanks to the experts of academic and telecom profession for their valuable times to complete the expert opinion parts of this thesis work. Special admiration goes to all of my classmates and other students of IAT who helped me during my thesis work.

I am also very much grateful to my family members whose help and inspiration in various steps in some busy and difficult situations capable me to proceed with the work and complete this thesis.

(Md. Maruf Hossain)

ABSTRACT

The usages and demand of wireless technologies has been increased incredibly in urban, suburban as well in rural area. To fulfill the user demand and for the self-interest, many service provider companies had been established in Bangladesh with different techniques as, Mobile communication system, WiMAX system and small area Wi-Fi services. Especially mobile wireless communication system has become crowded to fulfill the user demands over the nation. As a result radio frequency plans also getting a challenging factor to cover the whole national area by the updated wireless technologies. To facilitate the users in rural area by the updated 3G and 4G mobile technologies, it is needed to choose an appropriate frequency band to alleviate the existing coverage problem of mobile signals.

The aim of this thesis work is to find out a suitable frequency band for 3G mobile communication system in Bangladesh. Three available frequency bands 900 MHz, 1800 MHz and 2100 MHz are selected as the alternatives to complete the analysis of finding suitable target frequency band for 3G system. For this study Analytic Hierarchy Process is applied as a Multi-criteria Decision Making Method (MCDM) which is a technology assessment tool. The assessment has been conducted by considering the quality of signal, operation cost, coverage area, signal penetration, environmental values, economic impacts as criteria and sub-criteria for the target of this thesis work.

A number of telecommunication researchers from different universities and professionals of renowned telecommunication industries have been selected and taken their interview to avail expert opinion for the assessment works. Most of those researchers and professionals expressed their opinion as lower band 900 MHz would be a better choice for mobile operators to facilitate more 3G coverage area with less integration and maintenance cost.

Based on the thesis result it can be ascertained that lower frequency band 900 MHz can be an appropriate additional choice for high speed 3G mobile communication system in Bangladesh to enhance the coverage area especially in suburban and rural areas. So from the outcomes of this work, mobile operators may be guided to choose an appropriate frequency band for their existing 3G network as lower band spectrum has been proposed to improve the signal penetration as well for more coverage area.

CONTENTS

LIST OF FIGURE

LIST OF TABLE

LIST OF TABLE

LIST OF TABLE

1G	1st generation
2G	2nd generation
3G	3rd generation
4G	4th generation
AHP	Analytic Hierarchy Process
AMPS	Advanced Mobile Phone System
BPDB	Bangladesh Power Distribution Board
BS	Base Station
BW	Band-Width
BTRC	Bangladesh Telecommunication Regulatory Commission
CAPEX	Capital Expenditure
CDMA	Code Division Multiple Access
DCS	Digital Cellular System
FDD	Frequency Division Duplex
FDI	Foreign Direct Investment
FDMA	Frequency Division Multiple Access
Gbps	Giga Bit Per Second (10^9 bps)
Glb	Global
GSM	Global System for Mobile communications
IMT-2000	International Mobile Telecommunications-2000
IRR	Internal Rate of Return
IS-95	International Standard for the CDMA phone system developed by Qualcomm Inc.
IS-54	The first mobile communication system
IS-136	Interim Standard 136 use TDMA

ITU	International Telecommunication Union
Kbps	Kilo Bit Per second
MCDM	Multi-Criteria Decision-Making
Mbps	Mega Bit Per Second (10^6 bps)
MIMO	Multiple Input Multiple Output
NFAP	National Frequency Allocation Plan
NPV	Net Present Value
OFDM	Orthogonal Frequency Division Multiplexing
OPEX	Operating Expenditure
PV	Priority Vector
PBP	Payback Period
QAM	Quadrature Amplitude Modulation
PDB	Power Distribution Board
REB	Rural Electric Board
RF	Radio Frequency
RV	Random Variables
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
UMTS	Universal Mobile Telecommunications Service
UTRA	Universal Terrestrial Radio Access/ UMTS Terrestrial Radio Access Network
WHO	World Health Organization

INTRODUCTION 1

1.1 Introduction

Since last twenty years, wireless communication system is playing an important and unavoidable role in human community all over the world. Nowadays, in personal life it is a standard of having the facility of video streaming, Internet browsing, voice calling for twenty four hours. All these facilities are being served mostly over wireless mobile communication systems.

The incredible usages and demand of wireless technologies since last decade has produced an extensive modernization and expansion of wireless networks. Bangladesh already introduced 2G, 3G WiMax and 4G mobile communications by different operators, both governments' owned and multinational renowned companies. In wireless communication system, spectrum is a highly demanded, limited and expensive resource [1]. To ensure the high-quality services for customers, radio frequency planning is required as well to control the cost. [2]. Planning means not only to meet current status and demands, but the solution should also comply with the future requirements by providing an acceptable development path [3]. The limited available spectrum and the inefficiency in the spectrum usage necessitate a new communication paradigm to exploit the existing wireless spectrum [4]. For mobile operators, selecting and deploying spectrum resource is one of the challenges to meet the demand of wireless communication system [5].

To facilitate the users with demands, these facts, together with a great variety of mobile devices and numerous different services that are becoming increasingly resource-demanding, have attracted the attention of many researchers into the area of radio resource planning and optimization [6]. To ensure more coverage area by updated techniques as well as considering cost, it may be needed to merge and optimize the spectrums among the different mobile communication systems (2G, 3G and 4G) using appropriate frequency bands, in Bangladesh. In this respect, this thesis work is focused on selecting appropriate frequency band for 3G wireless communication system in Bangladesh.

1.2 Background Problem and Motivation

In current human life, not only voice and data transmission but also multimedia and real time video is being used in urban society and even in rural life. Most of the businessmen, job seekers, students and even farmers are used to use internet in their daily life. Moreover the social communications media, online business and entertainments are most using over wireless mobile systems. This huge demand of internet over mobile communication system is increasing in skyrocketing manner even in rural area. Especially internet users are being increased all over the country. To fulfill these demands 2G, 3G and 4G already have been launched in Bangladesh. All the mobile operators trying to setup 3G base station along with their existing 2G BS to ensure quality 3G services specially to their internet users over the nation. But due to the spectrum issue such as using 2100MHz frequency in 3G and 2100MHz & 1800MHz in 4G, distance users from the base stations are not able to get enough bandwidth for their purposes. And in urban area indoor signal strength over mobile communication systems are also not so strong by same frequency bands. As the population dense is too high in Bangladesh hence mobile operator are facing difficulties to ensure the resources (like: available channel) for all users under a serving cell. Most of the cells are occupied by over loaded number of mobile users. So the "growth of mobile data", "channel data throughput", "system capacity" and to ensure good "signal strength" are the real time challenge for mobile operators to facilitate their users with a satisfactory voice quality and smooth data speed [7], [8].

One question may arise that why 3G service is concerned in this thesis work when 4G already launched in Bangladesh. This is because 3G systems have the facility of voice and high speed (possible around 50 Mbps) data service (compared to 2G systems) hence this 3G generation will remain in the world for more decades of years, though 4G mobile services launched in different countries. In developing countries like Bangladesh, 3G system declines will take more time considering the network implementation cost as well compatible mobile set availability in user's hand. According to a forecast analysis conducted in 2010, worldwide 3G subscriber will reach at around 4.2 billion on year 2020 [9]. According to the below figure, conducted by 4gamericas.org, 3G subscribers will remain in a significant number in 2020 and on an increasing manner, trend from 2015 [9]. A subscribers forecast is shown in the following figure.

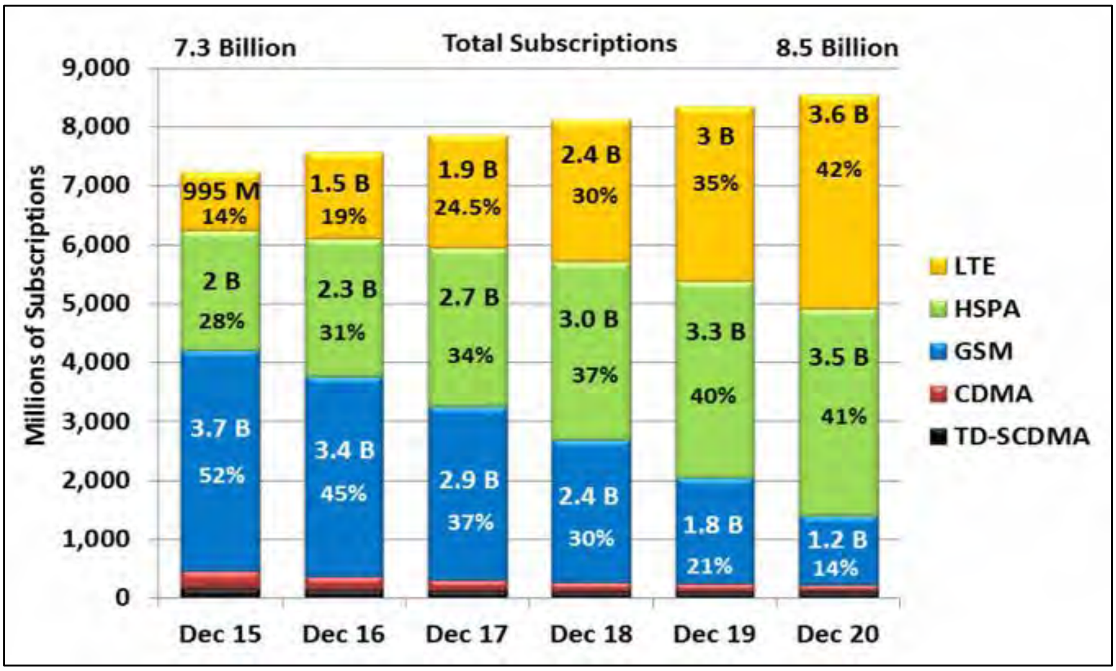

Figure 1.1: Global Technology Forecast Subscriptions and Market Share

In Bangladesh this 3G mobile services also will be continued more years for it's both voice and data services availability, especially in sub-rural and rural areas. As living in a developing country, still people are used to make direct voice call over cellular network instead of using data call. Again mobile handset dependency also a constraint to switch to 4G because middle class people/subscribers cannot effort to purchase a new 4G enabled mobile phone in shortest time. Hence mobile users would be intended to use internet services over 3G mobile communication systems for more years.

In sense of mobile operator it is a big matter of cost/investment to swap all the old 3G equipment's by updated 4G equipment's. Moreover it is possible to fulfill the data service demand of low dense rural area by 3G mobile services.

After having license (from Bangladesh Telecommunication Regulatory Commission (BTRC) on 2012, most of the mobile operators in Bangladesh have started launching their 3G mobile networks all over the country with their existing 2G base stations, phase by phase as per priority. At that time BTRC announced only 2100 MHz for the mobile operators to serve 3G services and later in 2018 BTRC announced the facility of frequency neutrality for operators to avail the privilege of using 900 MH or 1800 MHz for 3G mobile communication system.

Fulfilling the demand in traditional ways, i.e. network expansion by installing new base stations or introducing new technologies (with better frequency efficiency) involve a huge expense for mobile operators. In this respect, using of lower frequency bands such as 900 MHz or 1800 MHz in 3G mobile communication system may be a better choice to mitigate the above mentioned problems in a significant way. Several countries like United States of America (USA), Mexico, and Japan already introduced lower bands (e.g. 850 MHz and 900 MHz frequency bands) for their 3G mobile systems [10], [11]. In this perspective an assessment on frequency selection may be a fruitful way for Bangladesh to justify the feasibility of using 900 MHz or 1800 MHz in 3G system.

1.3 Research Objective

The objectives and outcome of this research are as follows:

To select the appropriate frequency band (GSM, DCS or 2100MHz) for 3G mobile communication system in Bangladesh, by applying the Multi-Criteria Decision Making (MCDM) Technology Assessment (TA).

The expected outcome will be a technology assessment for selecting appropriate frequency band for 3G mobile communication system in Bangladesh. This research will guide to optimize the frequency planning for 3G network, in order to ensure more coverage area by hi-speed mobile network.

LITERATURE REVIEW 2

2.1 Introduction

Over the years different generations of mobile technology have been established, and each having their own attributes. Basically those technologies which are being used in mobile communication systems have a strong and important use of frequency bands. An understanding of how those technologies work as well frequency distribution for mobile system are necessary before moving to start the problem assessment.

2.2 **Overview of Cellular Networks**

A cellular network is basically a communication system in which the end user interface within wireless system. A new generation of cellular standards has appeared approximately every tenth year since 1G systems were introduced in 1981/1982. Actually 1980 was the starting period of first generation of mobile communication age, called 1G based on analog radio signal technology. In that age the main concern was voice communication traffic. Different standards such as Advanced Mobile Phone System (AMPS), Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), etc. have been introduced for 1G system. Each generation is characterized by new frequency bands, higher data rates and non–backward-compatible transmission technology. As per 10 years considered generation evolution of mobile communication system, 2G introduced in 1990. In this sequence 2000 was the period of 3G and 2010 is the generation year of 4G. Now the world is on the way to 5G. Different vendors as well operators already announced to launch 5G in 2019. A brief demonstration of different generations is taken place in the next sub chapters.

2.2.1 Second Generation: 2G

2G (or **2-G**) is short for second-generation cellular technology. 2G is the first to use digital encryption of conversations. Three primary benefits of 2G networks over their predecessors were that phone conversations were digitally encrypted; 2G systems were significantly more efficient on the spectrum enabling far greater wireless penetration levels and 2G introduced data services for mobile, starting with SMS text messages. 2G technologies enabled the various networks to provide the services such as text messages, picture messages, and MMS (multimedia messages). All the text messages sent over 2G are digitally encrypted, allowing the transfer of data in such a way that only the intended receiver can receive and read it [12]. In Finland Second-generation 2G cellular networks were commercially launched on the GSM standard by Radiolinja (now part of Elisa Oyj) in 1991 [13].

2.2.2 Global System for Mobile Communication GSM

GSM (Global System for Mobile Communications) is a second-generation digital mobile telephone standard using a variation of Time Division Multiple Access (TDMA).

GSM implements TDMA in a somewhat different and incompatible way from IS-136. Think of GSM and IS-136 as two different operating systems that work on the same processor, like Windows and Linux both working on an Intel Pentium III. GSM systems use encryption to make phone calls more secure. GSM operates in the 900-MHz and 1800-MHz bands in Europe and Asia and in the 850-MHz and 1900-MHz (sometimes referred to as 1.9-GHz) band in the United States. It is used in digital cellular and PCS-based systems. GSM is also the basis for Integrated Digital Enhanced Network (IDEN), a popular system introduced by Motorola and used by Nextel. AT&T and T-Mobile use GSM.

GSM is firstly developed by the European Telecommunications Standards Institute (ETSI) to describe the protocols for second-generation (2G) digital cellular networks used by mobile devices such as tablets. It was first deployed in Finland in December 1991 [14]. As of 2014, it has become the global standard for mobile communications – with over 90% market share, operating in over 193 countries and territories [15].

Along with voice service (circuit switch) some other services also introduced in 2G system. GPRS and EDGE are the data service (packet switch) features grown in 2G system which become popular and time demanded by shortest time.

2.2.3 Third generation 3G

3G, short for third generation, is the third generation of wireless mobile telecommunications technology. It is the upgrade for 2G and 2.5G GPRS networks, for faster internet speed. This is based on a set of standards used for mobile devices and mobile telecommunications use services and networks that comply with the International Mobile Telecommunications-2000 (IMT-2000) specifications by the International Telecommunication Union (ITU). It finds

application in wireless voice telephony, mobile Internet access, fixed wireless Internet access, video calls and mobile TV. 3G technology provides an information transfer rate of at least 200 kbit/s. Later 3G releases, often denoted 3.5G and 3.75G, also provide mobile broadband access of several Mbit/s to smartphones and mobile modems in laptop computers [16].
Later HSPA Release 7 has also added a Multiple Input Multiple Output (MIMO) multi-antenna solution and higher order modulation 64QAM to support even higher data rates over 3G mobile systems. HSPA pushes more functionality to the base station and allows flat architecture, which improves the efficiency and the Quality of Service (QoS) capabilities for packet services [8].

2.2.3.1 Data Rate in 3G

After 2G mobile system (EDGE with less than 200 kbps) data throughput, commonly known as internet speed was a major concern for the next generation technology. By the time of 3G launching over the world, expectation of a much better 3G data speed was expected from users demand.

ITU has not provided a clear definition of the data rate that users can expect from 3G equipment or providers. Thus users bought 3G service may not be able to point to a standard and say that the rates it specifies are not being met. While stating in commentary that "it is expected that IMT-2000 will provide higher transmission rates: a minimum data rate of 2 Mbit/s for stationary or walking users, and 348 kbit/s in a moving vehicle," the ITU does not actually clearly specify minimum required rates, nor required average rates, nor what modes of the interfaces qualify as 3G, so various data rates are sold as '3G' in the market [16], [17].

In market implementation, 3G downlink data speeds defined by telecom service providers vary depending on the underlying technology deployed; up to 384kbit/s for WCDMA, up to 7.2Mbit/sec for HSPA and a theoretical maximum of 21.6 Mbit/s for HSPA+ (technically 3.5G, but usually clubbed under the trade name of 3G). Later more features like MIMO system have been developed to enhance 3G data speed up to 42 Mbps or even 65 Mbps in downlink channel. 3G data systems enhanced with MIMO technologies provide higher peak data rates and better coverage than conventional systems [8].

The following table summarizes the history of 3G MIMO techniques candidate for 3G standards. Although the table additionally contains the future part but the contents are not clearly filled out since the future is not precisely predictable [18].

Table 2.1: 3G data speed evolution

Generation	**3G**	**3G evolution**	**Beyond 3G**	**Future**
Deployment	2003/4	2005~6/2007~8/2009~10	2012~2015	2015~2020
Standard	WCDMA	HSPA/HSPA+/LTE	IMT-Advanced	Beyond IMT-Adv
Total rate	384kbit/s	14/42/65~250Mbit/s	1Gbit/s	>10Gbit/s
Bandwidth	5 MHz	5 MHz/20 MHz	20~100 MHz	>100 MHz

2.2.3.2 Technologies used in 3G

UMTS (Universal Mobile Telecommunications System) is an umbrella term for the third generation radio technologies developed within 3GPP [19]. The radio access specifications provide for Frequency Division Duplex (FDD) and Time Division Duplex (TDD) variants, and several chip rates are provided for in the TDD option, allowing UTRA technology to operate in a wide range of bands and co-exist with other radio access technologies [19]. The radio access technology used in 3G is WCDMA (Wideband Code Division Multiple Access)

2.2.3.3 Wideband Code Division Multiple Access (WCDMA)

WCDMA is a wideband Direct-Sequence Code Division Multiple Access (DS-CDMA) system, i.e. user information bits are spread over a wide bandwidth by multiplying the user data with quasi-random bits (called chips) derived from CDMA spreading codes. In order to support very high bit rates (up to 2 Mbps), the use of a variable spreading factor and multi code connections is supported [20].

WCDMA supports highly variable user data rates, in other words the concept of obtaining Bandwidth on Demand (BoD) is well supported. The user data rate is kept constant during each 10 ms frame. However, the data capacity among the users can change from the frame to frame. This fast radio capacity allocation will typically be controlled by the network to achieve optimum throughput for packet data services [20].

WCDMA supports two basics modes of operation: Frequency Division Duplex (FDD) and Time Division Duplex (TDD). In the FDD mode, separate 5 MHz carrier frequencies are used for the uplink and downlink respectively, whereas in TDD only one 5 MHz is timeshared between the uplink and downlink. Uplink is the connection from the mobile to the base station, and downlink is that from the base station to the mobile [20].

2.3 Global Frequency Distribution

Frequency allocation (or **spectrum allocation** or spectrum management) is the allocation and regulation of the electromagnetic spectrum into radio frequency bands, which is normally done by governments in most countries. Because radio propagation does not stop at national boundaries, governments have sought to harmonize the allocation of RF bands and their standardization [21]. But there have a global regulatory body to distribute and review the overall frequency allocation worldwide.

The International Telecommunication Union (ITU), United Nations organization, is responsible for regulating the international use of spectrum. The ITU-R Radio Regulation 2015 (RR15) Article 5, contain the international frequency allocation table. This table is important in that it forms the global framework for international, regional and national spectrum planning.

The key features of the ITU Frequency Allocation Table is that it sets out the frequency bands that have been allocated to services and divides the world into three distinctive regions, with introduction of variety of services and applications, ICT sector has evolved over the years and has brought about changes in economic and social aspects of the global society. It is now evident that an effective telecommunication infrastructure is the essential impetus that enables a country to achieve successful social and economic development [22].

The International Telecommunication Union defines frequency allocation as being of "a given frequency band for the purpose of its use by one or more terrestrial or space radio communication services or the radio astronomy service under specified conditions" [23].

2.3.1 Bodies for frequency allocation

Several bodies set standards for frequency allocation, including:

- International Telecommunication Union (ITU)
- European Conference of Postal and Telecommunications Administrations (CEPT)

- Inter-American Telecommunication Commission (CITEL)

To improve harmonization in spectrum utilization, most service allocations are incorporated in national Tables of Frequency Allocations and Utilizations within the responsibility of the appropriate national administration.

2.3.2 National Table for Frequency Allocation (NTFA)

One of the most important tools for effective spectrum management is the National Table of Frequency Allocation (NTFA). The NTFA is the published outcome of national spectrum planning. This shows how the spectrum can be used in the country [23]. ITU have a detail guideline for the preparation of a NTFA. A National Frequency Allocation Plan (NFAP) has been developed in Bangladesh which is according to the ITU radio regulations.

2.3.3 ITU Region

The International Telecommunication Union (ITU), in its International Radio Regulations, divides the world into three ITU regions for the purposes of managing the global radio spectrum. Each region has its own set of frequency allocations, the main reason for defining the regions [24]. For the allocation of frequencies the world has been divided into three Regions as shown on the following map and described in following sub sections [25].

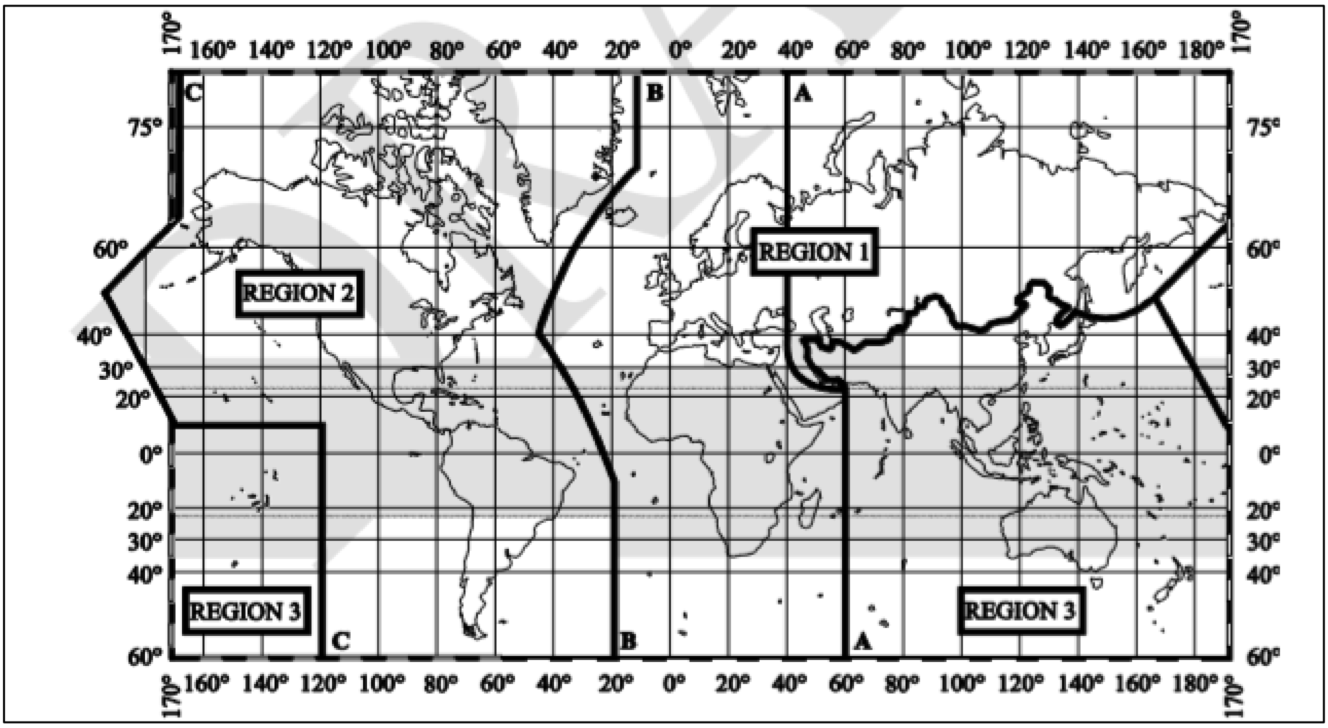

Figure 2.1: Region distribution by ITU

According to ITU distribution, Bangladesh is belonged to region 3 along with the Non-Former Soviet Union (FSU) countries and most of Oceania.

