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DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

EXPLORING THE INTERACTION BETWEEN THE INTERNATIONAL RADIO SPECTRUM MANAGEMENT REGIME AND NATIONAL RADIO SPECTRUM MANAGEMENT POLICIES

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To my wife, Engy, for being always there for me

To my daughters, Mariam and Laila, for bringing joy and happiness to my life

To my parents, for raising me to be the person I am today

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Abstract

National spectrum management policy is once more a key issue facing the global telecommunications industry in order to meet the rapid growth in wireless services and the increasing demand for mobile broadband. Three approaches are usually suggested to overcome the deficiencies of the command and control approach to spectrum management: spectrum markets, spectrum commons, and spectrum easements. Meanwhile, while a few countries have reformed or planned to reform their national policies, in most of the word, especially in the developing countries, radio spectrum is managed along the lines of traditional government administration due to different factors. Largely overlooked in current debates, however, is the influence of the international spectrum management regime on national policy reform.

To address such influence, this thesis has examined the main research question ‘How do the international radio spectrum management regime and national radio spectrum management policies interact?’ With a focus on the cases of Egypt and UAE, this research has examined the research question regarding three main concepts, radiocommunication service allocation flexibility, technology neutrality, and opportunistic access in the TV White Spaces (TVWS), which are considered as main elements of the three alternative approaches to command and control. Data was collected through semi-structured interviews with main national and international actors.

The main finding of the thesis is that the international spectrum management regime does not prevent adopting radiocommunication service allocation flexibility, technology neutrality, or opportunistic access in the TVWS. However, there are different elements of flexibility and restriction that have an influence on regulators’ flexibility regarding radiocommunication service allocation, regulators’ tendency towards technology neutrality, and deployment of opportunistic access in the TVWS. These elements are dependent on the country’s geographical position, country’s relationship with neighbouring countries, size of country market, being advanced in technology, interpretation of the international regulations, and national telecommunication market status.

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List of Abbreviations

2G: Second Generation
3G: Third Generation
3GPP: Third Generation Partnership Project
4G: Fourth Generation
AfriSWoG: African Spectrum Working Group
A.I.: Agenda Item
APT: Asia Pacific Telecommunity
ARENTO: Arab Republic of Egypt National Telecommunications Organization
ASA: Authorised Shared Access
ASMG: Arab Spectrum Management Group
ATU: African Telecommunications Union
BEM: Block Edge Mask
BR: Radiocommunication Bureau
BSS: Broadcasting Satellite Service
BTA: Basic Telecommunication Agreement
BWA: Broadband Wireless Access
CAQDAS: Computer-Assisted Qualitative Data Analysis Software
CCIR: International Radio Consultative Committee
CCV: Coordination Committee for Vocabulary
CDMA 2000 1X EVDO: Code Division Multiple Access One Carrier-Evolved, Data-Optimized
CDMA MC: Multi-Carrier Code Division Multiple Access
CDMA: Code Division Multiple Access
CEPT: European Conference of Postal and Telecommunications Administrations
CITEL: Inter-American Telecommunication Commission
CPC: Cognitive Supporting Pilot Channel
CPG: CEPT Conference Preparatory Group
CPM: Conference Preparatory Meeting
CRS: Cognitive Radio System
DECT: Digital Enhanced Cordless Telecommunications
DFS: Dynamic Frequency Selection
DNS: Domain Name System
DSA: Dynamic Spectrum Access
DSO: Digital Switchover
DVB-T: Digital Video Broadcasting — Terrestrial
EC: European Commission
ECC: Electronic Communications Committee