2.4 Frequency for Mobile Communication Systems

Frequency is a major component or parameter for the wireless system. So for mobile systems whatever it is 2G, 3G, 4G or 5G frequency play an important role for coverage, signal strength, penetration, etc. As per ITU there have multiple available frequency bands for different generations of wireless mobile communication systems.

2.4.1 Second Generation (2G) Frequency bands

A number of frequency bands used for 2G mobile system over the world. Primarily ITU have a guideline of choosing the frequency bands, named GSM and DCS frequency bands. Then the regulatory board of each country offer license justifying the availability and uses of nearby frequency bands for other wireless systems (like: Army, Traffic, Police, Fire service team, etc.) in their territory. According to ITU distribution following table represents the common available frequency bands for 2G system [54].

Table 2.2: Frequency allocation for 2G mobile system

GSM band	f (MHz)	Uplink (MHz)	Downlink (MHz)	Channel number or ARFCN(N)	Uplink Frequency equation (F_{UL})	Equivalent
		(Mobile to Base)	(Base to Mobile)			LTE band
GSM-450	450	450.6 – 457.6	460.6 – 467.6	259 – 293	450.6 + 0.2*(N-259)	31
GSM-480	480	479.0 – 486.0	489.0 – 496.0	306 – 340	479+0.2*(N-306)	
GSM-750	750	777.2 – 792.2	747.2 – 762.2	438 – 511	747.2 + 0.2*(N-438)	
GSM-850	850	824.2 – 848.8	869.2 – 893.8	128 – 251	824.2+0.2*(N-128)	5
P-GSM-900	**900**	**890.0 – 915.0**	**935.0 – 960.0**	**1 – 124**	890+0.2*N	
E-GSM-900	900	880.0 – 915.0	925.0 – 960.0	975 – 1023, 0 - 124	890+0.2*(N-1024)	8
R-GSM-900	900	876.0 – 915.0	921.0 – 960.0	955 – 1023, 0 - 124	890+0.2*(N-1024)	
DCS-1800	**1800**	**1710.2 – 1784.8**	**1805.2 – 1879.8**	**512 – 885**	1710.2+0.2*(N-512)	**3**
PCS-1900	1900	1850.2 – 1909.8	1930.2 – 1989.8	512 – 810	1850.2 + 0.2*(N-512)	2

2.4.2 Frequency bands allocation for 3G

A numbers of frequency bands are allowed by ITU for global 3G mobile system. The most common frequency bands are as in below table [55]. All the available frequency bands are mentioned in appendix-i.

Table 2.3: Common 3G frequency bands.

UTRA	*f*	Common name	Uplink frequencies	Downlink frequencies
band	(MHz)		UE transmit (MHz)	UE receive (MHz)
1	2100	IMT	1920 – 1980	2110 – 2170
3	1800	DCS	1710 – 1785	1805 – 1880
5	850		824 – 849	869 – 894
8	900	E-GSM	880 – 915	925 – 960
9	1700		1749.9 – 1784.9	1844.9 – 1879.9
26	850		814 – 849	859 – 894

2. 4.3 Fourth Generation (4G LTE) Frequency bands

The LTE standard covers a range of many different bands, each of which is designated by both a frequency and a band number [26]:

- North America – 600, 700, 850, 1700 (AWS), 1900, 2300 (WCS), 2500, 2600 MHz (bands 2, 4, 5, 7, 12, 13, 17, 25, 26, 29, 30, 41, 66, 71)
- Latin America and Caribbean – 700, 850, 900, 1700, 1800, 1900, 2100, 2600 MHz (bands 1, 2, 3, 4, 5, 7, 8, 13, 17, 28)
- Europe – 450, 700, 800, 900, 1500, 1800, 2100, 2300, 2600, 3500, 3700 MHz (bands 1, 3, 7, 8, 20, 22, 28, 31, 32, 38, 40, 42, 43)
- **Asia – 450, 700, 800, 850, 900, 1500, 1800, 1900, 2100, 2300, 2500, 2600, 3500 MHz (bands 1, 3, 5, 7, 8, 11, 18, 19, 21, 26, 21, 31, 38, 39, 40, 41, 42)**
- Africa – 700, 800, 850, 900, 1800, 2100, 2500, 2600 MHz (bands 1, 3, 5, 7, 8, 20, 28, 41)
- Oceania (incl. Australia and New Zealand) – 700, 800, 850, 1800, 2100, 2300, 2600 MHz (bands 1, 3, 7, 12, 20, 28, 40).

As a result, phones from one country may not work in other countries. Users will need a multi-band capable phone for roaming internationally.

2.5 Frequency Using in Different Countries for Mobile Systems

Mobile Frequency Bands in United States of America

There have variety of frequency band usages in America for the mobile communication system. Following frequency bands are being used for mobile system in America, by several mobile operators [10].

Table 2.4: United States Carrier Frequency Use

Carrier	2G Frequency (MHz)			3G Frequency (MHz)			4G LTE Frequency (MHz)								
	Band name			Band name			Band name								
	800	850	1900	850	1700 / 2100	1900	600	700	850	1700 / 2100	1900	2300	2500	3500	5200
AT&T	No	No	No	Yes	No	Partial	No	Yes	Partial	Yes	Partial	Yes	No	No	Yes
C Spire	No	Yes	No	No	No	Yes	Partial	Partial	No	Yes	Yes	No	Partial	No	No
Sprint	Yes	No	Partial	No	No	Yes	No	No	Yes	No	Partial	No	Yes	No	Yes
T-Mobile	No	No	Yes	No	Partial	Yes	Yes	Yes	Partial	Yes	Partial	No	No	No	Yes
U.S. Cellular	No	Yes	Partial	Partial	No	Yes	No	Yes	Partial	Yes	Partial	No	No	No	No
Verizon	No	Yes	Partial	Partial	No	Yes	No	Yes	Partial	Yes	Partial	No	No	No	Yes

Below is the list of available frequencies [11] of some other countries as plotted in the following tables.

Mobile Frequency Bands in Australia

Following frequency bands are being used for mobile system in Australia, by several mobile operators.

Table 2.5: Frequency bands used for mobile system in Australia

3G Frequency (MHz)			4G LTE Frequency (MHz)					
Band name			Band name					
850	900	2100	700	850	900	1800	2300	2600

Mobile Frequency Bands in French

In French, following frequency bands are being used by several mobile operators.

Table 2.6: Frequency bands used for mobile system in French

3G Frequency (MHz)	4G LTE Frequency (MHz)		
Band name	**Band name**		
2100	800	1800	2600

Mobile Frequency Bands in India

India is one of the largest mobile markets in world. Following frequency bands are being used for mobile system in India, by several mobile operators.

Table 2.7: Frequency bands used for mobile system in India

3G Frequency (MHz)		4G LTE Frequency (MHz)
Band name		**Band name**
1900	2100	1800

Mobile Frequency Bands in Colombia

Following frequency bands are being used for mobile system in Colombia, by several mobile operators.

Table 2.8: Frequency bands used for mobile system in Colombia

3G Frequency (MHz)		4G LTE Frequency (MHz)
Band name		**Band name**
850	1900	1700

2.6 Frequency Distribution in Bangladesh

The radio frequency spectrum is a finite national resource. It is therefore highly desired that the spectrum resource is utilized in an efficient and effective manner [27].

According to NFAP (National Frequency Allocation Plan), spectrum of 900 MHz & 1800 MHz bands are allocated for second generation mobile service. At present four operators are providing this second generation mobile service by GSM technology [28].

1. In 1989 Cellular mobile phone Company, "Pacific Bangladesh Telephone Limited and Bangladesh Telecom" got license and launched Advanced Mobile Phone System (AMPS). AMPS is an analog mobile phone system. This was 1st generation with frequency 800 MHz(CDMA 800 MHZ) [28];
2. Pacific Bangladesh Telecom Limited (PBTL, now Citycell) operating under CDMA technology was offered a cellular license in Bangladesh in 1993 which was with 2nd Generation (CDMA 800 MHZ) technology [29].
3. In 1996, Bangladesh was preparing to auction off private cell phone licenses to four companies for 2nd Generation mobile services with frequency 900 MHz and 1800 MHz [30].
4. In 2012, Teletalk started 3rd Generation mobile communication in Bangladesh with frequency band 2100 MHz and Other Operators got licensed on 2013 for the same [28].

After those (above declarations) in 2018 BTRC announced an auction for the available frequencies from 900 MHz, 1800 MHz and 2100 MHz bands, while selling the license for 4G/LTE system in Bangladesh. At that time BTRC also sold the license of frequency neutrality to permit the implementation of the common frequency band (purchased by any operator) in any generation (2G or 3G or 4G). So with the frequency neutrality facility mobile operators can use their licensed 900 MHz or 1800 MHz for the 3G or 4G systems.

2.7 Characteristics of different band frequencies

Different frequency bands have different individualities in transmission, strength and penetration ability in wireless communication systems.

2.7.1 Pros and cons of different band frequencies

In this thesis works three available bands 900 MHz, 1800 MHz and 2100 MHz Frequency have been considered for the assessment.

900 MHz, 1800 MHz and 2100 MHz Frequency transmits information from mobile station to base station and vice-versa. This frequency is used in several regions of the world,

specifically in Asia, Africa, Australia, Europe, Middle East and Oceania. Use of 900 MHz frequency is mostly preferred for outdoors fixed wireless application.

Advantages of 900 MHz Frequency

The transmitter at 900 MHz range allows different characteristics. Following are the advantages of this frequency:

- **Reliable Connectivity and Signal Strength:** The primary advantage of 900 MHz range is the reliability of connection and signal penetration. This can be understood from the Path Loss Formula. A Path Loss Formula is used to calculate the loss of signal over the distance between the transmitter and the receiver.
- **Further Reach:** 900 MHz frequency fixed radio link can be almost 2 times farther in distance than an 1800 MHz connection.
- **Better Penetration:** A longer wavelength of 900 MHz transmission allows the connection to easily penetrate amongst dense materials such as tree line between sites etc. This property helps hugely in benefiting two linking sites where dense vegetation would otherwise cause hindrance.

Disadvantages of 900 MHz Frequency

- **Data Rate Availability:** The major drawback for incorporating a 900 MHz solution is the data rate availability and possible signal interference. Though different manufacturers boast about different data transfer rates. The General rule for all wireless networks is that the higher the band the greater is the transfer speed.
- **Signal Hindrance:** Since 900 MHz has a lower frequency when compared to higher frequency modules such as 1800 MHzor 2100 MHzit is extremely susceptible to both broadcast as well as tall physical objects on a long range.

Advantages of 1800 MHz Frequency

1800 MHz also have some advantages and disadvantages compared to 900 MHz and 2100 MHz frequencies.

- **Reliable Connectivity and Signal Strength:** Have relatively less reliability of connection and signal penetration than 900 MHz and a little bit better than 2100 MHz.

- **Better Penetration:** 1800 MHz penetrate more dense materials than of 2100 MHz but less compared to 900 MHz. Sub-urban area may be a good geographical area for serving by 1800 MHz.
- **Interference:** Less interference is an advantage of 1800 MHz as relativity very few existence of this type of bands for other purposes.

Disadvantages of 1800 MHz Frequency

Data Rate Availability: Some disadvantages are as follows.

- **Coverage area:** Low coverage is the main drawback of using 1800 MHz for mobile communication system.

Advantages of 2100 MHz Frequency

Like other bands, 2100 MHz also have some advantages and disadvantages compared to 900 MHz and 2100 MHz frequencies.

- **High Data Rate:** High data rate is the main advantages of higher band frequency, hence 2100 MHz is a better choice in dense area.
- **Less Interference:** Less interference is another advantage of 2100 MHz as relativity very few existence of this type of bands for other purposes.

Disadvantages of 2100 MHz Frequency

Some disadvantages of 2100 MHz are as follows.

- **Less Penetration:** 2100 MHz have less penetration availability Compared to 900 MHz**.**
- **Coverage area:** Very low coverage is the main drawback of using 2100 MHz for mobile communication system.

2.8 Review of research works related with wireless system and assessment

From the first age of wireless communication system, different transmission techniques and modulation schemes have been developed to enhance the performances as well mitigate the limitations. A numbers of frequency bands are being used for wireless systems. Several methods, like “spectrum sharing”, “spectrum reuse”, “spectrum overlay”, “spectrum underlay”, etc. also been developed for wireless communications to fulfill the on time demands. Also researches are ongoing on dynamic frequency allocation among collocated multiple “radio access networks”.

In the further subsections a brief review of different notable research works related to approaches and scenarios of frequency selection and optimization is presented.

A research work relating to the Performance Evaluation of Different Frequency Bands for WiMAX system [31] particularly focused on comparison of frequency spectrums in terms of path loss using dissimilar propagation models. This work analyzed different frequency bands for urban and rural area and finally proposed 2.5 GHz as a better selection of spectrum compared to 3.5 GHz.

An assessment performed to find the market demand and feasibility of introducing 3G mobile system in Bangladesh [32]. The research work conducted by considering the capital and operational costs for implementing the new technology in Bangladesh. As there had market demand for the new features of 3G system, causing possibility of returns of investment, it was found that 3G mobile communication would be feasible to implement on that time.

By applying Analytic Hierarchy Process (AHP) a study had been conducted to find the successful adoption of 4G in Bangladesh [33]. Considered the facilities of existing 2G and 3G mobile communication systems and compared with 4G system to explore the user demands in market. According to the number of expert’s opinion, this research outcome indicated that mobile users would appreciate the introduction of 4G mobile communication system in Bangladesh and it was a time demand to lunch 4G on time.

A techno-economic analysis was performed for two wireless technologies, called third generation (3G) implemented at 900 MHz and at 2100 MHz frequency bands, based on Tanzania. The objective of this analysis was to investigate the economic feasibility and to determine a cost effective option between the two options (900 or 2100 for 3G). Results show that, 3G at 900 HMz is a feasible and cost-effective connectivity technology in Tanzania [34]. In this work also suggested to implement same in other developing countries, since rural areas pose similar characteristics with regard to ICT infrastructure development.

A feasibility analysis work conducted to find the feasibility of implementing 3G macro additional sector in existing base stations to mitigate the user demands (satisfactory data throughput) at dense area [35]. Techno-economic approach applied considering the capital expenditure, operating expenditure as well as expected Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PBP). Feasibility analysis results showed that it is feasible with a positive NPV and good percentage of IRR.

“A Feasibility Study of Wireless Networks for 17 and 60 GHz and the Impact of Deployment Strategies on the System Performance” [36]. In this research work it was shown that the 60GHz band with achievable very limited cell radii is best suited for indoor applications with a dense infrastructure. Very high data rates and capacities can be offered due to the large amount of bandwidth allocated at 60GHz. In the other hand when capacity is less important, then 17GHz band should be preferred with the better propagation characteristics allow larger cells and fewer APs are required for reliable coverage.

An Analytic Hierarchy Process (AHP) model was built up as a multi-criteria decision making assessment tool to select the most suitable mobile network operator of a country. For this work three most familiar mobile operators (Celcom, Maxis and DiGi) had been chosen as the alternatives for the citizen of that area. As those operators promote variety of packages to attract mobile subscribers hence four major criteria associated with mobile operators like, “monthly commitment”, “monthly charges”, “rewards” and “value added services” had been selected to prepare the questionnaires for the experts to conduct the AHP calculation. After the AHP analysis it is found Celcom is the most preferable operator and “monthly commitment was the most important in the selection process [37].

To find the most preferable mobile operator, based on data applications, an assessment work conducted by applying Analytic Hierarchy Process (AHP) model, in Nigeria. In this case QoS had been evaluated to determine which operator serve the best QoS for mobile data service on 3G mobile networks, provided by different mobile operators of that country. Four criteria such as latency, jitter, data loss, and throughput are the parameters collected in drive testing over the mobile network, to evaluate the problem formulated as a multi-criteria decision problem. Users perception was considered as the raw input for the AHP analysis to determine which network provides the best quality QoS regarding data applications According to the AHP results in Java indicate that operator Etisalat is the alternative that offers the best QoS for web browsing application based on measured criteria, followed by Airtel and then MTN, while Glo was ranked as least operator for the same [38].

METHODOLOGY 3

3.1 Introduction

This thesis work is conducted by applying a technology assessment analysis to find the feasibility of choosing appropriate frequency band for 3G mobile communication system in Bangladesh. Technology assessment is a focus point to come to the target stage of this research. Hence in this chapter a brief description of technology assessment is introduced as well the method of assessment tools used here. Analytic Hierarchy Process (AHP) is introduced here as a research tool of this work. Later the data source, data sampling, model development and questionnaire are described in a sub sequence manner.

3.2 Technology Assessment (TA)

Technology assessment (TA) is a scientific, interactive, and communicative process that aims to contribute to the formation of public and political opinion on societal aspects of science and technology [39].

Technology assessment defined by Joe Coates (1976) as:

A class of policy studies which systematically examine the effects on society that may occur when a technology is introduced, extended, or modified. It emphasizes those consequences that are unintended, indirect, or delayed.

It involves the collection, interpretation and evaluation of information and perspectives around contending technological options. In the absence of TA, technologies may fail to serve their desired function, or create unforeseen negative impacts [40].

The goal of technology assessment is to be to provide policy makers with information on policy alternatives.

In a summary, TA evaluates the technology in some way for making technological choices by a thorough analysis of all consequences [41].

3.2.1 Tools and Techniques used for Technology Assessment

Different types of Technology Assessment tools are being used over the world to conduct different types of technology assessments. Available tools and techniques for TA have been categorized into four groups [42].

- General Intuitive Methods,
- Important Component Methods,
- Structural Decomposition Methods, and
- Holistic Composition methods.

Each of these above class have several techniques used for technology assessment. Those sub-classifications are as follows [42].

1. General Intuitive Methods
    a. Expert Opinion,
    b. Polls and panels,
    c. Delphi techniques,
    d. Cross-Impact Analysis
2. Important Component Methods
    a. Ad hoc,
    b. Checklist,
    c. Matrices
3. Structural Decomposition Methods
    a. Relevance Tree (RT),
    b. Morphological analysis,
    c. Analytical hierarchy,
    d. Network
4. Holistic Composition methods
    a. Indices,
    b. Cost-benefits analysis,
    c. Scenario generation,
    d. Simulation model

Among those tools, Analytic Hierarchy Process (AHP) is one of the best-characterized and validated methods for multi-criteria decision-making (MCDM). It can perform better than other multi-criteria methods as by this method can easily be adapted to different numbers of attributes (criteria) and alternatives [43]. AHP is one of the popular tools practiced by the experts in the field of decision makings.

3.3 Research Tool used in this thesis work

To conduct the analysis, two technology assessment tools have been used in this thesis work, which are Analytic Hierarchy Process (AHP) and Cost Benefit Analysis (CBA).

3.3.1 Analytic Hierarchy Process (AHP)

The **analytic hierarchy process** (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then [40].

AHP is a decision making process in which a problem is first broken down to a hierarchy of interrelated decision elements and then uses the pair-wise comparisons taken place for criteria, sub-criteria and alternatives, focusing the target goal. For a technology assessment by AHP, following steps need to follow to execute the analysis.

I. First need to define the goal for which the assessment will be conducted,

II. The second step is "structure the decision problem in a hierarchy, relating with criteria, sub-criteria and alternatives",

III. Then come the pair-wise comparison of criteria and sub-criteria for each alternatives,

IV. In step four, to conduct calculation of the priorities and checking consistency,

V. Finally to evaluate the alternatives according to the weights, identified in above steps.

3.3.2 Cost Benefit Analysis (CBA)

Cost Benefit Analysis (CBA) is a systematic process to predict the benefit for the technological choices, as well for calculating and comparing the benefits and costs of a technology project or decisions.

Cost Benefit Analysis (CBA) has two major purposes [44],

1. To determine if an investment (or decision) is sound, ascertaining if – and by how much – its benefits outweigh its costs.
2. To provide a basis for comparing investments (or decisions), comparing the total expected cost of each option with its total expected benefits.

3.4 Research Model

Analytical Hierarchy Process (AHP) has been chosen in this work, as a prime analysis tool for the technology assessment to identify the feasibility of choosing GSM or DCS frequency band for 3G mobile system in Bangladesh. As per ITU multiple frequency bands are available for GSM/DCS systems. Among those in Bangladesh only 900 MHz and 1800 MHz bands are allowed and licensed by BTRC. For 3G system telecom operators have 2100 MHz band, purchased from BTRC. Initially ITU announced this 2100 MHz as "Band-1" for 3G system on 2000 and later another around 30 frequency bands declared to use in 3G system. A ranking among these three bands (900 MHz, 1800 MHz and 2100 MHz) has been performed by applying AHP so that operator can choose the appropriate band for their 3G network in Bangladesh. For this ranking preferences of academic researchers and telecom professionals have been taken based on variables related to target goal.

Another tool Cost Benefit Analysis (CBA) also conducted to compare and justify the benefits and costs for the operators for the different frequency bands for 3G network, considering urban, sub-urban and rural area.

3.4.1 Source of data

Available data from Bangladesh Telecommunication Regulatory Commission (BTRC) will be considered as major source for wireless communication techniques in Bangladesh. Relevant extended data were collected through Internet, Books, Journals and other source of mobile wireless technology information.

3.4.2 Sampling design

Well-structured questionnaires have been prepared and sample survey have been conducted by following the principles of Technology Assessment tools. For this survey face to face interview taken from a number of academic researchers (from Bangladesh University of Engineering and Technology (BUET), Chittagong University of Engineering and Technology (CUET), Khulna University (KU) and International Islamic University Chittagong (IIUC)) and telecom professionals (from Grameenphone, Robi Axiata, Teletalk, Ericsson, Huawei and other related companies at abroad) who are directly or indirectly related to telecommunication systems. Those academic researchers and telecom professionals have been treated as expert for this research work. Expert opinion conducted by the interview based on their study, research and telecom expertise experiences. The achieved expert opinion is used as the raw data of matrix (according to the strategy of AHP tools) to conduct the further AHP calculation.

3.4.3 Model development

In this work, Analytical Hierarchy Process (AHP) has been chosen for the assessment. An **AHP** consists of an overall goal, a group of options or alternatives for reaching the goal, and a group of factors or criteria that relate the alternatives to the goal [45]. For this empirical analysis, three criteria and nine sub-criteria have been designed for ranking the available licensed frequency bands (900 MHz, 1800 MHz and 2100 MHz) as alternatives. In a summary word, AHP model uses four stages for data hierarchy. All the stages are as follows:

First Stage: Research goals,
Second Stage: Criteria of ranking,
Third Stage: Sub-criteria,
Forth Stage: Alternative options.

A table of stages for the AHP model has been formed as in the following table.

Table 3.1: Research goal, criteria, sub-criteria and alternatives.

Stages	**Options/Factors**
Goal	Finding Appropriate Frequency Band for 3G Mobile Communication in Bangladesh
Criteria	Quality Factors
	Cost Components
	Other Effects
Sub-criteria	Coverage Area
	User Capacity
	Stability / Signal Penetration
	Integration Cost
	License Cost
	Maintenance Cost
	Social Impact
	Environmental Effects
	Economic Impacts
Alternatives	900 MHz
	1800 MHz
	2100 MHz

A brief demonstration of the above criteria and sub-criteria are as follows.

Quality Factors: For any service, quality is a major factor to be considered. For wireless communication system quality is not only a single term. It is consisted of several factors, like Call Setup Success Rate, Handover Success Rate, Data Throughput, audio quality, etc. which are directly or indirectly depends on user capacity, accessibility, signal penetration, signal strength (coverage) of the serving cell site.

Cost Components: Entrepreneurs who want to launch any service, must analysis the cost need to invest for that service. In mobile communication systems, for network part, integration cost and maintenance cost are the main considerable cost factors. Beside these two, license cost also need to consider as a huge investment lies to avail the right of using spectrum, from the regulatory board of the country.

Other Effects: In this study, "other effects" have been considered by the belonging of Social Impacts, Environmental Effects and Economic Impacts. Experts considers these factors while expressing their opinion for the questionnaires.

User Capacity: By capacity it is meant how many users (voice call service) can be supported by one serving cell or how much bandwidth/throughput possible over one cell of a base station. Actually have no such dependency upon frequency band (of same channel width) for the above two factors (user capacity and channel bandwidth). But as high frequency served with less wave length hence can serve more user in populated area with comparatively high bit rate.

Coverage Area: Coverage area means how distance a cell site (base station) can serve by it's radiated signal. Frequency has an important role upon coverage as wave length is inversely proportional to frequency ($v = f\lambda$). If frequency is higher definitely the signal coverage is less.

In an open area by 900 MHz frequency band cell coverage is possible up to 26.9 km and by 1800 MHz it is around 14 km whereas by 2100 MHz cell radius is 12 km. Following picture shown a relative comparison of coverage by different frequencies [46].

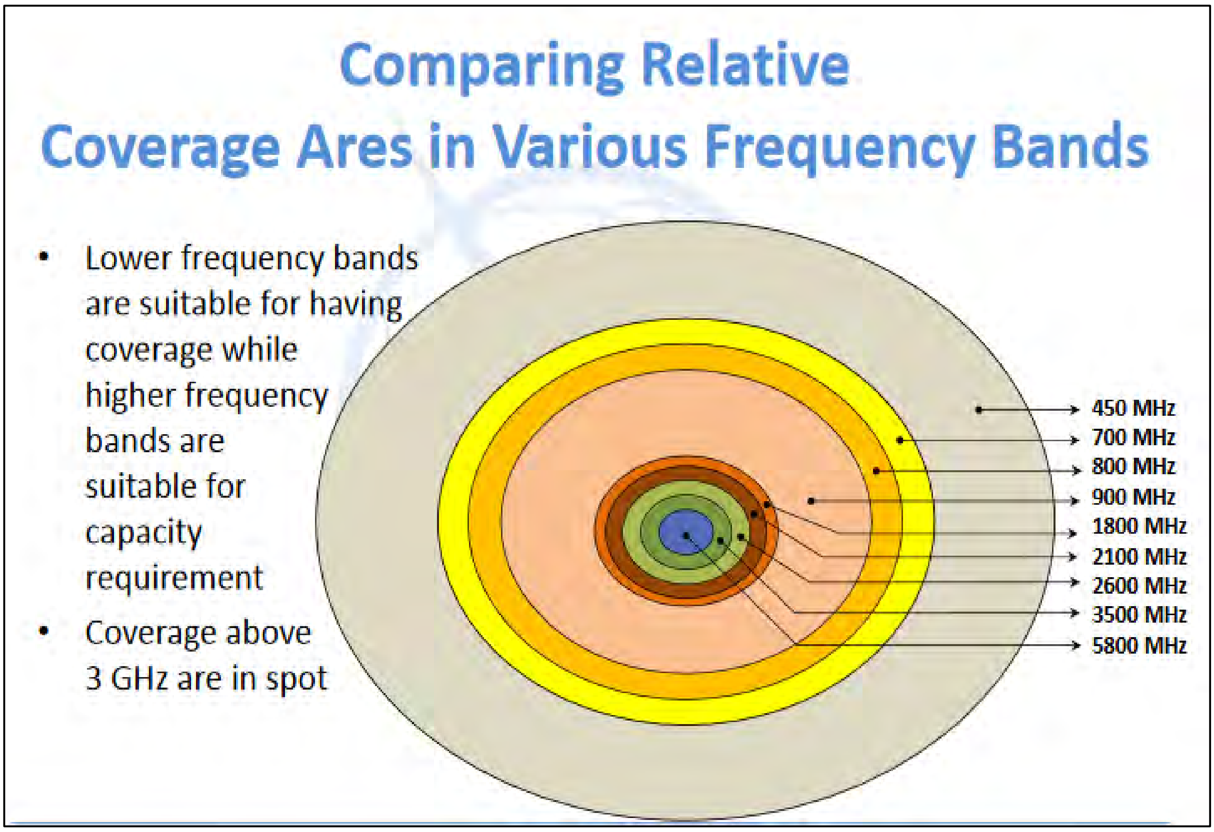

Figure 3.1: Coverage variation by different frequencies

Stability / Signal Penetration: Signal penetration is one of the major challenges for RF planners to insure the inside building coverage as well inside the vehicle in mobility. Signal penetration have a dependency on frequency variation, like 900 MHz have a wall more penetration strength than 2100 MHz due to the variation in wave length characteristics.

Integration Cost: Capex is must for any business or service initiation or any modification in existing systems and integration cost is one of the major parts of capex. For mobile communication system, integration cost is the sum of Site requisition, Base station platform construction, Power supply integration, Backhaul transmission path setup, Equipment purchase and installation. So the integration cost is almost proportional to the number of base stations (BS).

A chart shown as below visualized the integration cost variation scenario by the different frequency bands [46].

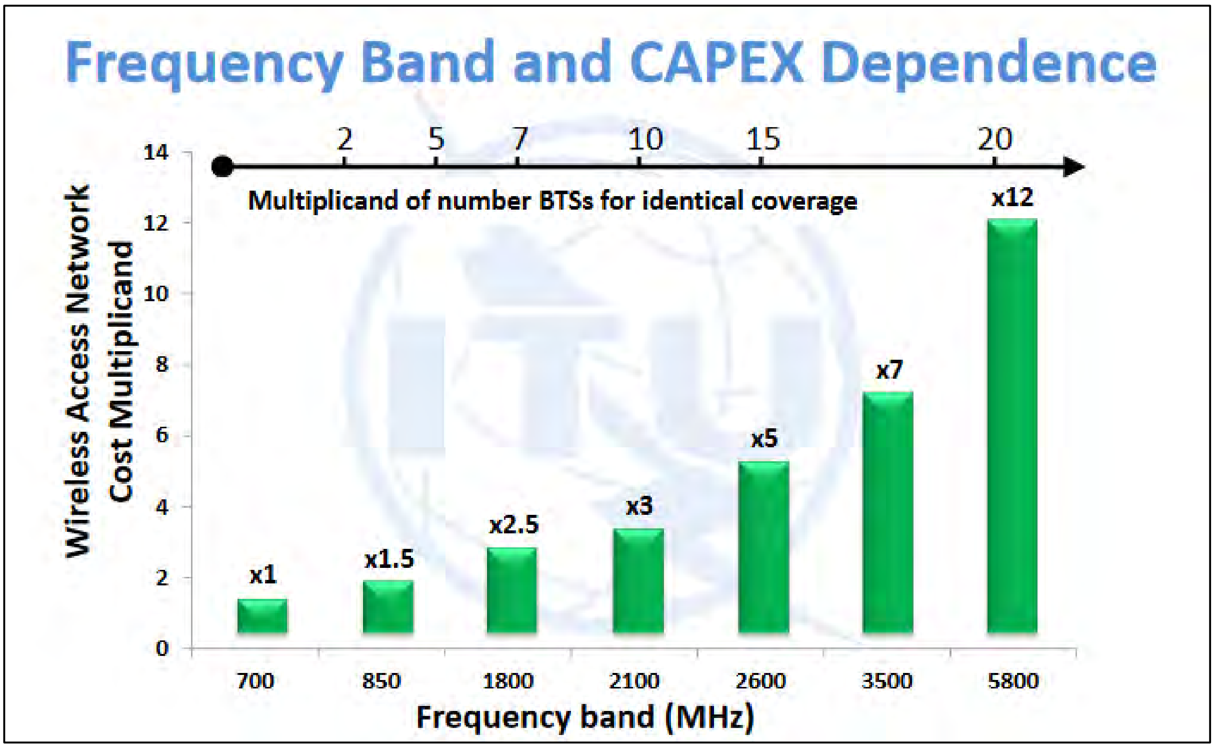

Figure 3.2: Integration cost variation scenario by the different frequency bands

License Cost: A large amount of cost is needed to invest for mobile operator to avail the spectrum license from regulatory board (as BTRC in Bangladesh). Operators are to pay the license fee while acquiring the right of using any particular frequency band for particular service, like 2G, 3G or 4G. Another payment is for the frequency neutrality that means if any operator wants to use the acquired frequency of 2G (900 MHz or 1800 MHz) for the 3G service, need to pay the fixed amount of fees to BTRC. Total license costs are the initial license acquiring fees and annual renew fees as per BTRC announcement [47].

Maintenance Cost: Monthly Energy cost (Power supply from PDB/REB or by own generator), Annual Site rental fees and the regular site corrective maintenance cost (man power, transportation, spares, etc.) due to different physical and logical fault detection and rectification works are the major scope of maintenance cost. The most of the OpEx costs of any mobile operator lies in regular maintenance costs. For better stable network and to avoid sudden fault, operators need to perform preventive maintenance of their network infrastructures as well telecom equipment's. Generally maintenance cost increase with the increasing of number of base stations.

Social impacts: It measures, how the society is being impacted by the mobile communication system. Doubtlessly now the social life is faster with the use of mobile system by both voice and internet services. People can easily communicate with their dear once from anywhere and anytime. A strong network coverage and quality services can smooth this social communications. A good signal coverage have dependency on frequency band, antenna height & tilt, transmit power, etc. So frequency selection have an influence on mobile network coverage especially in rural area, like by lower band frequency can be served wide geographic area from a single base station.

Environmental Effects: Considering environmental effect is an essential factor to analysis, before launching any technology in a community. All the electro-magnetic signal have radiation in environment. Mobile phones use electromagnetic radiation in the range of 450 MHz to 3800 MHz. As per World Health Organization (WHO) no adverse health effects on human body by this frequency bands [48]. But the higher frequency, the more radiation is true for electromagnetic radiation.

Economic Impacts: Mobile communication systems have a great impact on national economy. Starting from Foreign Direct Investment (FDI) as most of the mobile operators in Bangladesh are of foreign company who invested a large amount to establish nationwide mobile communication services [49]. Later the end user in urban, sub-urban and even in rural area, number of sales representatives, retailers are employed for sales. Even different small businesses grown up after the available mobile communication services, which have a direct impact on national economy. A better and stable mobile signal strength can enhance those economic developments even in rural area. Selecting frequency band (by operators) may have an indirect influence upon this impact as signal coverage mostly depends on the frequency band.

Relevance tree for AHP calculation:

Decision making by AHP method is depends on the criteria and sub-criteria for each alternatives. After the above criteria, sub-criteria and alternatives, a relevance tree has been formed according to this research work which is as given below.

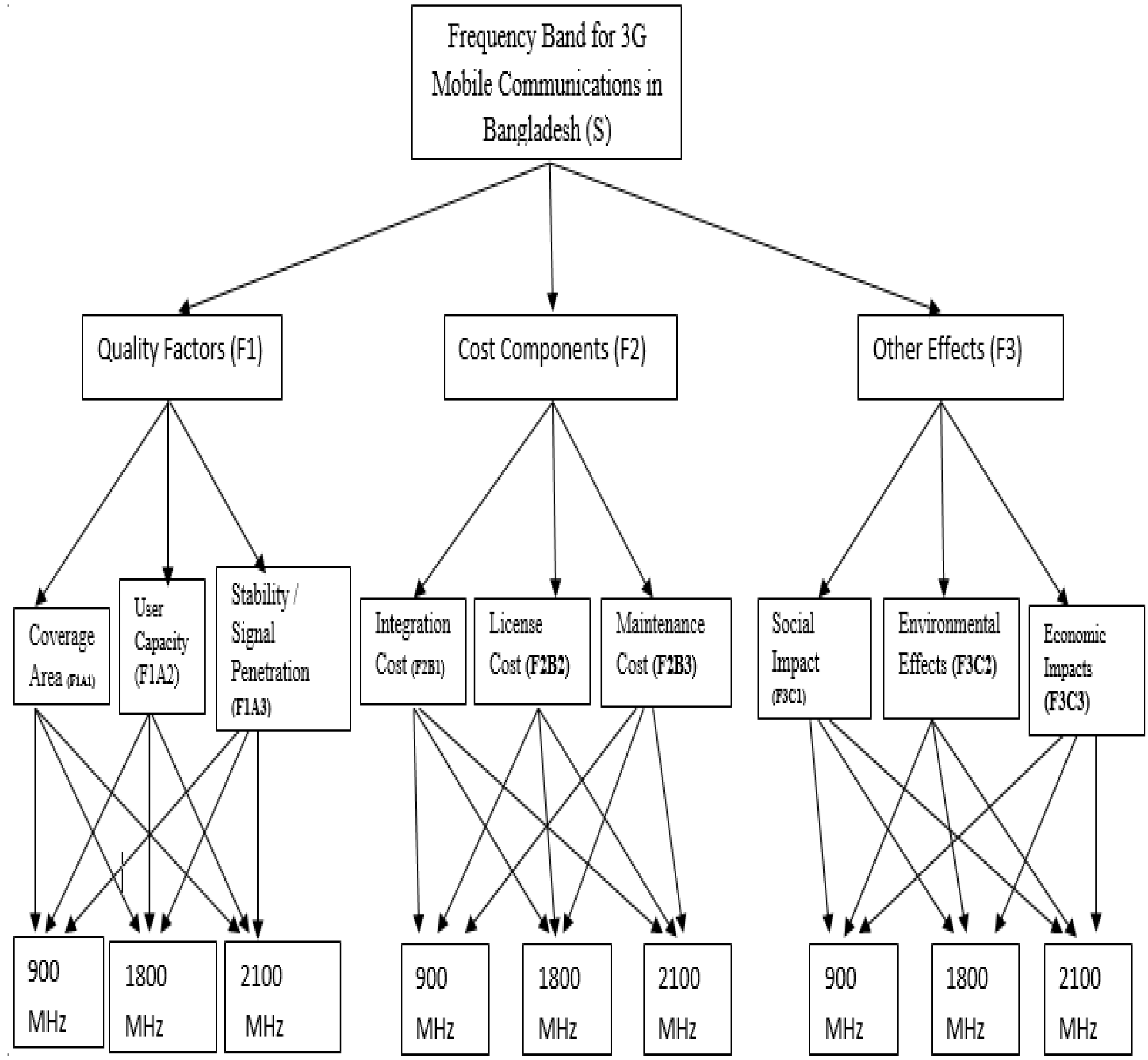

Figure 3.3: AHP relevance tree based on Criteria and sub-criteria

3.4.4 Questionnaires Development

Based on the above relevance tree, the questionnaires were formed to complete the further analysis.

The scale of weights, considered for this research is from 1 (Equally Preferred) to 9 (Extremely Preferred).

Table 3.2: Scale of weights for AHP calculation

Pair-wise Comparison Scale For AHP	
Judgment of Preference	Numerical Scale
Equally Preferred	1
Equally to Moderate Preferred	2
Moderately Preferred	3
Moderately to Strong Preferred	4
Strongly Preferred	5
Strongly to very strong Preferred	6
Very strongly Preferred	7
Very strongly to extreme Preferred	8
Extremely Preferred	9

As in below, first the criteria then sub-criteria and at the last alternative options are chosen to form questionnaires for the pair wise comparisons.

Three sample questionnaires for the criteria have been shown as follows. All the questionnaires are available in appendix-II.

Questionnaires for Criteria:

1. Let given the frequency selection options, what is more important to you: the Quality Factors (F1) or Cost Components (F2)? And please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one. (Please tick mark on your choice)

i. Quality Factors (F1); ii. Cost Components (F2)

Weight	1	2	3	4	5	6	7	8	9

2. Let given the frequency selection options, what is more important to you: Quality Factors (F1) or Other Effects (F3)? And please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one. (Please tick mark on your choice)

i. Quality Factors (F1); ii. Other Effects (F3)

Weight	1	2	3	4	5	6	7	8	9

3. Let given the frequency selection options, what is more important to you: the factor of Cost Components (F2) or Other Effects (F3)? And please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one. (Please tick mark on your choice)

i. Cost Components (F2); ii. Other Effects (F3)

Weight	1	2	3	4	5	6	7	8	9

Rest 33 questionnaires are available in appendix-II.

3.4.5 Data Analysis by Analytical Hierarchy Process (AHP) Tool

An implementation of AHP can be in three consecutive steps [51], which are

1. Computing the vector of criteria weights,
2. Computing the matrix of option scores, and
3. Ranking the scores

There are numerous methodology presented in many publications for deriving priority weights in the AHP. Practically, the most common approach is the originally proposes eigenvector method [50]. In this research work sum method has been used to conduct the eigenvector calculation.

Let $A = (a_{ij})$ where a is the n*n judgement matrix as per the pair-wise comparison value from expert opinion.

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}$$

Firstly we normalize the column vectors in the judging matrix, then add the normalized matrix in rows. The result should be normalized again to get the eigenvector.

A sample calculation is as follows.

Let form a 3*3 matrix for 3 criteria's F1, F2 and F3 of a goal as shown in following table (Table-3.5).

Step-1:

First of all finding the n^{th} root of product, is the value of multiplying each row together and then performing n^{th} root of that multiplied value, like n^{th} root of (F1) = $(F1*F2*F3*\ldots Fn)^{1/n}$.

$(F1) = (F1*F2*F3*\ldots Fn)^{1/n}$ …………………………………………………..……………(3.1)

Table 3.3: Calculating Priority Vector (*PV*)

Criteria	F1	F2	F3	n Root of Product	Priority Vector (PV)	PV%
F1	*1*	*x*	*y*	*X*	*X/S*	(*X/S*)*100
F2	*1/x*	*1*	*z*	*Y*	*Y/S*	(*Y/S*)*100
F3	*1/y*	*1/z*	*1*	*Z*	*Z/S*	(*Z/S*)*100
			Sum (*S*)	*X+Y+Z*	1	100

Where x, y and z would be the value from 1 to 9 from table-3.2 as per the choice of individual expert.

So $S = X+Y+Z$;

Where $X = (1*x*y)^{1/3}$, $Y = (1/x*1*z)^{1/3}$ and $Z = (1/y*1/z*1)^{1/3}$. Here n=3 as considered the number of criteria is 3 (F1, F2 and F3).

After that the Priority Vector is the normalized value of aforementioned n^{th} root of product; Priority Vector (Weight) = n^{th} root of product/Sum. The sum of priority vectors must be equal to 1. So the equation for this calculation be as follows.

$PV_i = X_i/S$ ………………………………………………………………………………… (3.2)

From the above calculations we have the priority vector of each criterion. Similarly the priority vectors for sub-criteria and alternatives are calculated by the corresponding pair-wise comparison weights from expert opinions.

Now the "**Global Priority**" is the multiplication of the PVs of criteria and sub-criteria.
For an example Glb priority of Coverage Area (*F1A1*) = (*PV* of (Quality Factors (F1)) * (*PV* of Coverage Area (F1A1)).

At the end of calculation need to find the "final weight" of each alternatives, which is the multiplication of aforementioned "priority vector"(of alternative) and corresponding "Global priority" (of sub-criteria).
Final weight = aforementioned "priority vector" * "Global priority".

3.4.6 Consistency Analysis

Consistency analysis is the test to verify whether the result weights of AHP calculation is within acceptable range or not. As the results are based on the expert opinion hence if the result of any category is not below consistent values then experts are requested to re-evaluate his opinion for the same. The major parts of consistency analysis are,

1. Calculate the consistency index (CI), and
2. Calculate the consistency ratio (CR).

Consistency Index (CI) = (Lambda Max-n)/ (n-1). ……………………………………….. (3.3)
Where "Lambda Max" is the sum of all "Sum PV" values. And n= Matrix size.
Consistency Ratio *CR=CI/RI*…………………………………………………………...… (3.4)

Where RI is the Random Index [52].

Table 3.4: Random index values

Random Index(RI)									
n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

For the above sample calculation, an execution of consistency check have been performed. To do so according to AHP strategy, first calculated the "Sum PV" which is the multiplying value of "Column Sum" and Corresponding "Priority Vector". Following table is a sample calculation as a reference of the final result calculation of this thesis work.

Table 3.5: Calculating Sum PV and λ_{max}

Criteria	**F1**	**F2**	**F3**	**n Root of Product**	**Priority Vector (PV)**	**PV%**
F1	1	*x*	*y*	*X*	*X/S*	(X/S)*100
F2	*1/x*	*1*	*z*	*Y*	*Y/S*	(Y/S)*100
F3	*1/y*	*1/z*	*1*	*Z*	*Z/S*	(Z/S)*100
Column Sum	*(1+1/x+1/y)*	*(x+1+1/z)*	*(y+z+1)*	Sum (*S*) = (*X*+*Y*+*Z*)	1	100
Sum PV	*(1+1/x+1/y)*(X/S)*	*(x+1+1/z)*(Y/S)*	*(y+z+1)*(Z/S)*	λ_{max}		

Where λ_{max} (Lamda max) is the sum of all "Sum PV" values.

$\lambda_{max} = A + B + C$; $A=(1+1/x+1/y)*(X/S)$, $B=(x+1+1/z)*(Y/S)$ and $C=(y+z+1)*(Z/S)$;

So the Consistency Index, $CI = \lambda_{max}/(n-1)$; in this sample n=3;

And Consistency Ratio $CR=CI/RI$.

Using the above calculations for the opinion of each expert, the final calculation for our target goal is to identify the weights of 900 MHz, 1800 MHz and 2100 MHz have found as demonstrated in coming chapter.

RESULT AND DISCUSSION 4

4.1 Introduction

In this chapter the detail data analysis has been demonstrated to acquire the target result of technology assessment by using AHP tool. The AHP calculation produced graphical representations which presents the final comparison of weight among 900 MHz, 1800 MHz and 2100 MHz which helped to identify the priority of selecting appropriate frequency band for 3G mobile system.

4.2 Result calculation

Data analysis in this work has been conducted by using a Microsoft Spread Sheet developed according to the Analytical Hierarchy Process (AHP) tool and technique. This value also has been evaluated by the AHP online software.

In this analysis the goal is “Finding Appropriate Frequency Band for 3G Mobile Communication in Bangladesh”. The selected criteria are Quality Factors, Cost Components, and Other Effects. Later the sub-criteria taken as Coverage Area, User Capacity, Stability / Signal Penetration, Integration Cost, License Cost, Maintenance Cost, Social Impact, Environmental Effects and Economic Impacts. The final stage of analysis for the alternatives which are 900 MHz, 1800 MHz and 2100 MHz.

For this assessment works conducted interview with more than 20 experts of telecommunication field (both profession and researchers) to avail the expert opinion for the AHP analysis. According to AHP tools pair wise comparison has been collected from individual experts for criteria, sub-criteria and alternatives. Then formed the corresponding matrices to finalize the calculation. Each matrix represents the intensities of the expert’s preference for the alternatives.

AHP calculation for expert-1

From the interview result of expert-1, the following matrix is constructed to calculate the weight for the selected three criteria’s, Quality Factors, Cost Components and Other Effects.

Table 4.1: Matrix as per pair wise values from expert opinion

Criteria	F1	F2	F3
Quality Factors(F1)	1	5	7
Cost Components(F2)	1/5	1	3
Other Effects(F3)	1/7	1/3	1

Now the 3rd (nth) root of product is the value of multiplying each row together and then cubic root. Calculated using equation (3.1). And later the priority vector is calculated by following the equation (3.2), "Priority Vector" is the normalized value of aforementioned nth root of product;

Priority Vector (Weight) = n^{th} root of product/Sum. Here n=3 as the number of criteria's.

Table 4.2: Priorities vector for the pair wise comparison matrix for criteria.

Criteria	F1	F2	F3	3rd Root of Product	Priority Vector
Quality Factors(F1)	1	5.000	7.000	3.271	0.731
Cost Components(F2)	0.200	1	3.000	0.843	0.188
Other Effects(F3)	0.143	0.333	1	0.362	0.081
			Sum	4.477	**1**

Now the consistency check is performed by using equations (3.3) and (3.4) to check whether the opinion is acceptable as well result is consisted for the AHP analysis for the selected sub-criteria, result found as follows.