EDGE: Enhanced Data rates for GSM Evolution
EGP: Egyptian Pound
EIRP: Equivalent Isotropically Radiated Power
eMBMS: Multimedia Broadcast Multicast Service
ERTU: Egyptian Radio and Television Union
FCC: Federal Communications Commission
FDD: Frequency Division Multiplexing
FPLMTS: Future Public Land Mobile Telecommunication System
FWA: Fixed Wireless Access
GCC: Gulf Cooperation Council
GDP: Gross Domestic Product
GE-06: Geneva 2006
GPRS: General Packet Radio Service
GPS: Global Positioning System
GSM: Global System for Mobile Communications
GSR: Global Symposium for Regulators
HAPS: High Altitude Platform Stations
HSDPA: High-Speed Downlink Packet Access
HSPA: High Speed Packet Access
HSUPA: High-Speed Uplink Packet Access
ICT: Information and Communications Technology
IDEN: Integrated Digital Enhanced Network
IDI: ICT Development Index
IEEE: Institute of Electrical and Electronics Engineers
IMT: International Mobile Telecommunication
IMT-2000: International Mobile Telecommunications-2000
IP-OFDMA: Internet Protocol – Orthogonal Frequency-Division Multiple Access (OFDMA)
IPTV: Internet Protocol Television
ISM: Industrial, Scientific and Medical
ITR: International Telecommunication Regulations
ITU: International Telecommunications Union
ITU-D: Development Sector of International Telecommunication Union
ITU-R: Radio Sector of International Telecommunication Union
ITU-T: Standardization Sector of International Telecommunication Union
JTG: Joint Task Group
LMDS: Local Multipoint Distribution Service
LSA: Licensed Shared Access
LTE: Long Term Evolution

MCIT: Ministry of Communication and Information Technology
MIFR: Master International Frequency Register
NIB: Non-Interference-Basis
NMC: National Media Council
NRA: National Regulator Authority
NTIA: National Telecommunications and Information Administration
NTRA: National Telecommunication Regulatory Authority
Ofcom: The Office of Communications
OFDM: Orthogonal Frequency Division Multiplexing
OOBE: Out of Band Emissions
PCAST: President's Council of Advisors on Science and Technology
PFD: Power Flux Density
PMR: Private/ Public Mobile Radio
PMSE: Program Making and Special Event
PSD: Power Spectral Density
QOS: Quality of Service
RA: Radiocommunication Assembly
RAG: Radiocommunication Advisory Group
RCC: Regional Commonwealth in the Field of Communications
RFP: Request for Proposal
R-LAN: Radio Local Area Network
RR: Radio Regulations
RRB: Radio Regulations Board
RRC: Regional Radiocommunication Conference
RSPG: Radio Spectrum Policy Group
SDL: Supplemental Downlink
SDR: Software-Defined Radio
SFN: Single Frequency Network
SG: Study Group
SND: Spectrum Networking Database
SPTF: Spectrum Policy Task Force
SRD: Short Range Devices
SUR: Spectrum Usage Rights
TAS: Time, Area, Spectrum
TDD: Time Division Multiplexing
TD-SCDMA: Time Division Synchronous Code Division Multiple Access
TE: Telecom Egypt
TETRA: Terrestrial Trunked Radio
TIES: Telecommunication Information Exchange Service

TPC: Transmit Power Control
TRA: Telecommunication Regulatory Authority
TUF: Titulo de Usufructo de Frecuencia
TVWS: TV White Spaces
UHF: Ultra High Frequency
UMTS: Universal Mobile Telecommunications System
U-NII: Unlicensed National Information Infrastructure
UWB: Ultra Wide Band
VHF: Very High Frequency
VSAT: Very Small Aperture Terminal
WAPECS: Wireless Access Platform for Electronic Communication Services
WARC: World Administrative Radio Conference
WCDMA: Wideband Code Division Multiple Access
Wi-Fi: Wireless Fidelity
WIMAX: Worldwide Interoperability for Microwave Access
WirelessMAN-Advanced: Wireless Metropolitan Area Networks - Advanced
WLAN: Wireless Local Area Network
WLL: Wireless Local Loop
WP: Working Party
WRC: World Radiocommunication Conference
WTO: World Trade Organisation

1 Introduction

1.1 *Background*

“*The ITU does not attract the sort of attention and analysis received by other international organisations…The apparent lack of drama at the ITU is one reason…But the importance of telecommunications to modern society makes the ITU too important to ignore*”.