Table 4.3: Finding Column sum and Sum *PV*.

Consistency Check						
Criteria	**F1**	**F2**	**F3**	**3rd Root of Product**	**Priority Vector**	PV (%)
Quality Factors(F1)	1	5.000	7.000	3.271	0.731	73.064
Cost Components(F2)	0.200	1	3.000	0.843	0.188	18.839
Other Effects(F3)	0.143	0.333	1	0.362	0.081	8.096
Column Sum	1.343	6.333	11	4.477	1	100
Sum PV	0.981	1.193	0.891	3.065		
				Lambda Max (λ_{max})		

According to AHP methodology it is need to perform the consistency checking which is calculated as per the following relations.

Consistency Index (*CI*) = (λ_{max}-*n*)/ (*n*-1)

Consistency Index (*CI*) = 0.032;   as here *n*=3

Consistency Ratio (*CR*) = 0.056

Consistency Ratio (*CR* %) = 5.594, so the result is consistent as it is less than ten percent.

Now calculating the priority vector and consistency ratio for the sub-criteria (Coverage area, User capacity and Stability/signal penetration) under one criteria (sample taken as "quality factor") as shown below. One full set calculation for expert-1 is available in appendix-IV.

Table 4.4: Matrix as per pair wise values from expert opinion

Sub Criteria	**F1A1**	**F1A2**	**F1A3**
Coverage Area(F1A1)	1	6	1
User Capacity(F1A2)	1/6	1	1/3
Stability/ Signal penetration (F1A3)	1	3	1

Finding Priority Vector (Weight) = nth root of product/Sum as in below table.

Table 4.5: Priorities vector for the pair wise comparison matrix for sub-criteria

Sub Criteria	F1A1	F1A2	F1A3	3rd Root of Product	Priority Vector
Coverage Area(F1A1)	1	6.000	1.000	1.817	0.499
User Capacity(F1A2)	0.167	1	0.333	0.382	0.105
Stability/ Signal penetration (F1A3)	1.000	3.000	1	1.442	0.396
			Sum	3.641	**1**

Now the consistency check is performed by using equations (3.3) and (3.4), result found as follows,

For this first need to find the column sum and sum PV as shown in the following table.

Table 4.6: Finding Column sum and Sum PV

Consistency Check						
Sub Criteria	**F1A1**	**F1A2**	**F1A3**	**3rd Root of Product**	**Priority Vector**	PV (%)
Coverage Area(F1A1)	1	6.000	1.000	1.817	0.499	49.908
User Capacity(F1A2)	0.167	1	0.333	0.382	0.105	10.480
Stability/ Signal penetration (F1A3)	1.000	3.000	1	1.442	0.396	39.612
Column Sum	2.167	10.000	2.333	3.641	1	100
Sum PV	1.081	1.048	0.924	**3.054**		
				λ_{Max}		

So the consistency index and consistency ratio found as follows.

Consistency Index (CI) = 0.027

Consistency Ratio (CR) = 0.046

Consistency Ratio (CR %) = 4.623

Similarly the AHP calculation have been executed for the sub-criteria (User capacity and Stability/Signal penetration) under quality factor, sub-criteria (Integration cost, License cost and Maintenance cost) under "cost component" and for the sub-criteria (Social impact, Environmental effects and Economic impacts) under "Other effects, as shown in appendix-IV.

Now calculating the priority vector and consistency ratio for the alternatives (900 MHz, 1800 MHz and 2100 MHz) under sub-criteria Coverage Area as per opinion of expert-1, as shown below. One full set calculation for expert-1 is available in appendix-IV.

Table 4.7: Matrix as per pair wise values from expert opinion

Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**
900 MHz	1	5	7
1800 MHz	1/5	1	3
2100 MHz	1/7	1/3	1

Finding Priority Vector (Weight) = nth root of product/Sum as in below table.

Table 4.8: Priorities vector for the pair wise comparison matrix for sub-criteria

Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**	**3rd Root of Product**	**Priority Vector**
900 MHz	1	5	7	3.271	0.731
1800 MHz	0.200	1	3	0.843	0.188
2100 MHz	0.143	0.333	1	0.362	0.081
			Sum	4.477	**1**

Now the consistency check is performed by using equations (3.3) and (3.4), result found as follows

Table 4.9: Finding Column sum and Sum PV.

Consistency Check						
Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**	**3rd Root of Product**	**Priority Vector**	PV (%)
900 MHz	1	5	7	3.271	0.731	73.064
1800 MHz	0.200	1	3	0.843	0.188	18.839
2100 MHz	0.143	0.333	1	0.362	0.081	8.096
Column Sum	1.343	6.333	11	4.477	1	100
Sum PV	0.981	1.193	0.891	3.065		
				Lambda Max/ λ_{Max}		

Consistency Index (CI) = 0.032

Consistency Ratio (CR) = 0.056

Consistency Ratio (CR %) = 5.594

Similar calculation have been performed for the selected alternatives (900 MHz, 1800 MHz and 2100 MHz) under sub-criteria User capacity, Stability/Signal penetration, Integration cost, License cost, Maintenance cost, Social impact, Environmental effects and Economic impacts as shown in appendix-IV.

Now the final result for the expert-1 is the sum value as shown in following table.

Table 4.10: Final priorities and weights for frequencies for Expert-1.

							Pirity Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-1	Quality Factors (F1)	0.731	Coverage Area (F1A1)	0.499	0.365	36.465	0.731	0.188	0.081	0.266	0.069	0.030
			User Capacity (F1A2)	0.105	0.077	7.657	0.143	0.286	0.571	0.011	0.022	0.044
			Stability/Signal Penetration (F1A3)	0.396	0.289	28.942	0.701	0.193	0.106	0.203	0.056	0.031
	Cost Components (F2)	0.188	Integration Cost (F2B1)	0.237	0.045	4.466	0.715	0.187	0.098	0.032	0.008	0.004
			License Cost (F2B2)	0.064	0.012	1.212	0.143	0.286	0.571	0.002	0.003	0.007
			Maintenance Cost (F2B3)	0.699	0.132	13.161	0.761	0.166	0.073	0.100	0.022	0.010
	Other Effects (F3)	0.081	Social Impact (F3C1)	0.200	0.016	1.619	0.701	0.193	0.106	0.011	0.003	0.002
			Environmental Effects (F3C2)	0.600	0.049	4.858	0.769	0.147	0.084	0.037	0.007	0.004
			Economic Impacts (F3C3)	0.200	0.016	1.619	0.701	0.193	0.106	0.011	0.003	0.002
						100.00	0.596	0.204	0.200	0.674	0.193	0.132
									%	67.417	19.347	13.236

Where Global Priority = PV of Quality Factors (F1)* PV of Coverage Area (F1A1) and Final weight = aforementioned "priority vector" * "Global priority". Similarly calculation is conducted for each row.

From the above result it is observed that 900 MHz have the highest priority, 1800 MHz is the second choice and 2100 MHz have least score as per expert-1.

AHP calculation for expert-2

For the feedback from expert-2, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights have been reflected in the following table.

Table 4.11: Final priorities and weights for frequencies for Expert-2.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-2	Quality Factors (F1)	0.750	Coverage Area (F1A1)	0.065	0.049	4.878	0.769	0.147	0.084	0.038	0.007	0.004
			User Capacity (F1A2)	0.361	0.271	27.101	0.067	0.293	0.641	0.018	0.079	0.174
			Stability/Signal Penetration (F1A3)	0.574	0.430	43.021	0.749	0.198	0.052	0.322	0.085	0.023
	Cost Components (F2)	0.125	Integration Cost (F2B1)	0.218	0.027	2.720	0.763	0.176	0.061	0.021	0.005	0.002
			License Cost (F2B2)	0.054	0.007	0.677	0.062	0.285	0.653	0.000	0.002	0.004
			Maintenance Cost (F2B3)	0.728	0.091	9.103	0.070	0.559	0.371	0.006	0.051	0.034
	Other Effects (F3)	0.125	Social Impact (F3C1)	0.745	0.093	9.313	0.156	0.745	0.099	0.015	0.069	0.009
			Environmental Effects (F3C2)	0.156	0.020	1.956	0.078	0.635	0.287	0.002	0.012	0.006
			Economic Impacts (F3C3)	0.099	0.012	1.232	0.567	0.357	0.075	0.007	0.004	0.001
						100	0.365	0.377	0.258	0.429	0.316	0.256
									%	42.863	31.554	25.583

According to the above result (as per opinion from expert-2) 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh followed by 1800 MHz and 2100 MHz respectively.

AHP calculation for expert-3

For the feedback from expert-3, a similar data analysis has been conducted (as done for expert-1) by using the same excel template. The summarized result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.12: Final priorities and weights for frequencies for Expert-3.

							Pririty Vector			Final Wight		
Level 0	Level 1		Level 2		Glb Priority		900 MHz	1800 MHz	2100 MHz	900 MHz	1800 MHz	2100 MHz
AHP Calculation for Expert-3	Quality Factors (F1)	0.731	Coverage Area (F1A1)	0.176	0.129	12.878	0.763	0.176	0.061	0.098	0.023	0.008
			User Capacity (F1A2)	0.061	0.045	4.465	0.709	0.179	0.113	0.032	0.008	0.005
			Stability/Signal Penetration (F1A3)	0.763	0.557	55.721	0.785	0.149	0.066	0.438	0.083	0.037
	Cost Components (F2)	0.188	Integration Cost (F2B1)	0.156	0.029	2.947	0.066	0.149	0.785	0.002	0.004	0.023
			License Cost (F2B2)	0.099	0.019	1.857	0.088	0.139	0.773	0.002	0.003	0.014
			Maintenance Cost (F2B3)	0.745	0.140	14.035	0.066	0.149	0.785	0.009	0.021	0.110
	Other Effects (F3)	0.081	Social Impact(F3C1)	0.078	0.006	0.634	0.333	0.333	0.333	0.002	0.002	0.002
			Environmental Effects (F3C2)	0.171	0.014	1.387	0.691	0.218	0.091	0.010	0.003	0.001
			Economic Impacts (F3C3)	0.750	0.061	6.075	0.056	0.243	0.701	0.003	0.015	0.043
						100	0.395	0.193	0.412	0.595	0.161	0.243
									%	59.540	16.135	24.325

From the above table (as per opinion from expert-3) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 2100 MHz is the second preferred one and least preferred frequency band is 1800 MHz.

AHP calculation for expert-4

For the feedback from expert-4, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.13: Final priorities and weights for frequencies for Expert-4.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-4	Quality Factors (F1)	0.290	Coverage Area (F1A1)	0.070	0.020	2.039	0.785	0.149	0.066	0.016	0.003	0.001
			User Capacity (F1A2)	0.153	0.044	4.434	0.052	0.300	0.648	0.002	0.013	0.029
			Stability/Signal Penetration (F1A3)	0.777	0.225	22.501	0.749	0.198	0.052	0.169	0.045	0.012
	Cost Components (F2)	0.655	Integration Cost (F2B1)	0.582	0.382	38.151	0.763	0.176	0.061	0.291	0.067	0.023
			License Cost (F2B2)	0.069	0.046	4.554	0.062	0.212	0.726	0.003	0.010	0.033
			Maintenance Cost (F2B3)	0.348	0.228	22.830	0.763	0.176	0.061	0.174	0.040	0.014
	Other Effects (F3)	0.055	Social Impact (F3C1)	0.731	0.040	4.011	0.742	0.183	0.075	0.030	0.007	0.003
			Environmental Effects (F3C2)	0.081	0.004	0.444	0.054	0.218	0.728	0.000	0.001	0.003
			Economic Impacts (F3C3)	0.188	0.010	1.034	0.779	0.143	0.079	0.008	0.001	0.001
						100	0.528	0.195	0.277	0.693	0.188	0.119
									%	69.286	18.786	11.927

From the above table (as per opinion from expert-4) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 1800 MHz is the second preferred one and least preferred frequency band is 2100 MHz.

AHP calculation for expert-5

For the feedback from expert-5, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.14: Final priorities and weights for frequencies for Expert-5.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-5	Quality Factors (F1)	0.474	**Coverage Area (F1A1)**	0.333	0.158	15.808	0.055	0.290	0.655	0.009	0.046	0.104
			User Capacity (F1A2)	0.333	0.158	15.808	0.057	0.346	0.597	0.009	0.055	0.094
			Stability/Signal Penetration (F1A3)	0.333	0.158	15.808	0.777	0.153	0.070	0.123	0.024	0.011
	Cost Components (F2)	0.376	**Integration Cost (F2B1)**	0.188	0.071	7.091	0.078	0.287	0.635	0.006	0.020	0.045
			License Cost (F2B2)	0.081	0.030	3.047	0.731	0.188	0.081	0.022	0.006	0.002
			Maintenance Cost (F2B3)	0.731	0.275	27.501	0.777	0.153	0.070	0.214	0.042	0.019
	Other Effects (F3)	0.149	**Social Impact (F3C1)**	0.799	0.119	11.929	0.777	0.153	0.070	0.093	0.018	0.008
			Environmental Effects (F3C2)	0.105	0.016	1.567	0.777	0.153	0.070	0.012	0.002	0.001
			Economic Impacts (F3C3)	0.096	0.014	1.441	0.777	0.153	0.070	0.011	0.002	0.001
						100.000	0.534	0.208	0.258	0.498	0.216	0.286
									%	49.785	21.572	28.643

From the above table (as per opinion from expert-5) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 2100 MHz is the second preferred one and least one is 1800 MHz.

AHP calculation for expert-6

For the feedback from expert-6, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.15: Final priorities and weights for frequencies for Expert-6.

								Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**			**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-6	Quality Factors (F1)	0.443	**Coverage Area (F1A1)**	0.333	0.148	=	14.781	0.773	0.139	0.088	0.114	0.021	0.013
			User Capacity (F1A2)	0.333	0.148	=	14.781	0.088	0.243	0.669	0.013	0.036	0.099
			Stability/Signal Penetration (F1A3)	0.333	0.148	=	14.781	0.709	0.179	0.113	0.105	0.026	0.017
	Cost Components (F2)	0.387	**Integration Cost (F2B1)**	0.735	0.285	=	28.479	0.156	0.659	0.185	0.044	0.188	0.053
			License Cost (F2B2)	0.058	0.023	=	2.251	0.648	0.230	0.122	0.015	0.005	0.003
			Maintenance Cost (F2B3)	0.207	0.080	=	8.007	0.333	0.333	0.333	0.027	0.027	0.027
	Other Effects (F3)	0.169	**Social Impact (F3C1)**	0.094	0.016	=	1.587	0.174	0.634	0.192	0.003	0.010	0.003
			Environmental Effects (F3C2)	0.740	0.125	=	12.514	0.117	0.268	0.614	0.015	0.034	0.077
			Economic Impacts (F3C3)	0.167	0.028	=	2.819	0.188	0.731	0.081	0.005	0.021	0.002
							100	0.354	0.379	0.266	0.341	0.367	0.293
										%	34.057	36.651	29.292

From the above table (as per opinion from expert-6) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 1800 MHz is the second preferred one and least preferred frequency band is 2100 MHz.

AHP calculation for expert-7

For the feedback from expert-7, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.16: Final priorities and weights for frequencies for Expert-7.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-7	Quality Factors (F1)	0.327	**Coverage Area (F1A1)**	0.109	0.036	3.584	0.540	0.297	0.163	0.019	0.011	0.006
			User Capacity (F1A2)	0.582	0.190	19.045	0.113	0.379	0.508	0.022	0.072	0.097
			Stability/Signal Penetration (F1A3)	0.309	0.101	10.119	0.648	0.230	0.122	0.066	0.023	0.012
	Cost Components (F2)	0.260	**Integration Cost (F2B1)**	0.220	0.057	5.717	0.594	0.249	0.157	0.034	0.014	0.009
			License Cost (F2B2)	0.087	0.023	2.269	0.648	0.230	0.122	0.015	0.005	0.003
			Maintenance Cost (F2B3)	0.693	0.180	18.007	0.594	0.249	0.157	0.107	0.045	0.028
	Other Effects (F3)	0.413	**Social Impact (F3C1)**	0.333	0.138	13.753	0.168	0.349	0.484	0.023	0.048	0.067
			Environmental Effects (F3C2)	0.333	0.138	13.753	0.094	0.280	0.627	0.013	0.038	0.086
			Economic Impacts (F3C3)	0.333	0.138	13.753	0.064	0.237	0.699	0.009	0.033	0.096
						100.000	0.385	0.278	0.338	0.307	0.289	0.404
									%	30.684	28.947	40.369

From the above table (as per opinion from expert-7) it is found that 2100 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 1900 MHz is the second choice and least preferred frequency band is 1800 MHz.

AHP calculation for expert-8

For the feedback from expert-8, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.17: Final priorities and weights for frequencies for Expert-8.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-8	Quality Factors (F1)	0.614	**Coverage Area (F1A1)**	0.280	0.172	17.184	0.761	0.073	0.166	0.131	0.012	0.029
			User Capacity (F1A2)	0.094	0.058	5.752	0.105	0.637	0.258	0.006	0.037	0.015
			Stability/Signal Penetration (F1A3)	0.627	0.385	38.505	0.594	0.249	0.157	0.229	0.096	0.060
	Cost Components (F2)	0.268	**Integration Cost (F2B1)**	0.218	0.059	5.862	0.661	0.131	0.208	0.039	0.008	0.012
			License Cost (F2B2)	0.630	0.169	16.910	0.722	0.094	0.184	0.122	0.016	0.031
			Maintenance Cost (F2B3)	0.151	0.041	4.065	0.674	0.101	0.226	0.027	0.004	0.009
	Other Effects (F3)	0.117	**Social Impact (F3C1)**	0.157	0.018	1.841	0.500	0.250	0.250	0.009	0.005	0.005
			Environmental Effects (F3C2)	0.249	0.029	2.922	0.413	0.260	0.327	0.012	0.008	0.010
			Economic Impacts (F3C3)	0.594	0.070	6.959	0.413	0.260	0.327	0.029	0.018	0.023
						100	0.538	0.228	0.234	0.604	0.203	0.193
									%	60.351	20.310	19.339

From the above table (as per opinion from expert-8) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 1800 MHz is the second preferred one and least preferred frequency band is 2100 MHz.

AHP calculation for expert-9

For the feedback from expert-9, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.18: Final priorities and weights for frequencies for Expert-9.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-9	Quality Factors (F1)	0.218	**Coverage Area (F1A1)**	0.140	0.031	3.051	0.072	0.279	0.649	0.002	0.009	0.020
			User Capacity (F1A2)	0.528	0.115	11.533	0.067	0.218	0.715	0.008	0.025	0.082
			Stability/Signal Penetration (F1A3)	0.333	0.073	7.265	0.715	0.218	0.067	0.052	0.016	0.005
	Cost Components (F2)	0.715	**Integration Cost (F2B1)**	0.200	0.143	14.294	0.742	0.183	0.075	0.106	0.026	0.011
			License Cost (F2B2)	0.200	0.143	14.294	0.093	0.292	0.615	0.013	0.042	0.088
			Maintenance Cost (F2B3)	0.600	0.429	42.883	0.751	0.178	0.070	0.322	0.076	0.030
	Other Effects (F3)	0.067	**Social Impact (F3C1)**	0.751	0.050	5.019	0.333	0.333	0.333	0.017	0.017	0.017
			Environmental Effects (F3C2)	0.070	0.005	0.470	0.648	0.230	0.122	0.003	0.001	0.001
			Economic Impacts (F3C3)	0.178	0.012	1.190	0.333	0.333	0.333	0.004	0.004	0.004
						100	0.417	0.252	0.331	0.527	0.216	0.257
									%	52.706	21.569	25.725

From the above table (as per opinion from expert-9) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 2100 MHz is the second preferred one and least preferred frequency band is 1800 MHz.

AHP calculation for expert-10

For the feedback from expert-10, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.19: Final priorities and weights for frequencies for Expert-10.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-10	Quality Factors (F1)	0.796	**Coverage Area (F1A1)**	0.142	0.113	11.332	0.785	0.149	0.066	0.089	0.017	0.007
			User Capacity (F1A2)	0.179	0.143	14.277	0.467	0.467	0.067	0.067	0.067	0.010
			Stability/Signal Penetration (F1A3)	0.678	0.540	53.964	0.793	0.131	0.076	0.428	0.071	0.041
	Cost Components (F2)	0.125	**Integration Cost (F2B1)**	0.139	0.017	1.744	0.574	0.361	0.065	0.010	0.006	0.001
			License Cost (F2B2)	0.773	0.097	9.689	0.073	0.761	0.166	0.007	0.074	0.016
			Maintenance Cost (F2B3)	0.088	0.011	1.099	0.799	0.105	0.096	0.009	0.001	0.001
	Other Effects (F3)	0.079	**Social Impact (F3C1)**	0.129	0.010	1.021	0.785	0.129	0.085	0.008	0.001	0.001
			Environmental Effects (F3C2)	0.085	0.007	0.673	0.079	0.796	0.125	0.001	0.005	0.001
			Economic Impacts (F3C3)	0.785	0.062	6.201	0.777	0.153	0.070	0.048	0.009	0.004
						100.000	0.570	0.339	0.091	0.666	0.252	0.082
									%	66.595	25.167	8.238

From the above table (as per opinion from expert-10) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 1800 MHz is the second preferred one and least preferred frequency band is 2100 MHz.

AHP calculation for expert-11

For the feedback from expert-11, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.20: Final priorities and weights for frequencies for Expert-11.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-11	Quality Factors (F1)	0.691	Coverage Area(F1A1)	0.149	0.103	10.281	0.717	0.195	0.088	0.074	0.020	0.009
			User Capacity(F1A2)	0.066	0.045	4.545	0.163	0.297	0.540	0.007	0.013	0.025
			Stability/Signal Penetration (F1A3)	0.785	0.543	54.258	0.726	0.172	0.102	0.394	0.093	0.055
	Cost Components (F2)	0.149	Integration Cost(F2B1)	0.125	0.019	1.860	0.674	0.226	0.101	0.013	0.004	0.002
			License Cost(F2B2)	0.125	0.019	1.860	0.196	0.311	0.493	0.004	0.006	0.009
			Maintenance Cost(F2B3)	0.750	0.112	11.163	0.674	0.226	0.101	0.075	0.025	0.011
	Other Effects (F3)	0.160	Social Impact(F3C1)	0.625	0.100	10.021	0.333	0.333	0.333	0.033	0.033	0.033
			Environmental Effects(F3C2)	0.238	0.038	3.824	0.625	0.238	0.136	0.024	0.009	0.005
			Economic Impacts(F3C3)	0.136	0.022	2.188	0.674	0.226	0.101	0.015	0.005	0.002
						100	0.531	0.247	0.222	0.638	0.210	0.152
									%	63.843	20.951	15.206

From the above table (as per opinion from expert-11) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 1800 MHz is the second preferred one and least preferred frequency band is 2100 MHz.

AHP calculation for expert-12

For the feedback from expert-12, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.21: Final priorities and weights for frequencies for Expert-12.

							Priority Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-12	Quality Factors (F1)	0.114	Coverage Area(F1A1)	0.138	0.016	1.576	0.131	0.076	0.793	0.002	0.001	0.012
			User Capacity(F1A2)	0.064	0.007	0.729	0.063	0.194	0.743	0.000	0.001	0.005
			Stability/Signal Penetration (F1A3)	0.798	0.091	9.093	0.763	0.061	0.176	0.069	0.006	0.016
	Cost Components (F2)	0.814	Integration Cost(F2B1)	0.130	0.105	10.545	0.195	0.088	0.717	0.021	0.009	0.076
			License Cost(F2B2)	0.808	0.658	65.806	0.814	0.114	0.072	0.536	0.075	0.047
			Maintenance Cost(F2B3)	0.062	0.051	5.070	0.798	0.064	0.138	0.040	0.003	0.007
	Other Effects (F3)	0.072	Social Impact(F3C1)	0.064	0.005	0.459	0.785	0.066	0.149	0.004	0.000	0.001
			Environmental Effects(F3C2)	0.138	0.010	0.993	0.733	0.068	0.199	0.007	0.001	0.002
			Economic Impacts(F3C3)	0.798	0.057	5.728	0.733	0.068	0.199	0.042	0.004	0.011
						100.000	0.557	0.089	0.354	0.722	0.101	0.178
									%	72.156	10.055	17.790

From the above table (as per opinion from expert-12) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 2100 MHz is the second preferred one and least preferred frequency band is 1800 MHz.