James G. Savage, 1989.

The rapid growth in wireless services and the increasing demand for mobile broadband have called for re-examining how radio spectrum, a critical component in the delivery of wireless services, is managed. This has inspired several scholars to review the traditional approach to national spectrum management, ‘command and control’, where the regulator manages spectrum by designating appropriate uses, technologies and users (OECD, 2006). The command and control approach has been criticised for creating artificial scarcity that is due to inefficient utilisation rather than spectrum shortage (Wellenius and Neto, 2005).

The literature suggests three alternative approaches to overcome these challenges and to reform national spectrum management policies. The first one, spectrum market, calls for treating spectrum assignments in a similar way to other property rights and allowing spectrum usage flexibility so that service and technology neutrality occur (Coase, 1959, Hazlett, 1998a). The second approach, spectrum commons, enables spectrum open access to all users and as a result renders license exclusivity obsolete (Baran, 1995, Benkler, 1998, Gilder, 1994, Noam, 1995, Noam, 1998). The third approach, spectrum easements, is based on allowing other users rather than the spectrum owner to use the owner spectrum as a non-interference easement (Faulhaber and Farber, 2003).

Meanwhile, while few countries have reformed or planned to reform their national spectrum management policies, in most of the world, especially in the developing countries, radio spectrum is managed along the lines of traditional governmental administration although significant changes have been introduced to the telecommunications market (Wellenius and Neto, 2007). This could be due to different factors such as the influence of the public sector, especially the military, the absence of political support for such reform, and the difficulty to re-farm current spectrum assignments (El-Moghazi et al., 2008).

However, one potential factor that is largely overlooked in the debate is the interaction between national spectrum management policies and the international spectrum management regime and the influence of such interaction on national policy reform. More specifically, the literature does not explain the influence of such interaction on national spectrum policy reform from command and control towards spectrum market, commons and easements approaches. This is important as the international spectrum management regime was created in line with the formulation process of national policies at the early days of wireless communication to handle interference and to enable international operability. The main principles underpinning the regime have not been changed since then. By investigating such interaction, this research will investigate whether the international regime is considered to be a restriction on national policy reform.

1.2 *Research Objectives*

This research has examined the influence of the international spectrum management regime on national radio spectrum policy reform. This has been motivated by the recognition that most of the debate on spectrum policy addresses the pros and cons of the alternative spectrum management approaches while it largely overlooks the influence of the international regime. However, investigating the whole influence on the different spectrum management approaches and vice versa is beyond the time and resources available to this research.

Therefore, it was decided to focus on some particular issues of an importance, radiocommunication service allocation flexibility, technology neutrality, and opportunistic access in the TV White Spaces (TVWS), which are considered as main elements of the three alternative approaches to command and control. In addition, while the international regime has an influence on spectrum policy at the national level, it is recognised also that there is the influence of the national regulators on the international regime in order to integrate their interests. Hence, the research addresses the interaction between the two spheres of international regime and national policies to explore the interplay and relationship between them.

It is also acknowledged that although spectrum policy is the decision of national regulator, it is the output of complex interactions between the different actors within the national spectrum policy domain. Hence, this research takes a more holistic view into the spectrum policy debate and perceives the international regime and national policies as the result of interaction between the different stakeholders and not limited to national regulators (e.g. operators, broadcasters, manufactures).

Having said that, the research main question is formulated to be **'How do the international radio spectrum management regime and national radio spectrum management policies interact?'** More specifically, three sub-questions are formulised to address the interaction with regard to three main concepts: **radiocommunication service allocation flexibility, technology selection neutrality, and opportunistic access in the TVWS.**

In order to achieve that, this research takes an empirical approach that focuses on two case studies, Egypt and UAE. Data was collected through interviews with main national and international actors. More specifically, the research examines the influence of the international radiocommunication service allocation framework on flexibility regarding service allocation on the national level. The research also explores the interaction between mobile standardisation activities at the Radio Sector of the International Telecommunication Union (ITU-R) and national regulators' decision with regard to technology selection and technology neutrality. Finally, it studies the interaction between the international regime and TVWS national deployment.