AHP calculation for expert-13

For the feedback from expert-13, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.22: Final priorities and weights for frequencies for Expert-13.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-13	Quality Factors (F1)	0.405	Coverage Area(F1A1)	0.174	0.071	7.069	0.773	0.139	0.088	0.055	0.010	0.006
			User Capacity(F1A2)	0.192	0.078	7.780	0.778	0.111	0.111	0.061	0.009	0.009
			Stability/Signal Penetration (F1A3)	0.634	0.257	25.690	0.735	0.207	0.058	0.189	0.053	0.015
	Cost Components (F2)	0.481	Integration Cost(F2B1)	0.150	0.072	7.205	0.709	0.179	0.113	0.051	0.013	0.008
			License Cost(F2B2)	0.106	0.051	5.077	0.333	0.333	0.333	0.017	0.017	0.017
			Maintenance Cost(F2B3)	0.744	0.358	35.782	0.714	0.143	0.143	0.256	0.051	0.051
	Other Effects (F3)	0.114	Social Impact(F3C1)	0.143	0.016	1.628	0.333	0.333	0.333	0.005	0.005	0.005
			Environmental Effects(F3C2)	0.714	0.081	8.141	0.735	0.207	0.058	0.060	0.017	0.005
			Economic Impacts(F3C3)	0.143	0.016	1.628	0.333	0.333	0.333	0.005	0.005	0.005
						100.000	0.605	0.221	0.174	0.698	0.180	0.122
									%	69.832	18.017	12.150

From the above table (as per opinion from expert-13) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 1800 MHz is the second preferred one and least preferred frequency band is 2100 MHz.

AHP calculation for expert-14

For the feedback from expert-14, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.23: Final priorities and weights for frequencies for Expert-14.

							Pririty Vector			Final Wight		
Level 0	Level 1		Level 2		Glb Priority		900 MHz	1800 MHz	2100 MHz	900 MHz	1800 MHz	2100 MHz
AHP Calculation for Expert-14	Quality Factors (F1)	0.726	Coverage Area(F1A1)	0.058	0.042	4.218	0.709	0.179	0.113	0.030	0.008	0.005
			User Capacity(F1A2)	0.207	0.150	15.003	0.091	0.455	0.455	0.014	0.068	0.068
			Stability/Signal Penetration (F1A3)	0.735	0.534	53.364	0.743	0.194	0.063	0.396	0.103	0.034
	Cost Components (F2)	0.172	Integration Cost(F2B1)	0.194	0.033	3.337	0.731	0.188	0.081	0.024	0.006	0.003
			License Cost(F2B2)	0.063	0.011	1.089	0.091	0.455	0.455	0.001	0.005	0.005
			Maintenance Cost(F2B3)	0.743	0.128	12.786	0.113	0.709	0.179	0.014	0.091	0.023
	Other Effects (F3)	0.102	Social Impact(F3C1)	0.143	0.015	1.458	0.089	0.559	0.352	0.001	0.008	0.005
			Environmental Effects(F3C2)	0.143	0.015	1.458	0.078	0.635	0.287	0.001	0.009	0.004
			Economic Impacts(F3C3)	0.714	0.073	7.288	0.091	0.455	0.455	0.007	0.033	0.033
						100.000	0.304	0.425	0.271	0.489	0.332	0.180
									%	48.878	33.159	17.963

From the above table (as per opinion from expert-14) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 1800 MHz is the second preferred one and least preferred frequency band is 2100 MHz.

AHP calculation for expert-15

For the feedback from expert-15, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.24: Final priorities and weights for frequencies for Expert-15.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-15	Quality Factors (F1)	0.584	Coverage Area (F1A1)	0.333	0.195	19.472	0.798	0.138	0.064	0.155	0.027	0.012
			User Capacity (F1A2)	0.333	0.195	19.472	0.174	0.634	0.192	0.034	0.123	0.037
			Stability/Signal Penetration (F1A3)	0.333	0.195	19.472	0.717	0.195	0.088	0.140	0.038	0.017
	Cost Components (F2)	0.232	Integration Cost (F2B1)	0.717	0.166	16.628	0.200	0.683	0.117	0.033	0.114	0.019
			License Cost (F2B2)	0.088	0.020	2.042	0.333	0.333	0.333	0.007	0.007	0.007
			Maintenance Cost (F2B3)	0.195	0.045	4.513	0.333	0.333	0.333	0.015	0.015	0.015
	Other Effects (F3)	0.184	Social Impact (F3C1)	0.081	0.015	1.490	0.200	0.600	0.200	0.003	0.009	0.003
			Environmental Effects (F3C2)	0.731	0.134	13.444	0.117	0.268	0.614	0.016	0.036	0.083
			Economic Impacts (F3C3)	0.188	0.035	3.466	0.218	0.630	0.151	0.008	0.022	0.005
						100.000	0.344	0.424	0.233	0.410	0.391	0.199
									%	41.035	39.057	19.908

From the above table (as per opinion from expert-15) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 1800 MHz is the second preferred one and least preferred frequency band is 2100 MHz.

AHP calculation for expert-16

For the feedback from expert-16, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.25: Final priorities and weights for frequencies for Expert-16.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-16	Quality Factors (F1)	0.77	Coverage Area(F1A1)	0.066	0.051	5.087	0.793	0.131	0.076	0.040	0.007	0.004
			User Capacity(F1A2)	0.149	0.115	11.506	0.785	0.149	0.066	0.090	0.017	0.008
			Stability/Signal Penetration (F1A3)	0.785	0.607	60.724	0.799	0.105	0.096	0.485	0.064	0.059
	Cost Components (F2)	0.09	Integration Cost(F2B1)	0.139	0.012	1.220	0.814	0.114	0.072	0.010	0.001	0.001
			License Cost(F2B2)	0.088	0.008	0.769	0.333	0.333	0.333	0.003	0.003	0.003
			Maintenance Cost(F2B3)	0.773	0.068	6.778	0.735	0.207	0.058	0.050	0.014	0.004
	Other Effects (F3)	0.14	Social Impact(F3C1)	0.066	0.009	0.916	0.333	0.333	0.333	0.003	0.003	0.003
			Environmental Effects(F3C2)	0.785	0.109	10.930	0.731	0.188	0.081	0.080	0.021	0.009
			Economic Impacts(F3C3)	0.149	0.021	2.071	0.814	0.114	0.072	0.017	0.002	0.001
						100.000	0.682	0.186	0.132	0.778	0.131	0.091
									%	77.773	13.147	9.079

From the above table (as per opinion from expert-16) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 1800 MHz is the second preferred one and least preferred frequency band is 2100 MHz.

AHP calculation for expert-17

For the feedback from expert-17, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.26: Final priorities and weights for frequencies for Expert-17.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-17	Quality Factors (F1)	0.47	Coverage Area(F1A1)	0.39	0.18	18.29	0.76	0.18	0.06	0.14	0.03	0.01
			User Capacity(F1A2)	0.44	0.21	20.93	0.20	0.31	0.49	0.04	0.07	0.10
			Stability/Signal Penetration (F1A3)	0.17	0.08	7.99	0.72	0.19	0.09	0.06	0.02	0.01
	Cost Components (F2)	0.44	Integration Cost(F2B1)	0.61	0.27	27.30	0.25	0.25	0.50	0.07	0.07	0.14
			License Cost(F2B2)	0.27	0.12	11.92	0.16	0.30	0.54	0.02	0.04	0.06
			Maintenance Cost(F2B3)	0.12	0.05	5.21	0.54	0.30	0.16	0.03	0.02	0.01
	Other Effects (F3)	0.08	Social Impact(F3C1)	0.11	0.01	0.96	0.57	0.29	0.14	0.01	0.00	0.00
			Environmental Effects(F3C2)	0.12	0.01	1.01	0.59	0.25	0.16	0.01	0.00	0.00
			Economic Impacts(F3C3)	0.76	0.06	6.39	0.63	0.24	0.14	0.04	0.02	0.01
						100.00	0.49	0.26	0.25	0.41	0.25	0.34
									%	40.50	25.25	34.25

From the above table (as per opinion from expert-17) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 2100 MHz is the second preferred one and least preferred frequency band is 1800 MHz.

AHP calculation for expert-18

For the feedback from expert-18, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.27: Final priorities and weights for frequencies for Expert-18.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-18	Quality Factors (F1)	0.287	Coverage Area (F1A1)	0.287	0.082	8.249	0.777	0.153	0.070	0.064	0.013	0.006
			User Capacity (F1A2)	0.078	0.022	2.239	0.109	0.309	0.582	0.002	0.007	0.013
			Stability/Signal Penetration (F1A3)	0.635	0.182	18.233	0.750	0.171	0.078	0.137	0.031	0.014
	Cost Components (F2)	0.078	Integration Cost (F2B1)	0.153	0.012	1.193	0.761	0.166	0.073	0.009	0.002	0.001
			License Cost (F2B2)	0.070	0.005	0.549	0.109	0.309	0.582	0.001	0.002	0.003
			Maintenance Cost (F2B3)	0.777	0.061	6.054	0.731	0.188	0.081	0.044	0.011	0.005
	Other Effects (F3)	0.635	Social Impact (F3C1)	0.614	0.390	39.005	0.648	0.230	0.122	0.253	0.090	0.048
			Environmental Effects (F3C2)	0.268	0.170	17.037	0.761	0.166	0.073	0.130	0.028	0.012
			Economic Impacts (F3C3)	0.117	0.074	7.442	0.648	0.230	0.122	0.048	0.017	0.009
						100.00	0.588	0.214	0.198	0.688	0.201	0.111
									%	68.805	20.085	11.110

From the above table (as per opinion from expert-18) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 1800 MHz is the second preferred one and least preferred frequency band is 2100 MHz.

AHP calculation for expert-19

For the feedback from expert-19, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.28: Final priorities and weights for frequencies for Expert-19.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-19	Quality Factors (F1)	0.188	Coverage Area (F1A1)	0.140	0.026	2.631	0.067	0.218	0.715	0.002	0.006	0.019
			User Capacity (F1A2)	0.528	0.099	9.944	0.072	0.279	0.649	0.007	0.028	0.065
			Stability/Signal Penetration (F1A3)	0.333	0.063	6.264	0.069	0.244	0.687	0.004	0.015	0.043
	Cost Components (F2)	0.731	Integration Cost (F2B1)	0.200	0.146	14.613	0.742	0.183	0.075	0.108	0.027	0.011
			License Cost (F2B2)	0.200	0.146	14.613	0.100	0.300	0.600	0.015	0.044	0.088
			Maintenance Cost (F2B3)	0.600	0.438	43.839	0.751	0.178	0.070	0.329	0.078	0.031
	Other Effects (F3)	0.081	Social Impact (F3C1)	0.751	0.061	6.083	0.333	0.333	0.333	0.020	0.020	0.020
			Environmental Effects (F3C2)	0.070	0.006	0.570	0.648	0.230	0.122	0.004	0.001	0.001
			Economic Impacts (F3C3)	0.178	0.014	1.443	0.333	0.333	0.333	0.005	0.005	0.005
						100.00	0.346	0.255	0.398	0.494	0.224	0.282
									%	49.445	22.384	28.171

From the above table (as per opinion from expert-19) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 2100 MHz is the second preferred one and least preferred frequency band is 1800 MHz.

AHP calculation for expert-20

For the feedback from expert-20, a similar data analysis has been conducted by using the same excel template. The detail result for the priorities of criteria, sub-criteria and alternatives as well the final weights of alternatives have been reflected in the following table.

Table 4.29: Final priorities and weights for frequencies for Expert-20.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-20	Quality Factors (F1)	0.717	Coverage Area (F1A1)	0.333	0.239	23.908	0.731	0.188	0.081	0.175	0.045	0.019
			User Capacity (F1A2)	0.333	0.239	23.908	0.649	0.279	0.072	0.155	0.067	0.017
			Stability/Signal Penetration (F1A3)	0.333	0.239	23.908	0.798	0.138	0.064	0.191	0.033	0.015
	Cost Components (F2)	0.195	Integration Cost (F2B1)	0.642	0.125	12.498	0.785	0.149	0.066	0.098	0.019	0.008
			License Cost (F2B2)	0.049	0.010	0.963	0.659	0.156	0.185	0.006	0.002	0.002
			Maintenance Cost (F2B3)	0.309	0.060	6.008	0.659	0.156	0.185	0.040	0.009	0.011
	Other Effects (F3)	0.088	Social Impact (F3C1)	0.333	0.029	2.936	0.625	0.238	0.136	0.018	0.007	0.004
			Environmental Effects (F3C2)	0.333	0.029	2.936	0.661	0.208	0.131	0.019	0.006	0.004
			Economic Impacts (F3C3)	0.333	0.029	2.936	0.814	0.114	0.072	0.024	0.003	0.002
						100.000	0.709	0.181	0.110	0.726	0.191	0.083
									%	72.633	19.074	8.293

From the above table (as per opinion from expert-20) it is found that 900 MHz is the most preferred choice for 3G mobile communication system in Bangladesh whereas 1800 MHz is the second preferred one and least preferred frequency band is 2100 MHz band.

4.3 Result Consolidation

The consolidated result is the average of all the 20 results. For this the available 20 results have been plotted as in the following table and then performed the average of those corresponding values. Finally the result found as shown in next table with ranking.

Table 4.30: Final weight of the frequency alternatives (Part-1)

Frequencies	Final Wight (Expert-1)	Final Wight (Expert-2)	Final Wight (Expert-3)	Final Wight (Expert-4)	Final Wight (Expert-5)	Final Wight (Expert-6)	Final Wight (Expert-7)
900 MHz	67.420	42.863	59.540	69.286	49.785	34.057	30.684
1800 MHz	19.350	31.554	16.135	18.786	21.572	36.651	28.947
2100 MHz	13.240	25.583	24.325	11.927	28.643	29.292	40.369

Table 4.30: Final weight of the frequency alternatives (Part-2)

Frequency Selection for 3G Mobile System							
Frequencies	Final Wight (Expert-8)	Final Wight (Expert-9)	Final Wight (Expert-10)	Final Wight (Expert-11)	Final Wight (Expert-12)	Final Wight (Expert-13)	Final Wight (Expert-14)
900 MHz	60.351	52.706	66.595	63.843	72.156	69.832	48.878
1800 MHz	20.310	21.569	25.167	20.951	10.055	18.017	33.159
2100 MHz	19.339	25.725	8.238	15.206	17.790	12.150	17.963

Table 4.30: Final weight of the frequency alternatives (Part-3)

Frequency Selection for 3G Mobile System							
Frequencies	Final Wight (Expert-15)	Final Wight (Expert-16)	Final Wight (Expert-17)	Final Wight (Expert-18)	Final Wight (Expert-19)	Final Wight (Expert-20)	**Final Average Wight (%)**
900 MHz	41.035	77.773	40.501	68.805	49.445	72.633	56.909
1800 MHz	39.057	13.147	25.247	20.085	22.384	19.074	23.061
2100 MHz	19.908	9.079	34.251	11.110	28.171	8.293	20.030

From the above calculation it is observed that the highest final weight is of 900 MHz which is 56.91%. Other two alternatives 1800 MHz and 2100 MHz have acquired values 23.06% and 20.03% respectively as the second and third selection for 3G mobile system in Bangladesh. A comparison figure has been shown as in the following figure.

Finally a ranking table has been formed and plotted below, according to the result observed from overall calculation by AHP technique.

Table 4.31: Final ranking for the frequency selection.

Frequency Selection for 3G Mobile System	
Frequencies	Ranking
2100 MHz	3
1800 MHz	2
900 MHz	1

4.4 Result Analysis (Acquired by AHP model)

After the result calculations by AHP, based on the expert opinion from 20 experts (researchers and telecom professionals) it is observed that 900 MHz is mostly preferable frequency band among other available bands, for 3G network in Bangladesh. In criteria level different experts have shown different priorities. Some expert selected "Quality factors" are mostly important, some expert expressed their opinion for "cost components" are important while some other experts declared their opinion for "other effects" like social, environmental are the most important factors. Though some experts chosen 18800 MHz and some experts insisted 2100 MHz for some cases like user capacity and license cost. But mostly preferred 900 MHz for other cases, like coverage, penetration, maintenance cost, etc.

As a result after the full calculation, found 900 MHz having highest priority for 3G network.

4.4.1 Result Analysis for the criteria

From the analysis it is found that among the 3 criteria's, "quality factors" having most priority as per the average value of all 20 expert's opinion and the second priority criteria is "cost component". A comparison chart is as follows.

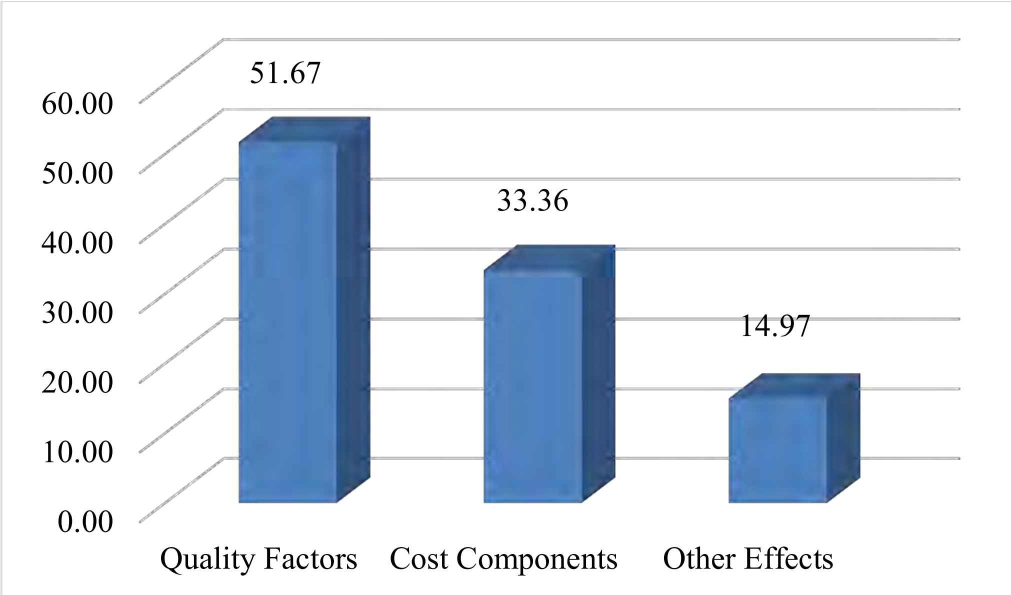

Figure 4.1: Result of Average Priority of Criteria

4.4.2 Result Analysis for the sub-criteria

From the analysis it is found that among the 10 sub-criteria's, "stability/signal penetration" having most priority as per the expert opinion and the second priority sub-criteria is "maintenance cost". A comparison chart for the sub-criteria is as follows.

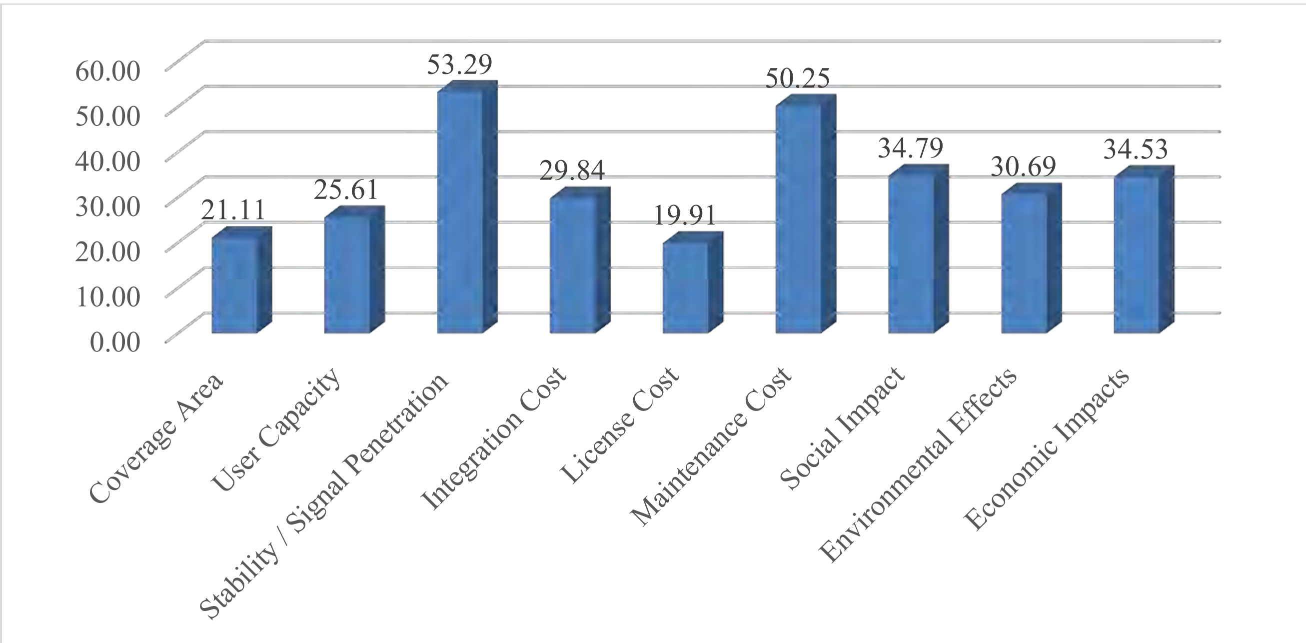

Figure 4.2: Result of Average Priority of Sub-Criteria

4.4.3 Result Analysis for the alternatives

Among the 20 experts, 14 declared their first choice is 900 MHz considering the selected 10 sub-criteria's, whereas 4 experts selected 1800 MHz as their first priority and rest 2 experts have chosen 2100 MHz with first priority.

Table 4.32: Priority result for alternatives (Part-1)

Frequencies	Priority (Expert-1)	Priority (Expert-2)	Priority (Expert-3)	Priority (Expert-4)	Priority (Expert-5)	Priority (Expert-6)	Priority (Expert-7)	Priority (Expert-8)	Priority (Expert-9)	Priority (Expert-10)
900 MHz	0.596	0.365	0.395	0.528	0.534	0.354	0.385	0.538	0.417	0.570
1800 MHz	0.204	0.377	0.193	0.195	0.208	0.379	0.278	0.228	0.252	0.339
2100 MHz	0.200	0.258	0.412	0.277	0.258	0.266	0.338	0.234	0.331	0.091

Table 4.32: Priority result for alternatives (Part-2)

Frequencies	Priority (Expert-11)	Priority (Expert-12)	Priority (Expert-13)	Priority (Expert-14)	Priority (Expert-15)	Priority (Expert-16)	Priority (Expert-17)	Priority (Expert-18)	Priority (Expert-19)	Priority (Expert-20)
900 MHz	0.531	0.557	0.605	0.304	0.344	0.682	0.491	0.588	0.346	0.709
1800 MHz	0.247	0.089	0.221	0.425	0.424	0.186	0.255	0.214	0.255	0.181
2100 MHz	0.222	0.354	0.174	0.271	0.233	0.132	0.254	0.198	0.398	0.110

From the above result an average priority graph has been plotted for the three (3) alternatives as in the below figure. It is observed that 900 MHz have the most priority (49.19%) whereas 1800 MHz and 2100 MHz have almost same average priorities (25.75% and 25.05% respectively).

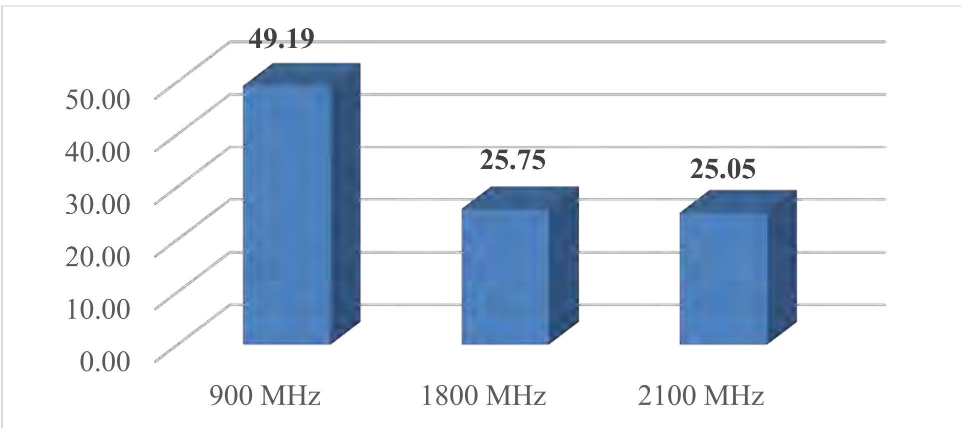

Figure 4.3: Average priority of alternatives

4.4.4 Result Analysis for the academic researchers

For Criteria (academic researchers)

From the analysis it is found that among the 3 criteria's, "quality factors" having most priority as per the average value of 8 academic researchers expert's opinion and the second priority is "cost component" with a little difference from first one. A Priority comparison chart is as follows.

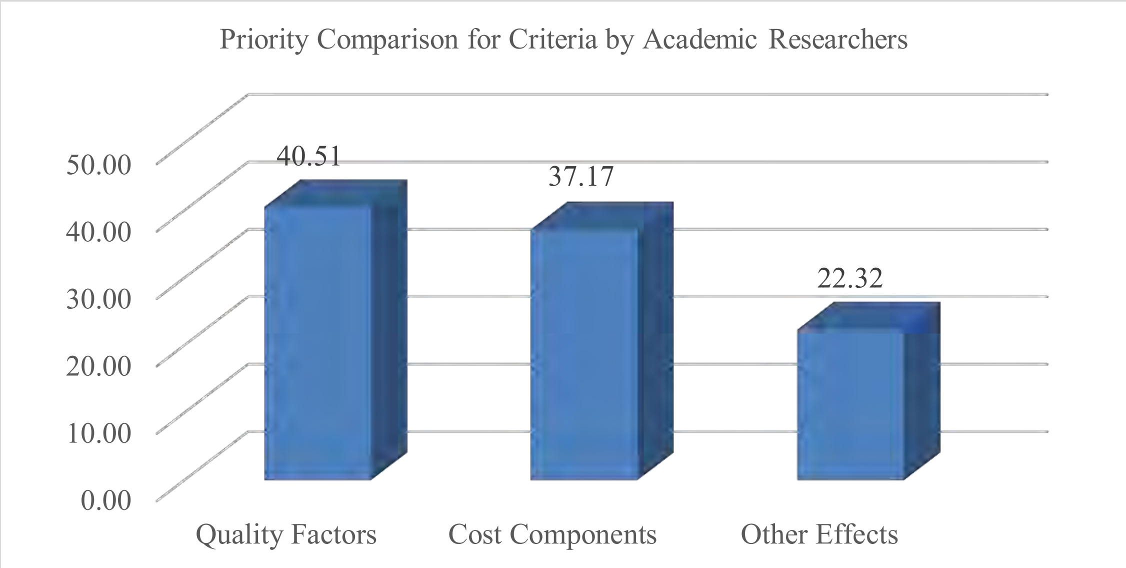

Figure 4.4: Priority Comparison for Criteria by Academic Researchers

For Sub- Criteria (academic researchers)

For the sub-criteria as per the opinion of academic researchers, "maintenance cost" is the most important factor. A result of all 10 sub-criteria has been plotted as in below figure.

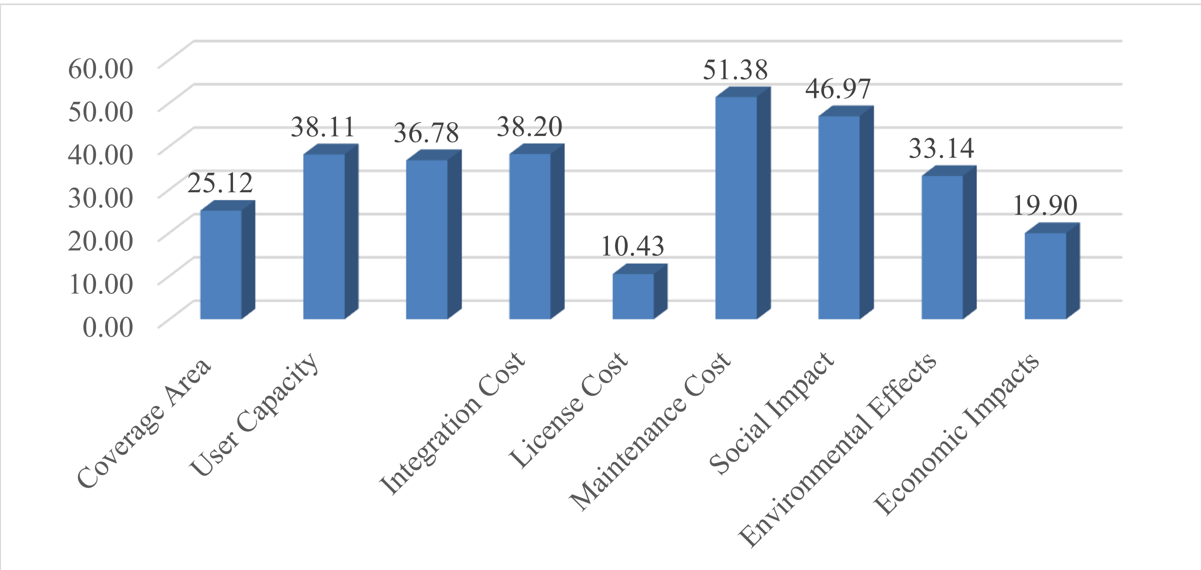

Figure 4.5: Priority Comparison for Sub-Criteria according to Academic Researchers

For Alternatives (academic researchers)

From the result of 8 academic researchers, it is observed that 900 MHz is the first selection of 5 experts considering only the sub-criteria's, whereas 2 have 1800 MHz and 1 for 2100 MHz as per their first choice for 3G mobile system in Bangladesh.

Table 4.33: Priority result for alternatives (academic researchers)

Frequencies	Priority (Expert-5)	Priority (Expert-6)	Priority (Expert-7)	Priority (Expert-9)	Priority (Expert-15)	Priority (Expert-18)	Priority (Expert-19)	Priority (Expert-20)
900 MHz	0.534	0.354	0.385	0.417	0.344	0.588	0.346	0.709
1800 MHz	0.208	0.379	0.278	0.252	0.424	0.214	0.255	0.181
2100 MHz	0.258	0.266	0.338	0.331	0.233	0.198	0.398	0.110

The average priorities of available 3 alternatives have been shown below which is according to the opinion of academic researchers.

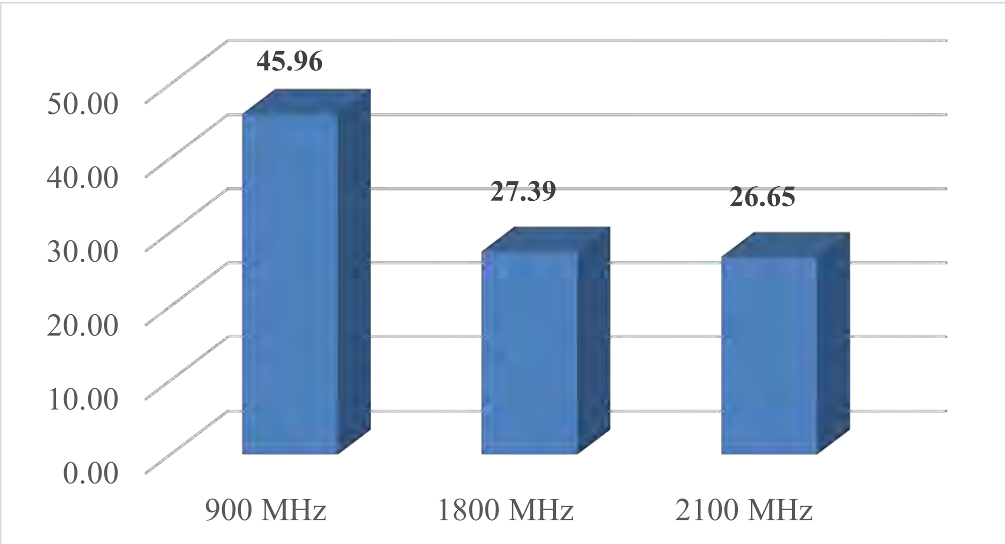

Figure 4.6: Average priority according to researchers

4.4.5 Result Analysis for the professional experts

For Criteria (Telecom Professionals)

From the result of 12 telecommunication professional experts "quality factors" is the most priority choice from the 3 criteria. In the other hand "other effects" have a very poor weight compared to quality factors. And cost considered with a middle class weight. A priority comparison chart is as follows.

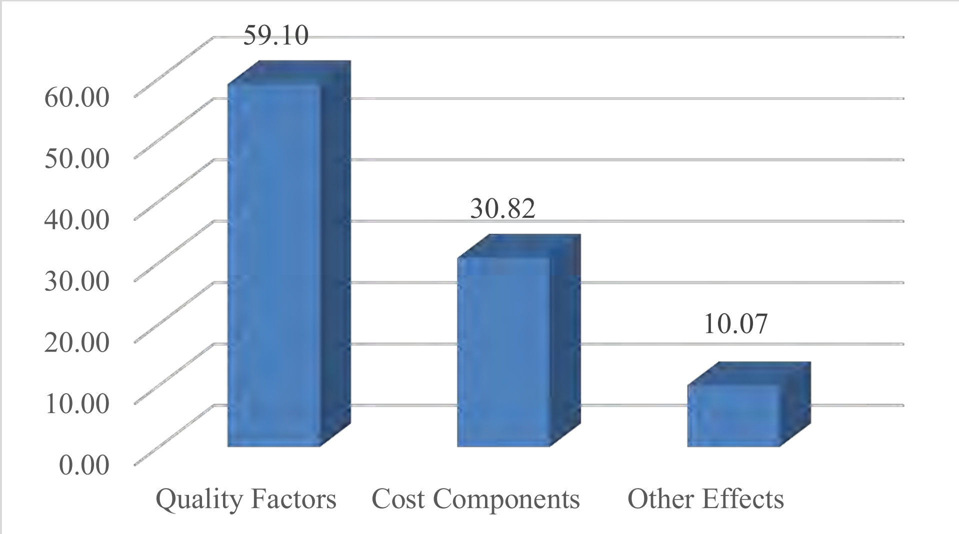

Figure 4.7: Priority Comparison for Criteria according to Telecom professionals

For Sub- Criteria (Telecom Professionals)

For the 10 sub-criteria's, as per the opinion of technical professionals, "stability/signal penetration" is the most important factor for frequency selection assessment. A result of all 10 sub-criteria has been plotted as in below figure.

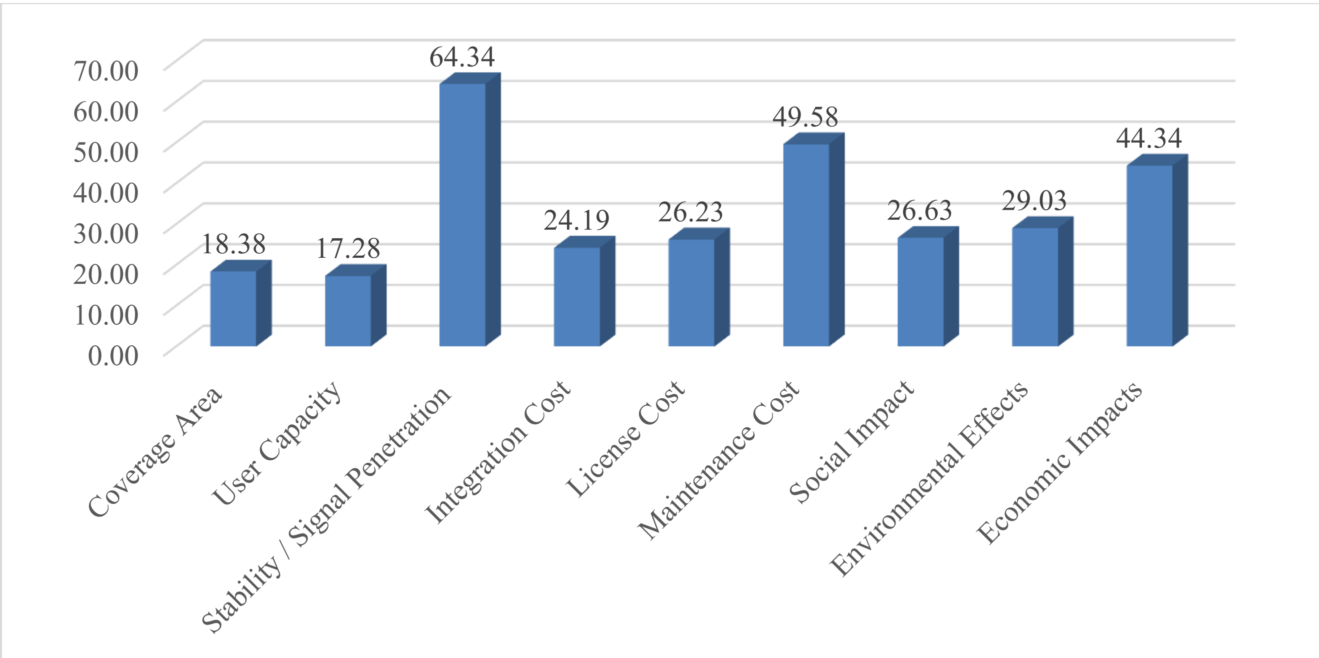

Figure 4.8: Priority Comparison for Sub-Criteria according to Telecom professionals

For Alternatives (Telecom Professionals)

From the result of 12 telecom professionals, it is observed that 900 MHz is the first selection of 9 experts considering only the sub-criteria's, whereas 2 have 1800 MHz and 1 for 2100 MHz as per their first choice for 3G mobile system in Bangladesh.

Table 4.34: Priority result for alternatives (Telecom Professionals)

Frequencies	Priority (Expert-1)	Priority (Expert-2)	Priority (Expert-3)	Priority (Expert-4)	Priority (Expert-8)	Priority (Expert-10)	Priority (Expert-11)	Priority (Expert-12)	Priority (Expert-13)	Priority (Expert-14)	Priority (Expert-16)	Priority (Expert-17)
900 MHz	0.596	0.365	0.395	0.528	0.538	0.570	0.531	0.557	0.605	0.304	0.682	0.491
1800 MHz	0.204	0.377	0.193	0.195	0.228	0.339	0.247	0.089	0.221	0.425	0.186	0.255
2100 MHz	0.200	0.258	0.412	0.277	0.234	0.091	0.222	0.354	0.174	0.271	0.132	0.254

The average priority of available 3 alternatives have been shown below which is according to the opinion of academic researchers.

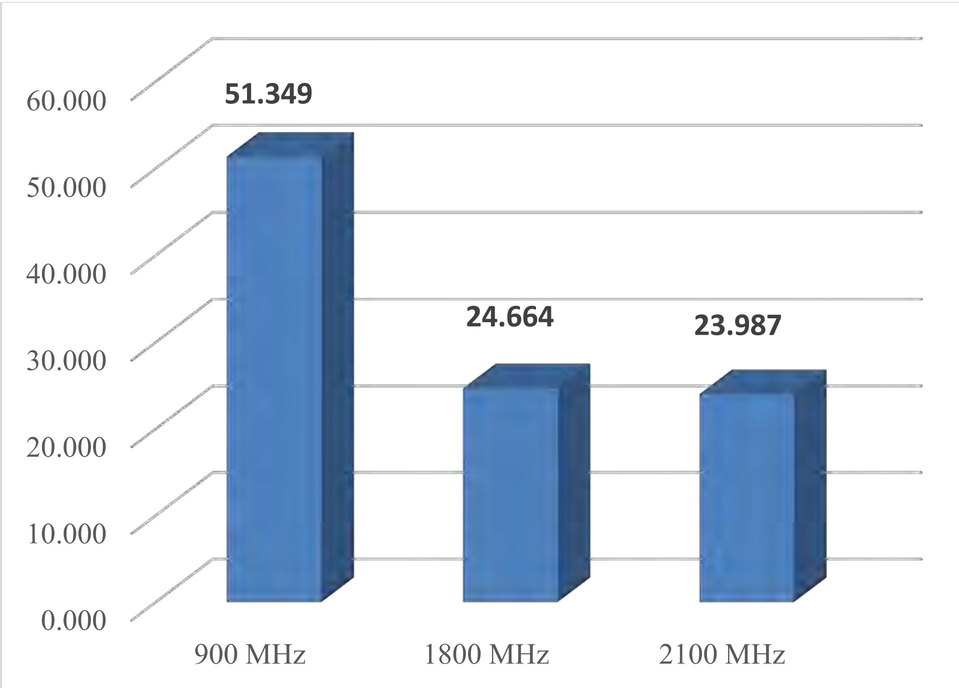

Figure 4.9: Average priority of Alternatives according to telecom professionals

4.4.6 Comparison between the Academic researchers and Technical Professional

The overall final weights (accumulated from Criteria, sub-criteria and alternatives) for frequency selection, according to Academic Researchers are as follows.

Table 4.35: Final weights for alternatives (academic researchers)

Frequencies	Final Wight (Expert-5)	Final Wight (Expert-6)	Final Wight (Expert-7)	Final Wight (Expert-9)	Final Wight (Expert-15)	Final Wight (Expert-18)	Final Wight (Expert-19)	Final Wight (Expert-20)
900 MHz	49.785	34.057	30.684	52.706	41.035	68.805	49.445	72.633
1800 MHz	21.572	36.651	28.947	21.569	39.057	20.085	22.384	19.074
2100 MHz	28.643	29.292	40.369	25.725	19.908	11.110	28.171	8.293

Again the overall final weights (accumulated from Criteria, sub-criteria and alternatives) for frequency selection, according to telecom professionals are as follows.

Table 4.36: Final weights for alternatives (telecom professionals)

Frequencies	Final Wight (Expert-1)	Final Wight (Expert-2)	Final Wight (Expert-3)	Final Wight (Expert-4)	Final Wight (Expert-8)	Final Wight (Expert-10)	Final Wight (Expert-11)	Final Wight (Expert-12)	Final Wight (Expert-13)	Final Wight (Expert-14)	Final Wight (Expert-16)	Final Wight (Expert-17)
900 MHz	67.417	42.863	59.540	69.286	60.351	66.595	63.843	72.156	69.832	48.878	77.773	40.501
1800 MHz	19.347	31.554	16.135	18.786	20.310	25.167	20.951	10.055	18.017	33.159	13.147	25.247
2100 MHz	13.236	25.583	24.325	11.927	19.339	8.238	15.206	17.790	12.150	17.963	9.079	34.251

Now the comparison between the two types of experts for selecting the frequency bands for 3G mobile system in Bangladesh. A comparison table is as in table-"4.70". Also a graphical presentation is shown in figure-"4.31". From the below table it is observed that telecom professionals have strongly preferred 900 MHz compared to other two alternatives. Academic researchers also expressed their opinion to 900 MHz as the first choice for 3G mobile communication system in Bangladesh.

Table 4.37: Result comparison between academic researchers and telecom professionals

Frequencies	Final Average Wight (%) by Academic Researchers	Final Average Wight (%) by Telecom Professionals
900 MHz	49.89	61.59
1800 MHz	26.17	20.99
2100 MHz	23.94	17.42

A graphical comparison is shown as in the following figure.

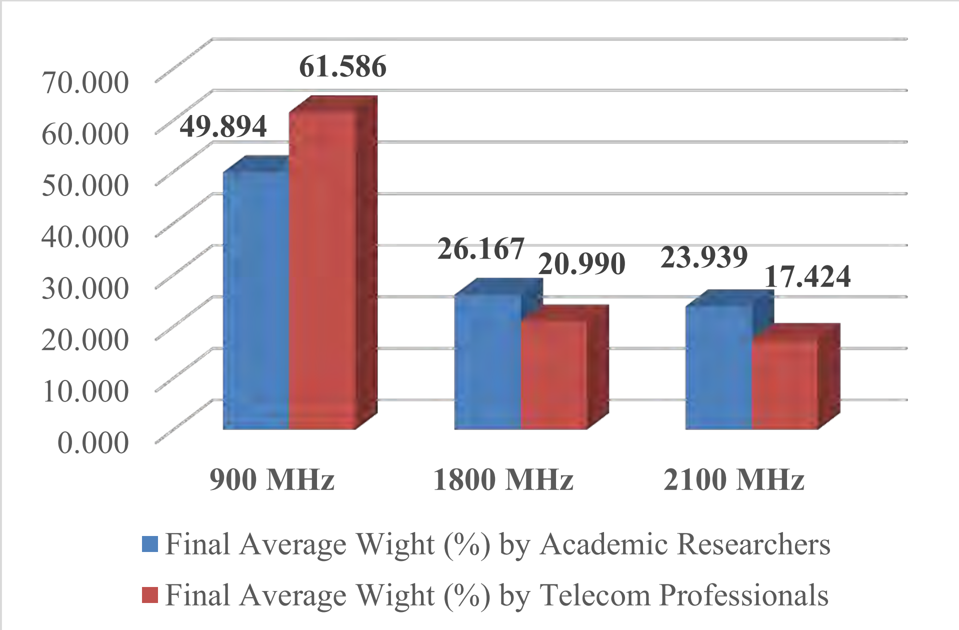

Figure 4.10: Result comparison between academic researchers and telecom professionals

From the overall analysis it is observed that always 900 MHz achieved most priority by academic researchers and telecom professionals.

4.5 Cost Benefit Analysis

A cost-benefit analysis is a process businesses use to analyze decisions of having sums the benefits of a situation or action and then subtracts the costs associated with taking that action. For the case in this thesis work let consider a geographical area of 100 square kilometers which need to cover by 3G mobile network.

As we know there have a relation among "frequency band", "wavelength" and "velocity", like $v = f\lambda$, where velocity $v = 3*10^8$ m/s, f = frequency and λ is the wave length.

Or $\lambda = v/f$ ……………………………………………………………………………… (4.1)

So it is very much clear that wave length is inversely proportional to frequency. From a general test conducted by Huawei, a distance comparison among 900 MHz, 1800 MHz and 2100 MHz is shown in the following table.

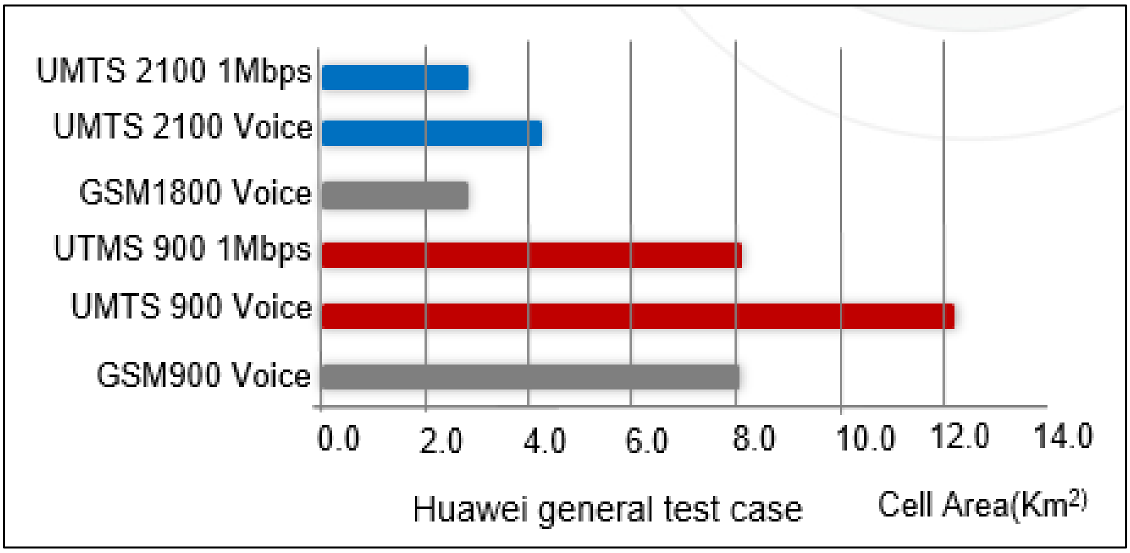

Figure 4.11: Coverage comparison among 900 MHz, 1800 MHz and 2100 MHz

From the above chart it is shown that UMTS 900MHz coverage distance 3 times larger than UMTS 2100. So for a particular area to be covered by 3G mobile signals of 2100 MHz frequency, need 3 times more base stations than of 900 MHz frequency band. As a result for that area if N number of BSs are required by 2100 MHz frequency then need N/3 BSs by 900 MHz band.

Let the installation cost of a single base station is BDT 2500000.00 (a rough assumption). Then by 2100 MHz need total cost of BDT (N)*2500000.00 and by 900 MHz need BDT (N/3)* 3000000.00 for that supposed area.

Now the ratio is $\frac{900\ MHz}{2100\ MHz} = \frac{(N/3)*2500000}{(N)*2500000}$

$$\text{Or, } \frac{900\ MHz}{2100\ MHz} = \frac{1}{3}$$

From the above relation is shown that initial cost is 3 times more for 2100 MHz than of 900 MHz. Similarly if the maintenance cost considered for one fiscal year then required at least 2 to 2.5 times more cost for 2100 MHz network compared to 900 MHz 3G network.

Again comparing between 900 MHz and 1800 MHz ratio is like 3/8,

So we get $$\frac{900\ MHz}{1800\ MHz} = \frac{(N*3/8)*2500000}{(N)*2500000}$$

$$\frac{900\ MHz}{1800\ MHz} = \frac{3}{8}$$

Other major technical costs lie in license and operation & maintenance. License cost is a one-time purchase and yearly renew charge as per regulatory council. In Bangladesh charge of license for different bands are similar hence has a very little influence on cost-benefit ratio [47]. Again the operation and maintenance is proportional to number base stations hence total cost scenario also be similar as like of integration cost assumed by 900 MHz, 1800 MHz and 2100 MHz as in above paragraph.

When the user number considered as fixed for a geographical area then the income or total benefits will be same from that area, whatever the operators launched their network by 2100 MHz or 1800 MHz or by 900 MHz frequency signals.

Thus the result showed that operators will be profitable by operating their 3G network by 900 MHz instead of conventional 2100 MHz as well users will be satisfied by stronger signals and better signal penetration inside the buildings.

CONCLUSION AND FUTURE WORK 5

This chapter concludes the thesis work by summarizing the principle contributions which are analyzed during the research work. The potential future work also presented here in the last sub-chapter.

5.1 Conclusions

The goal has been set to assess the selecting of the frequency band for 3G mobile communication systems in Bangladesh. The key research questions have been raised as whether the network signal strength (RxLevel), coverage and end user performance can be improved by introducing 900 MHz or 1800 MHz in 3G mobile system. Secondly considered, what will be the overall cost for network integration and maintenance over 900 MHz/1800 MHz instead of using conventional 2100 MHz? Also the social, economic as well environmental impacts considered. These questions were set to be answered by performing a technology assessment of selecting an appropriate frequency band for 3G mobile network. The available three licensed (owned by the existing mobile operators in Bangladesh) bands have been chosen as the alternatives for the assessment. The experts considered the current network status and user demands of to fulfill their opinion (as expert opinion) for the assessment calculation, conducted by AHP tool.

The acquired results from the assessment calculation by AHP showed that 900 MHz have the most potentiality over 1800 MHz and 2100 MHz, considering different realistic criteria and sub-criteria. Using 900 MHz in 3G system would be a better selection to cover a large geographical area and better signal strength. As well by using 900 MHz better signal penetration would be a considerable factor for mobile operators.

Moreover after the Cost-Benefit Analysis (CBA) it is also concluded that for 3G mobile system by 900 MHz is an appropriate choice as the network implementation by this band reduces integration and maintenance cost. Because of having large coverage characteristics by lower frequency band in wireless system which reduce the number of base station for the same geographical area, comparing the network of 1800 MHz or 2100 MHz.

5.2 Recommendation and Future Work

After this thesis work, the conducted analysis through the AHP tool helped to gain additional insight into a more efficient ways of frequency spectrum usage. However, some unanswered questions are left. As an extension of this project, a more extensive study of different upcoming mobile technologies & generations like, 4G/LTE and 5G could be done, by different methods.

As 900 MHz have a very small band allocation (only 25 M) for mobile (as per ITU allocation), and a large number of users use feature phones (Mobile set not supported in 3G system) hence considering more lower bands like 700 MHz or 800 MHz for the 3G systems.

Moreover, some researches can be conducted to develop the technologies or algorithm to avail the feasibility of using dynamic frequency bands among 2G, 3G and 4G as per user dense and demands under specific serving base station.

More research works can be conducted on frequency selection for Army, Navy, Police and such types of government organizations who are already using wireless communication systems for their internal requirements.

References

1. Stankus, I. P., “Assessment of Dynamic Spectrum Allocation in Realistic Mobile Networks”, Master of Science Thesis, Delft University of Technology, December 2015.

2. Eisenblatter, A., Geerdes, H-F., and Grotschel, M., “Planning UMTS Radio Networks”, Article, https://www.researchgate.net/publication/228874610, December 2008.

3. Laiho, J., “Radio Network Planning and Optimization for WCDMA”, Thesis for the degree of Doctor of Science in Technology, Helsinki University of Technology (Espoo, Finland), July 2002.

4. Akyildiz, I. F., Lee, W. Y.,Vuran, M. C. and Mohanty, S.,“NeXt generation/dynamic spectrum access/cognitive radio wireless networks: A survey.” Computer Networks, 50(13):2127 – 2159, 2006.

5. Bezabeh, E., “Spectrum Re-farming in LTE Network Planning: the Case of Addis Ababa”, Master Thesis, ADDIS ABABA UNIVERSITY, Addis Ababa, Ethiopia, March , 2016.

6. Siomina,I., “Radio Network Planning and Resource Optimization: Mathematical Models and Algorithms for UMTS, WLNs and Ad Hoc Networks”,PhD Thesis, Linkoping University, SE-601 74 Norrkoping, Sweden, Norrkoping-2007.

7. International Telecommunication Union, "Cellular Standards for the Third Generation", 1 December 2005, Archived from the original on 24 May 2008, available at https://web.archive.org /web/20080524050117/ http:/www. itu.int/ osg/spu/imt-2000/technology.html# Cellular% 20Standards% 20for%20 the% 20 Third%20Generation.

8. Gómez, J. V., “Third Generation Mobile Technology and it’s evolution towards Fourth Generation”, Tampere, Finland, February 2009.

9. “Annual Global Technology Forecast Subscriptions and Market Share 2015-2020”, available at https://www.thinksmallcell.com%2FOpinion%2Fmobile-network-statistics-for-2016.html, visited on 5th January 2019.

10. “Cellular frequencies in the US”, available at https://en.wikipedia.org/wiki/Cellular_frequencies_in_the_US, accessed on 22nd August 2018.

11. Always Online Wireless, “3G & 4G Frequency List”, available at https://support.alwaysonlinewireless.com/hc/en-us/articles/115002446723-3G-4G-Frequency-List, visited on 20th August 2018.

12. 2G, “Mobile phone generations”, available at https://en.wikipedia.org/wiki/2G, accessed on 7th November 2018.

13. "Radiolinja's History". 20 April 2004. Archived from the original on 23 October 2006, Retrieved 23 December 2009, available at https://web.archive.org/web/20061023212724/http://matkaviestinta.elisa.fi/public/search.do?query=Radiolinja's History, accessed on 11th January 2019.

14. Huurdeman, A. A., “The Worldwide History of Telecommunications”, John Wiley & Sons, 31 juli 2003, page 529.

15. 4G Americas, “GSM Global system for Mobile Communications", Archived from the original on 8 February 2014. Retrieved 2014-03-22, available at https://web.archive.org/web/20140208025938/http:/www.4gamericas.org/index.cfm?fuseaction=page&sectionid=242, accessed on 17th February 2019.

16. Mobile Phone Generations, “3G”, available at https://en.wikipedia.org/wiki/3G, accessed on 29th December 2018.

17. International Telecommunications Union, "Cellular Standards for the Third Generation", 1 December 2005, Archived from the original on 24 May 2008, available at https://web.archive.org/web/20080524050117/ http:/www.itu.int /osg/ spu/imt-2000/technology.html# Cellular%20Standards% 20for%20the%20 Third % 20 Generation.

18. “3G MIMO”, available at https://en.wikipedia.org/wiki/3G_MIMO, accessed on 24th October 2018.

19. 3GPP, The Mobile Broadband Standard, "Universal Mobile Telecommunications System", available at http://www.3gpp.org/technologies/keywords-acronyms/103-umts, accessed on 10th November 2018.

20. Raghavendra, J., Anji Reddy Y, Deepak Kumar R, Ravi T "3G Mobile UMTS" KL University, Vaddeswaram, AP, India.

21. "Frequency Allocation", available at https://en.wikipedia.org/wiki/ Frequency_allocation, accessed on 18th September 2018.

22. Bangladesh Telecommunication Regulatory Commission, "National Frequency Allocation Table 2017", Prepared by the Office of the Regulatory board, available at http://www.btrc.gov.bd/, accessed on 26th December 2018.

23. International Telecommunication Union, "Radio Regulations, Section IV", Radio Stations and Systems – Article 1.16, definition: allocation (of a frequency band).

24. National Table for Frequency Allocation (NTFA), "Workshop on National Spectrum Management and Spectrum Management System for Developing Countries (SMS4DC)", 8 -12 February 2016 Suva, Fiji. https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/Documents/Events/2016/Feb-SMS4DC-Pacific/NTFA.pdf.

25. International Telecommunication Union, "ITU Region", Available at https://en.wikipedia.org/wiki/ITU_Region, accessed on 3rd February 2019.

26. Mobile Phone Generations, LTE (telecommunication)", available at https://en. wikipedia.org/wiki/LTE (telecommunication), accessed on 24th February 2019.

27. Bangladesh Telecommunication Regulatory Commission, "Bangladesh National Frequency Allocation Plan, v1.2, Jan 2010", available at http://www.btrc.gov.bd/, accessed on 20th December 2018.

28. Bangladesh Telecommunication Regulatory Commission, "Cellular-mobile", http://www.btrc.gov.bd/cellular-mobile, accessed on 5th September 2018.

29. Jebin, L., "Case study on Grameenphone: Current scenario of post-paid package & 3G licensing of Grameenphone and their future prospects" BRAC University, Bangladesh, October 2013.

30. “Telecommunications in Bangladesh, available at https://en.wikipedia.org/wiki/Telecommunications_in_Bangladesh, accessed 17th October 2018.

31. Alam, M. D., Chowdhury, S., Alam, S., “Performance Evaluation of Different Frequency Bands of WiMAX and Their Selection Procedure”, University of Chittagong, Chittagong-4331, Bangladesh.

32. Islam, M.A., “Third generation (3G) mobile network market demand and feasibility study for implementation in Bangladesh”, Department of Industrial and Production Engineering, Bangladesh University of Engineering & technology. February 2009.

33. Mahmud, F., “Strategy Formulation for Successful Adoption of 4G Technology by Telecommunication Operators in Bangladesh”, Institute of Appropriate Technology (IAT), Bangladesh University of Engineering & technology, May 2016.

34. Simba, F., Trojer, L., Techno-economic Analysis of UMTS900 and UMTS2100 for Rural Connectivity in Tanzania, available at https://www.academia.edu/RegisterToDownload#RelatedPapers.

35. Tanjung, I. K., “Feasibility Analysis of Implementation 3G Macro Additional Sector Jabo area using Techno-economic Approach”, Universitas Mercu Buana, Jakarta 2017.

36. Unbehaun, M., “A Feasibility Study of Wireless Networks for 17 and 60 GHz and the Impact of Deployment Strategies on the System Performance”, Royal Institute of Technology, March 2001.

37. Hassan, N., “Selection of Mobile Network Operator Using Analytic Hierarchy Process (AHP)”, Universiti Kebangsaan Malaysia, 2013.

38. Asuquo, D. E., and Umoh, U. A., “Analytic Hierarchy Process for QoS evaluation of mobile data networks”, Department of Computer Science University of Uyo, PMB 1017, 520003, Uyo, Nigeria, November 2015.

39. Wikipedia, the free encyclopedia, “Technology assessment”, available at https://en.wikipedia.org/wiki/Technology_assessment, accessed on 23rd December 2018.

40. Adrian Ely, Patrick Van Zwanenberg & Andrew Stirling, "New Models of Technology Assessment for Development", STEPS Working Paper 45, Brighton: STEPS Centre, supported by Rockefeller Foundation, 2011.

41. Braun, E., "Technology in context: Technology Assessment for Managers", Technology Policy Unit, Aston University, Birmingham, United Kingdom, 2005.

42. Prf. Dr. M. Kamal Uddin, "Strategic Management of Technology, Institute of Appropriate Technology", Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.

43. "Analytic hierarchy process", available at https://en.wikipedia.org/wiki/Analytic _hierarchy_process, accessed on 2nd January 2019.

44. Wikipedia, free encyclopedia, "Cost–benefit analysis", available at https://en.wikipedia.org/wiki/Cost%E2%80%93benefit_analysis, accessed on 5th January 2019.

45. "Analytic hierarchy process", https://en.wikipedia.org/wiki/Analytic_hierarchy_ process, accessed on 12th August 2018.

46. International Telecommunication Union, "Spectrum Planning for Wireless Broadband", available at https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific /SiteAssets/Pages/Events/2016/Aug-WBB-Iran/Wirelessbroadband/ICT%20wireless %20broadband%20roadmap-Spectrum%20Planning%20for%20Wireless% 20Broadband%20fin.pdf. Accessed on 22nd February 2019.

47. Bangladesh Telecommunication Regulatory Commission, "Cellular Mobile", available at http://www.btrc.gov.bd/cellular-mobile, accessed on 10th January 2019.

48. "Mobile phone radiation and health", available at https://en.wikipedia.org/wiki/ Mobile_phone_radiation_and_health, accessed on 12th January 2019.

49. Nurul, K. T. I. M., "A roadmap for Digital Bangladesh", The Financial Express, 20th September 2014. Available at http://www.envnews.org/news/88926.html, accessed on 8th February 2019.

50. Dalalah, D., AL-Oqla, F., Hayajneh, M., “Application of the Analytic Hierarchy Process (AHP) in Multi-Criteria Analysis of the Selection of Cranes”, Industrial Engineering Department, Faculty of Engineering, Jordan University of Science and Technology, P.O. Box 3030, Irbid, 22110, Jordan.

51. Baric, D., Pilko, H., “An analytic hierarchy process model to evaluate road section design”, ResearchGate, March 2016, Available at https://www.researchgate.net/publication/299512227_An_analytic_hierarchy_process_model_to_evaluate_road_section_design

52. Saaty, T. L., “The Analytic Hierarchy Process”, McGraw-Hill, New York, USA, 1980.

53. Guston, D. H., Sarewitz, D., “Real-time technology assessment”, Bloustein School of Planning & Public Policy, Rutgers, The State University of New Jersey, 33 Livingston Ave., Suite 202, New Brunswick, NJ 08901-1980, USA; Center for Science, Policy, & Outcomes, 1 Thomas Circle, NW suite 1075, Washington, DC 20005, USA.

54. “GSM frequency bands”, available at https://en.wikipedia.org/wiki/GSM_frequency_bands, visited on 19th December 2018.

55. Wikipedia, “UMTS frequency bands”, available at https://en.wikipedia.org/wiki/UMTS_frequency_bands, accessed on 20th December 2018

Appendix-I

According to ITU following are the GSM frequency bands for the operation of 2G/GSM mobile phones and other mobile devices [54].

GSM band	f (MHz)	Uplink (MHz) (mobile to base)	Downlink (MHz) (base to mobile)	Channel numbers	Equivalent LTE band	Regional deployments
T-GSM-380	380	380.2 – 389.8	390.2 – 399.8	dynamic	?	None
T-GSM-410	410	410.2 – 419.8	420.2 – 429.8	dynamic	?	None
GSM-450	450	450.6 – 457.6	460.6 – 467.6	259–293	31	None
GSM-480	480	479.0 – 486.0	489.0 – 496.0	306–340	?	None
GSM-710	710	698.2 – 716.2	728.2 – 746.2	dynamic	12	None
GSM-750	750	777.2 – 792.2	747.2 – 762.2	438–511	?	None
T-GSM-810	810	806.2 – 821.2	851.2 – 866.2	dynamic	27	None
GSM-850	850	824.2 – 848.8	869.2 – 893.8	128–251	5	CALA, NAR
P-GSM-900	900	890.0 – 915.0	935.0 – 960.0	1–124	?	None
E-GSM-900	900	880.0 – 915.0	925.0 – 960.0	0–124, 975–1023	8	APAC, EMEA
R-GSM-900	900	876.0 – 915.0	921.0 – 960.0	0–124, 955–1023	?	None
T-GSM-900	900	870.4 – 876.0	915.4 – 921.0	dynamic	?	None
DCS-1800	1800	1710.2 – 1784.8	1805.2 – 1879.8	512–885	3	APAC, EMEA
PCS-1900	1900	1850.2 – 1909.8	1930.2 – 1989.8	512–810	2	CALA, NAR

Appendix-I

3G FDD frequency bands as per ITU declaration, as in the following table [55].

UTRA	*f*	Common name	Uplink frequencies	Downlink frequencies
band	(MHz)		UE transmit (MHz)	UE receive (MHz)
1	2100	IMT	1920 – 1980	2110 – 2170
2	1900	PCS A–F	1850 – 1910	1930 – 1990
3	1800	DCS	1710 – 1785	1805 – 1880
4	1700	AWS A–F	1710 – 1755	2110 – 2155
5	850	CLR	824 – 849	869 – 894
6	800		830 – 840	875 – 885
7	2600	IMT-E	2500 – 2570	2620 – 2690
8	900	E-GSM	880 – 915	925 – 960
9	1700		1749.9 – 1784.9	1844.9 – 1879.9
10	1700	EAWS A–G	1710 – 1770	2110 – 2170
11	1500	LPDC	1427.9 – 1447.9	1475.9 – 1495.9
12	700	LSMH A/B/C	699 – 716	729 – 746
13	700	USMH C	777 – 787	746 – 756
14	700	USMH D	788 – 798	758 – 768
15 -18		*Reserved*		
19	800		830 – 845	875 – 890
20	800	EUDD	832 – 862	791 – 821
21	1500	UPDC	1447.9 – 1462.9	1495.9 – 1510.9
22	3500		3410 – 3490	3510 – 3590
23 -24		*Reserved*		
25	1900	EPCS A–G	1850 – 1915	1930 – 1995
26	850	ECLR	814 – 849	859 – 894
27 - 31		*Reserved*		
32	1500	L-band	N/A	1452 – 1496

Appendix-I

Standardized 3G/UMTS bands and their regional use are shown in the following table [55].

UTRA band	f (MHz)	Common name	North America	Latin America	Europe	Asia	Africa	Oceania
1	2100	IMT	No	Aruba (SetarNV), Uruguay (Ancel), Brazil, Costa Rica	Yes	Yes	Yes	Yes
2	1900	PCS A–F	Yes	Yes	No	No	No	No
4	1700	AWS A–F	USA & PR (T-Mobile) Canada (Eastlink, Vidéotron, Freedom)	Chile (WOM) Mexico (AT&T)	No	No	No	No
5	850	CLR	Yes	Yes	No	Hong Kong (SmarTone), Israel (Cellcom, Pelephone), Philippines (SMART), Thailand (DTAC, True), Kazakhstan (Altel)	No	Australia (Telstra, VHA), New Zealand (Spark)
6	*800*	*UMTS 800*	*No*	*No*	*No*	replaced by band 19 [4]	*No*	*No*
8	900	E-GSM	No	Dominican Republic (Orange), Paraguay (VOX), Venezuela (Digitel)	Yes	Yes	South Africa (Cell C)	Australia (Optus, VHA), New Zealand (2degrees, Vodafone)
9	*1700*	*UMTS 1700*	*No*	*No*	*No*	*Japan (SoftBank)* *Mar 2007 - Jan 2018*	*No*	*No*
11	*1500*	*LPDC*	*No*	*No*	*No*	*Japan (SoftBank)* *Nov 2010 – Mar 2017*	*No*	*No*
19	800	*LB 800*	No	No	No	Japan (NTT docomo) *(only the lower band 6 part* *is used for UMTS)*	No	No

Appendix-II

Questionnaires for Criteria:

1. Let given the frequency selection options, what is more important to you: the Quality Factors (F1) or Cost Components (F2)? And please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one. (Please tick mark on your choice)

i. Quality Factors (F1); ii. Cost Components (F2)

Weight	1	2	3	4	5	6	7	8	9

2. Let given the frequency selection options, what is more important to you: Quality Factors (F1) or Other Effects (F3)? And please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one. (Please tick mark on your choice)

i. Quality Factors (F1); ii. Other Effects (F3)

Weight	1	2	3	4	5	6	7	8	9

3. Let given the frequency selection options, what is more important to you: the factor of Cost Components (F2) or Other Effects (F3)? And please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one. (Please tick mark on your choice)

i. Cost Components (F2); ii. Other Effects (F3)

Weight	1	2	3	4	5	6	7	8	9

Questionnaires for Sub-Criteria:

1. For the Criteria, Quality Factors (F1), what is more important as per your opinion: Coverage Area (F1A1) or User Capacity (F1A2)?
   Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.
   (Please tick mark on your choice)

i. Coverage Area (F1A1); ii. User Capacity (F1A2)

Weight	1	2	3	4	5	6	7	8	9

2. For the Criteria, Quality Factors (F1), what is more important as per your opinion: Coverage Area (F1A1) or Stability / Signal Penetration (F1A3)?
   Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.
   (Please tick mark on your choice)
   i. Coverage Area (F1A1); ii. Stability / Signal Penetration (F1A3)

Weight	1	2	3	4	5	6	7	8	9

3. For the Criteria, Quality Factors (F1), what is more important as per your opinion: Stability / Signal Penetration (F1A3) or User Capacity (F1A2)?
   Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.
   (Please tick mark on your choice)
   i. Stability / Signal Penetration (F1A3); ii. User Capacity (F1A2)

Weight	1	2	3	4	5	6	7	8	9

4. For the Criteria, Cost Components (F2), what is more important as per your opinion: Integration Cost (F2B1) or License Cost (F2B2)?
   Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.
   (Please tick mark on your choice)
   i. Integration Cost (F2B1); ii. License Cost (F2B2)

Weight	1	2	3	4	5	6	7	8	9

5. For the Criteria, Cost Components (F2), what is more important as per your opinion: Integration Cost (F2B1) or Maintenance Cost (F2B3)?

   Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

   (Please tick mark on your choice)

   i. Integration Cost (F2B1); ii. Maintenance Cost (F2B3)

Weight	1	2	3	4	5	6	7	8	9

6. For the Criteria, Cost Components (F2), what is more important as per your opinion: Maintenance Cost (F2B3) or License Cost (F2B2)?

   Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

   (Please tick mark on your choice)

   i. Maintenance Cost (F2B3); ii. License Cost (F2B2)

Weight	1	2	3	4	5	6	7	8	9

7. For the Criteria, Other Effects (F3), what is more important as per your opinion: Social Impacts (F3C1) or Environmental Effects (F3C2)?

   Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

   (Please tick mark on your choice)

   i. Social Impacts (F3C1); ii. Environmental Effects (F3C2)

Weight	1	2	3	4	5	6	7	8	9

8. For the Criteria, Other Effects (F3), what is more important as per your opinion: Social Impacts (F3C1) or Economic Impacts (F3C3)?

   Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

   (Please tick mark on your choice)

i. Social Impacts (F3C1); ii. Economic Impacts (F3C3)

Weight	1	2	3	4	5	6	7	8	9

9. For the Criteria, Other Effects (F3), what is more important as per your opinion: Environmental Effects (F3C2) or Economic Impacts (F3C3)?

   Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

   (Please tick mark on your choice)

   i. Environmental Effects (F3C2); ii. Economic Impacts (F3C3)

Weight	1	2	3	4	5	6	7	8	9

10. For the Sub-Criteria, Coverage Area (F1A1), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 1800 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 900 MHz; ii. 1800 MHz

Weight	1	2	3	4	5	6	7	8	9

11. For the Sub-Criteria, Coverage Area (F1A1), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 2100 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 900 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

12. For the Sub-Criteria, Coverage Area (F1A1), Which Frequency Band is more important for 3G mobile communications: 1800 MHz or 2100 MHz?

Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

(Please tick mark on your choice)

i. 1800 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

13. For the Sub-Criteria, User Capacity (F1A2), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 1800 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 900 MHz; ii. 1800 MHz

Weight	1	2	3	4	5	6	7	8	9

14. For the Sub-Criteria, User Capacity (F1A2), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 2100 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 900 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

15. For the Sub-Criteria, User Capacity (F1A2), Which Frequency Band is more important for 3G mobile communications: 1800 MHz or 2100 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 1800 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

16. For the Sub-Criteria, Stability / Signal Penetration (F1A3), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 1800 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 900 MHz; ii. 1800 MHz

Weight	1	2	3	4	5	6	7	8	9

17. For the Sub-Criteria, Stability / Signal Penetration (F1A3), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 2100 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 900 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

18. For the Sub-Criteria, Stability / Signal Penetration (F1A3), Which Frequency Band is more important for 3G mobile communications: 1800 MHz or 2100 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 1800 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

19. For the Sub-Criteria, Integration Cost (F2B1), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 1800 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

i. 900 MHz; ii. 1800 MHz

Weight	1	2	3	4	5	6	7	8	9

20. For the Sub-Criteria, Integration Cost (F2B1), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 2100 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 900 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

21. For the Sub-Criteria, Integration Cost (F2B1), Which Frequency Band is more important for 3G mobile communications: 1800 MHz or 2100 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 1800 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

22. For the Sub-Criteria, License Cost (F2B2), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 1800 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 900 MHz; ii. 1800 MHz

Weight	1	2	3	4	5	6	7	8	9

23. For the Sub-Criteria, License Cost (F2B2), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 2100 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 900 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

24. For the Sub-Criteria, License Cost (F2B2), Which Frequency Band is more important for 3G mobile communications: 1800 MHz or 2100 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 1800 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

25. For the Sub-Criteria, Maintenance Cost (F2B3), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 1800 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 900 MHz; ii. 1800 MHz

Weight	1	2	3	4	5	6	7	8	9

26. For the Sub-Criteria, Maintenance Cost (F2B3), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 2100 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

i. 900 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

27. For the Sub-Criteria, Maintenance Cost (F2B3), Which Frequency Band is more important for 3G mobile communications: 1800 MHz or 2100 MHz?
Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.
(Please tick mark on your choice)
i. 1800 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

28. For the Sub-Criteria, Social Impacts (F3C1), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 1800 MHz?
Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.
(Please tick mark on your choice)
i. 900 MHz; ii. 1800 MHz

Weight	1	2	3	4	5	6	7	8	9

29. For the Sub-Criteria, Social Impacts (F3C1), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 2100 MHz?
Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.
(Please tick mark on your choice)
i. 900 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

30. For the Sub-Criteria, Social Impacts (F3C1), Which Frequency Band is more important for 3G mobile communications: 1800 MHz or 2100 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 1800 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

31. For the Sub-Criteria, Environmental Effects (F3C2), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 1800 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 900 MHz; ii. 1800 MHz

Weight	1	2	3	4	5	6	7	8	9

32. For the Sub-Criteria, Environmental Effects (F3C2), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 2100 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

    i. 900 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

33. For the Sub-Criteria, Environmental Effects (F3C2), Which Frequency Band is more important for 3G mobile communications: 1800 MHz or 2100 MHz?

    Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.

    (Please tick mark on your choice)

i. 1800 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

34. For the Sub-Criteria, Economic Impacts (F3C3), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 1800 MHz?
Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.
(Please tick mark on your choice)
i. 900 MHz; ii. 1800 MHz

Weight	1	2	3	4	5	6	7	8	9

35. For the Sub-Criteria, Economic Impacts (F3C3), Which Frequency Band is more important for 3G mobile communications: 900 MHz or 2100 MHz?
Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.
(Please tick mark on your choice)
i. 900 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

36. For the Sub-Criteria, Economic Impacts (F3C3), Which Frequency Band is more important for 3G mobile communications: 1800 MHz or 2100 MHz?
Please indicate the scale (1 to 9) considering your choice that how much it is important than the pair one.
(Please tick mark on your choice)
i. 1800 MHz; ii. 2100 MHz

Weight	1	2	3	4	5	6	7	8	9

Appendix-III

S/N	Expert	Category	Organization
1	Expert-1	Telecom Professional	Bangladesh Telecommunication Company Ltd. (BTCL)
2	Expert-1	Telecom Professional	Banglalink Digital Communications Ltd.
3	Expert-2	Telecom Professional	Robi Axiata Ltd
4	Expert-3	Telecom Professional	From Australia (Former in Huawei Bangladeh Ltd.)
5	Expert-4	Academic Researcher	Bangladesh University of Engineering and Technology (BUET)
6	Expert-5	Academic Researcher	International Islamic University Chittagong (IIUC)
7	Expert-6	Academic Researcher	Bangladesh University of Engineering and Technology (BUET)
8	Expert-7	Telecom Professional	ZTE Corporation
9	Expert-8	Academic Researcher	Khulna University (KU)
10	Expert-9	Telecom Professional	Teletalk Bangladesh Ltd.
11	Expert-11	Telecom Professional	Teletalk Bangladesh Ltd.
12	Expert-12	Telecom Professional	Airtel-Chad (Northern Africa)
13	Expert-13	Telecom Professional	NAK, MCI, Iran (www.nak-mci.ir)
14	Expert-14	Telecom Professional	Teletalk Bangladesh Ltd.
15	Expert-15	Academic Researcher	International Islamic University Chittagong (IIUC)
16	Expert-16	Telecom Professional	Nokia Bangladesh Ltd.
17	Expert-17	Telecom Professional	Teletalk Bangladesh Ltd.
18	Expert-18	Academic Researcher	International Islamic University Chittagong (IIUC)
19	Expert-19	Academic Researcher	Bangladesh University of Engineering and Technology (BUET)
20	Expert-20	Academic Researcher	Khulna University (KU)

AHP calculation for expert-1

From the interview results of expert-1, the following matrix is constructed to calculate the weight for the selected three criteria's.

Table: Matrix as per pair wise values from expert opinion

Criteria	F1	F2	F3
Quality Factors(F1)	1	5	7
Cost Components(F2)	1/5	1	3
Other Effects(F3)	1/7	1/3	1

Now the 3rd (nth) root of product is the value of multiplying each row together and then cubic root. Calculated using equation (3). And later the priority vector is calculated by following the equation (4), "Priority Vector" is the normalized value of aforementioned nth root of product;

Priority Vector (Weight) = nth root of product/Sum

Table: Priorities vector for the pair wise comparison matrix for criteria.

Criteria	F1	F2	F3	3rd Root of Product	Priority Vector
Quality Factors(F1)	1	5.000	7.000	3.271	0.731
Cost Components(F2)	0.200	1	3.000	0.843	0.188
Other Effects(F3)	0.143	0.333	1	0.362	0.081
			Sum	4.477	**1**

Now the consistency check is performed by using equations (3.3) and (3.4), for which need to calculate the column sum and sum PV. Result found as follows

Appendix-IV

Table: Finding Column sum and Sum *PV*.

Consistency Check						
Criteria	**F1**	**F2**	**F3**	**3rd Root of Product**	**Priority Vector**	PV (%)
Quality Factors(F1)	1	5.000	7.000	3.271	0.731	73.064
Cost Components(F2)	0.200	1	3.000	0.843	0.188	18.839
Other Effects(F3)	0.143	0.333	1	0.362	0.081	8.096
Column Sum	1.343	6.333	11	4.477	1	100
Sum PV	0.981	1.193	0.891	3.065		

So the Lambda Max (λ_{Max}) is 3.065 as in the above table.

According to AHP methodology it is need to perform the consistency checking which is calculated as per the following relations.

Consistency Index (*CI*) = (Lambda Max-*n)/(n*-1)

Consistency Index (*CI*) = 0.032; as here *n*=3

Consistency Ratio (*CR*) = 0.056

Consistency Ratio (*CR* %) = 5.594

Now calculating the priority vector and consistency ratio for the sub-criteria under quality factor as shown below.

Table: Matrix as per pair wise values from expert opinion

Sub Criteria	**F1A1**	**F1A2**	**F1A3**
Coverage Area(F1A1)	1	6	1
User Capacity(F1A2)	1/6	1	1/3
Stability/ Signal penetration (F1A3)	1	3	1

Appendix-IV

Finding Priority Vector (Weight) = nth root of product/Sum as in below table.

Table: Priorities vector for the pair wise comparison matrix for sub-criteria

Sub Criteria	**F1A1**	**F1A2**	**F1A3**	**3rd Root of Product**	**Priority Vector**
Coverage Area(F1A1)	1	6.000	1.000	1.817	0.499
User Capacity(F1A2)	0.167	1	0.333	0.382	0.105
Stability/ Signal penetration (F1A3)	1.000	3.000	1	1.442	0.396
			Sum	3.641	**1**

Now the consistency check is performed by using equations (3.3) and (3.4), result found as follows

Table: Finding Column sum and Sum PV

Consistency Check						
Sub Criteria	**F1A1**	**F1A2**	**F1A3**	**3rd Root of Product**	**Priority Vector**	PV (%)
Coverage Area(F1A1)	1	6.000	1.000	1.817	0.499	49.908
User Capacity(F1A2)	0.167	1	0.333	0.382	0.105	10.480
Stability/ Signal penetration (F1A3)	1.000	3.000	1	1.442	0.396	39.612
Column Sum	2.167	10.000	2.333	3.641	1	100
Sum PV	1.081	1.048	0.924	**3.054**		
				λ_{Max}		

Consistency Index (CI) = 0.027

Consistency Ratio (CR) = 0.046

Consistency Ratio (CR %) = 4.623

In this section calculating the priority vector and consistency ratio for the sub-criteria under Cost Components as shown below.

Table: Matrix as per pair wise values from expert opinion

Sub Criteria	F2B1	F2B2	F2B3
Integration Cost(F2B1)	1	5	1/4
License Cost(F2B2)	1/5	1	1/8
Maintenance Cost(F2B3)	4	8	1

Now the 3rd (nth) root of product is the value of multiplying each row together and then cubic root. Calculated using equation (3). And later the priority vector is calculated by following the equation (4), "Priority Vector" is the normalized value of aforementioned nth root of product;

Finding Priority Vector (Weight) = nth root of product/Sum as in below table.

Table: Priorities vector for the pair wise comparison matrix for sub-criteria

Sub Criteria	F2B1	F2B2	F2B3	3rd Root of Product	Priority Vector
Integration Cost(F2B1)	1	5.000	0.250	1.077	0.237
License Cost(F2B2)	0.200	1	0.125	0.292	0.064
Maintenance Cost(F2B3)	4.000	8.000	1	3.175	0.699
			Sum	4.544	**1**

The consistency check for the above result is performed by using equations (3.3) and (3.4), result found as follows.

Table: Finding Column sum and Sum *PV*.

Consistency Check						
Sub Criteria	**F2B1**	**F2B2**	**F2B3**	**3rd Root of Product**	**Priority Vector**	PV(%)
Integration Cost(F2B1)	1	5	0.250	1.077	0.237	23.704
License Cost(F2B2)	0.200	1	0.125	0.292	0.064	6.434
Maintenance Cost(F2B3)	4.000	8	1	3.175	0.699	69.862
Column Sum	5.200	14	1.375	4.544	1	100
Sum PV	1.233	0.901	0.961	3.094		
				Lambda Max		

Consistency Index (*CI*) = 0.047

Consistency Ratio (*CR*) = 0.081

Consistency Ratio (*CR* %) = 8.105

In this section calculating the priority vector and consistency ratio for the sub-criteria under criteria “other effects” as shown below.

Table: Matrix as per pair wise values from expert opinion

Sub Criteria	**F3C1**	**F3C2**	**F3C3**
Social Impact(F3C1)	1	1/3	1
Environmental Effects(F3C2)	3	1	3
Economic Impacts(F3C3)	1	1/3	1

Now the 3rd (nth) root of product is the value of multiplying each row together and then cubic root. Calculated using equation (3). And later the priority vector is calculated by following the equation (4), “Priority Vector” is the normalized value of aforementioned nth root of product;

Appendix-IV

Table: Priorities vector for the pair wise comparison matrix for criteria.

Sub Criteria	F3C1	F3C2	F3C3	3rd Root of Product	Priority Vector
Social Impact(F3C1)	1	0.333	1.000	0.693	0.200
Environmental Effects(F3C2)	3.000	1	3.000	2.080	0.600
Economic Impacts(F3C3)	1	0.333	1	0.693	0.200
			Sum	3.467	**1**

Now the consistency check is performed by using equations (3.3) and (3.4), result found as follows

Table: Finding Column sum and Sum PV.

Consistency Check						
Sub Criteria	**F3C1**	**F3C2**	**F3C3**	**3rd Root of Product**	**Priority Vector**	PV (%)
Social Impact(F3C1)	1	0.333	1	0.693	0.200	20
Environmental Effects(F3C2)	3	1	3	2.080	0.600	60
Economic Impacts(F3C3)	1	0.333	1	0.693	0.200	20
Column Sum	5	1.667	5	3.467	1	100
Sum PV	1.000	1.000	1.000	3.000		
				Lambda Max		

Consistency Index (CI) = 0.000

Consistency Ratio (CR) = 0.000

Consistency Ratio (CR %) = 0.000

Now calculating the priority vector and consistency ratio for the alternatives under sub-criteria Coverage Area under quality factor as shown below.

Appendix-IV

Table: Matrix as per pair wise values from expert opinion

Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**
900 MHz	1	5	7
1800 MHz	1/5	1	3
2100 MHz	1/7	1/3	1

Finding Priority Vector (Weight) = nth root of product/Sum as in below table.

Table: Priorities vector for the pair wise comparison matrix for sub-criteria

Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**	**3rd Root of Product**	**Priority Vector**
900 MHz	1	5	7	3.271	0.731
1800 MHz	0.200	1	3	0.843	0.188
2100 MHz	0.143	0.333	1	0.362	0.081
			Sum	4.477	**1**

Now the consistency check is performed by using equations (3.3) and (3.4), result found as follows

Table: Finding Column sum and Sum PV.

Consistency Check						
Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**	**3rd Root of Product**	**Priority Vector**	PV (%)
900 MHz	1	5	7	3.271	0.731	73.064
1800 MHz	0.200	1	3	0.843	0.188	18.839
2100 MHz	0.143	0.333	1	0.362	0.081	8.096
Column Sum	1.343	6.333	11	4.477	1	100
Sum PV	0.981	1.193	0.891	3.065		
				Lambda Max		

Consistency Index (CI) = 0.032

Consistency Ratio (CR) = 0.056

Consistency Ratio (CR %) = 5.594

Appendix-IV

Similarly found the priority vector and corresponding consistency ration for User Capacity(F1A2), Stability / Signal Penetration (F1A3), Integration Cost(F2B1), License Cost(F2B2), Maintenance Cost(F2B3), Social Impact(F3C1), Environmental Effects(F3C2) and Economic Impacts(F3C3) as given below respectively.

Calculation for User Capacity (F1A2),

Table: Priorities vector for the pair wise comparison

Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**	**3rd Root of Product**	**Priority Vector**	PV (%)
900 MHz	1	0.500	0.250	0.500	0.143	14.286
1800 MHz	2	1	0.500	1.000	0.286	28.571
2100 MHz	4	2	1	2.000	0.571	57.143
Column Sum	7	3.500	1.750	3.500	1	100
Sum PV	1.000	1.000	1.000	3.000		

Consistency Index (CI) = 0.000

Consistency Ratio (CR) = 0.000

Consistency Ratio (CR %) = 0.000

Calculation for Stability / Signal Penetration (F1A3)

Table: Priorities vector for the pair wise comparison and sum

Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**	**3rd Root of Product**	**Priority Vector**	PV (%)
900 MHz	1	4	6	2.884	0.701	70.097
1800 MHz	0.250	1	2	0.794	0.193	19.288
2100 MHz	0.167	0.500	1	0.437	0.106	10.615
Column Sum	1.417	5.500	9.000	4.115	1	100
Sum PV	0.993	1.061	0.955	3.009		

Consistency Index (CI) = 0.005

Consistency Ratio (CR) = 0.008

Consistency Ratio (CR %) = 0.793

Calculation result for Integration Cost (F2B1)

Table: Priorities vector for the pair wise comparison for Integration cost

Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**	**3rd Root of Product**	**Priority Vector**	PV (%)
900 MHz	1	4	7	3.037	0.715	71.530
1800 MHz	0.250	1	2	0.794	0.187	18.696
2100 MHz	0.143	0.500	1	0.415	0.098	9.774
Column Sum	1.393	5.500	10	4.245	1	100
Sum PV	0.996	1.028	0.977	3.002		

Consistency checking

Consistency Index (CI) = 0.001

Consistency Ratio (CR) = 0.002

Consistency Ratio (CR %) = 0.171

Calculation result for License Cost (F2B2),

Table: Priorities vector for the pair wise comparison for License Cost

Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**	**3rd Root of Product**	**Priority Vector**	PV (%)
900 MHz	1	0.500	0.250	0.500	0.143	14.286
1800 MHz	2.000	1	0.500	1.000	0.286	28.571
2100 MHz	4.000	2.000	1	2.000	0.571	57.143
Column Sum	7.000	3.500	1.750	3.500	1	100
Sum PV	1.000	1.000	1.000	3.000		

Consistency checking for the calculation of license cost

Consistency Index (CI) = 0.000

Consistency Ratio (CR) = 0.000

Consistency Ratio (CR %) = 0.000

Calculation result for Maintenance Cost (F2B3),

Table: Priorities vector for the pair wise comparison for Maintenance Cost

Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**	**3rd Root of Product**	**Priority Vector**	PV(%)
900 MHz	1	6	8	3.634	0.761	76.116
1800 MHz	0.167	1	3	0.794	0.166	16.623
2100 MHz	0.125	0.333	1	0.347	0.073	7.261
Column Sum	1.292	7.333	12	4.775	1	100
Sum PV	0.983	1.219	0.871	3.074		

Consistency checking for maintenance cost

Consistency Index (CI) = 0.037

Consistency Ratio (CR) = 0.063

Consistency Ratio (CR %) = 6.337

Calculation result for Social Impact (F3C1),

Table 4.20: Priorities vector for the pair wise comparison for Social Impact

Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**	**3rd Root of Product**	**Priority Vector**	PV(%)
900 MHz	1	4	6	2.884	0.701	70.097
1800 MHz	0.250	1	2	0.794	0.193	19.288
2100 MHz	0.167	0.5	1	0.437	0.106	10.615
Column Sum	1.417	5.5	9	4.115	1	100
Sum PV	0.993	1.061	0.955	3.009		

Consistency checking for Social Impact (F3C1),

Consistency Index (CI) = 0.005

Consistency Ratio (CR) = 0.008

Consistency Ratio (CR %) = 0.793

Calculation result for Environmental Effects (F3C2)

Table: Priorities vector for the pair wise comparison for Environmental Effects

Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**	**3rd Root of Product**	**Priority Vector**	PV (%)
900 MHz	1	6	8	3.634	0.769	76.924
1800 MHz	0.167	1	2	0.693	0.147	14.676
2100 MHz	0.125	0.500	1	0.397	0.084	8.400
Column Sum	1.292	7.5	11	4.724	1	100
Sum PV	0.994	1.101	0.924	3.018		

Consistency checking for Environmental Effects (F3C2)

Consistency Index (CI) = 0.009 as here n=3

Consistency Ratio (CR) = 0.016

Consistency Ratio (CR %) = 1.577

Calculation result for and Economic Impacts (F3C3)

Table 4.22: Priorities vector for the pair wise comparison for Economic Impacts

Alternatives	**900 MHz**	**1800 MHz**	**2100 MHz**	**3rd Root of Product**	**Priority Vector**	PV (%)
900 MHz	1	4	6	2.884	0.701	70.097
1800 MHz	0.250	1	2	0.794	0.193	19.288
2100 MHz	0.167	0.500	1	0.437	0.106	10.615
Column Sum	1.417	5.500	9	4.115	1	100
Sum PV	0.993	1.061	0.955	3.009		

Consistency checking for Environmental Effects (F3C2)

Consistency Index (CI) = 0.005

Consistency Ratio (CR) = 0.008

Consistency Ratio (CR %) = 0.793

Now the final result for the expert-1 is the sum value as shown in following table.

Table 4.23: Final priorities and weights for frequencies for Expert-1.

							Pririty Vector			Final Wight		
Level 0	**Level 1**		**Level 2**		**Glb Priority**		**900 MHz**	**1800 MHz**	**2100 MHz**	**900 MHz**	**1800 MHz**	**2100 MHz**
AHP Calculation for Expert-1	Quality Factors (F1)	0.731	Coverage Area (F1A1)	0.499	0.365	36.465	0.731	0.188	0.081	0.266	0.069	0.030
			User Capacity (F1A2)	0.105	0.077	7.657	0.143	0.286	0.571	0.011	0.022	0.044
			Stability/Signal Penetration (F1A3)	0.396	0.289	28.942	0.701	0.193	0.106	0.203	0.056	0.031
	Cost Components (F2)	0.188	Integration Cost (F2B1)	0.237	0.045	4.466	0.715	0.187	0.098	0.032	0.008	0.004
			License Cost (F2B2)	0.064	0.012	1.212	0.143	0.286	0.571	0.002	0.003	0.007
			Maintenance Cost (F2B3)	0.699	0.132	13.161	0.761	0.166	0.073	0.100	0.022	0.010
	Other Effects (F3)	0.081	Social Impact (F3C1)	0.200	0.016	1.619	0.701	0.193	0.106	0.011	0.003	0.002
			Environmental Effects (F3C2)	0.600	0.049	4.858	0.769	0.147	0.084	0.037	0.007	0.004
			Economic Impacts (F3C3)	0.200	0.016	1.619	0.701	0.193	0.106	0.011	0.003	0.002
						100.00	0.596	0.204	0.200	0.674	0.193	0.132
									%	67.417	19.347	13.236

Where Global Priority = PV of Quality Factors (F1)* PV of Coverage Area (F1A1) and Final weight = aforementioned "priority vector" * "Global priority". Similarly for each row.

So finally the result for expert come as in following table.

Table: Final weights of the frequency alternatives for Expert-1

Final Wight		
900 MHz	1800 MHz	2100 MHz
67.417	19.347	13.236

The graphical presentation of the final calculation is shown as follows.

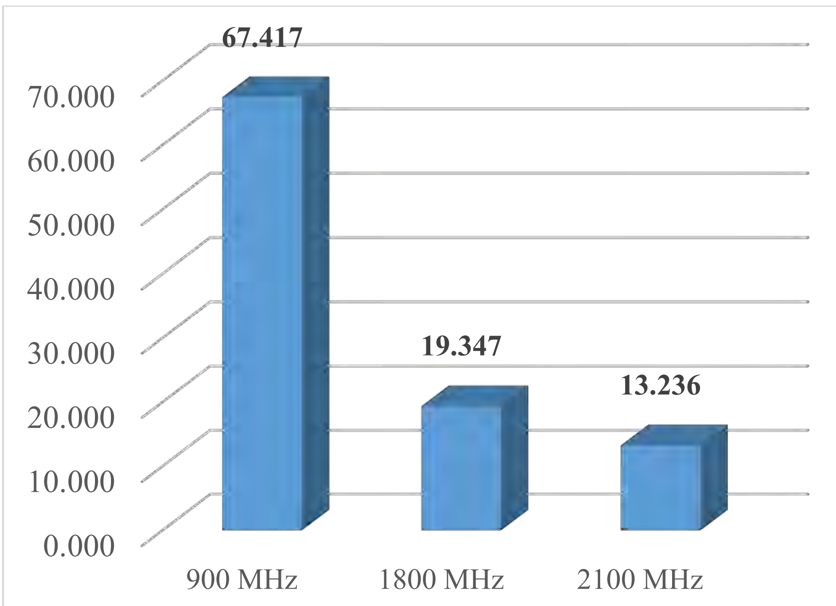

Figure: Result of final weights of the frequency alternatives for Expert-1

From the above result it is observed that 900 MHz have the highest priority, 1800 MHz is the second choice and 2100 MHz have least score as per expert-1.