1.3 *Thesis Structure*

This thesis is structured as shown in Figure 1-1. This chapter has presented a background on the research and its objectives. The rest of the chapter illustrates the thesis structure and ends with the research's main finding.

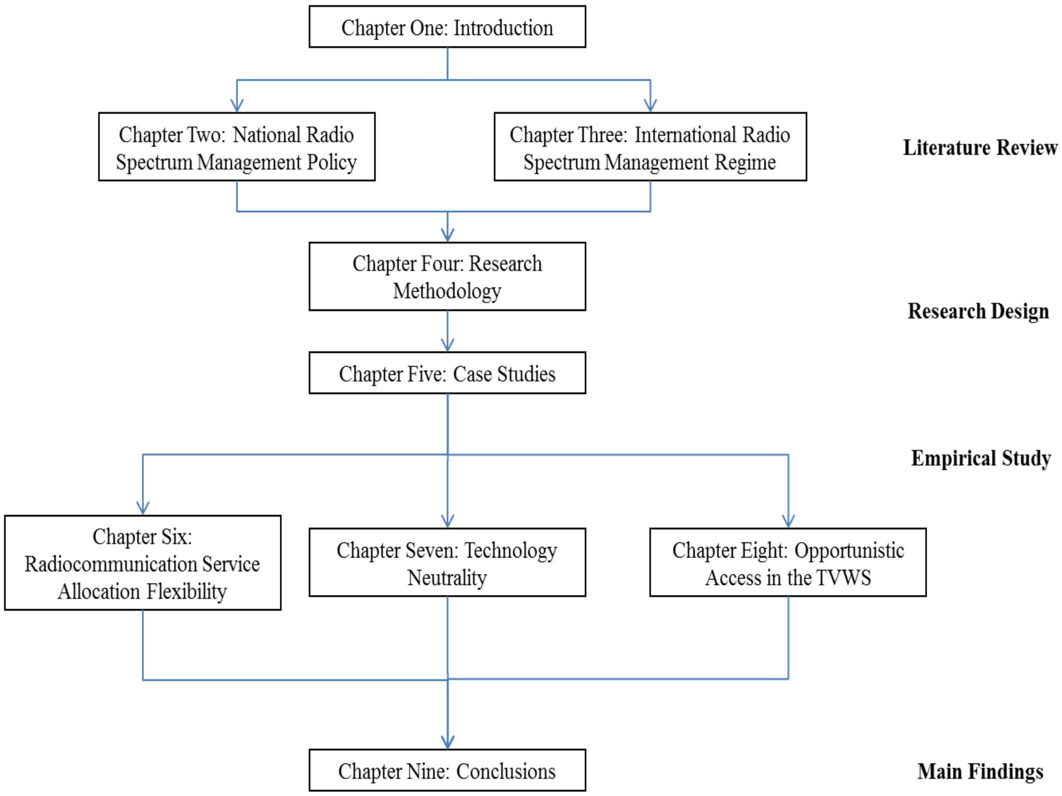

Figure 1-1: Structure of the Thesis

Chapters two and three present the literature review needed for this research. Chapter two provides background information on the radio spectrum and its management. It analyses national radio spectrum management policies in terms of four main elements: radiocommunication service allocation, technology selection, usage rights, and frequency assignments. The chapter also covers the four main approaches for spectrum management on the national level: command and control, spectrum market, spectrum commons, and spectrum easements.

Chapter three explores the main principles of spectrum management on the international level. It starts with brief background on international regimes in general and traces the origins of the international spectrum management regime. The chapter also analyses the international regimes in terms of the same four elements that were used in analysing national spectrum management policies.

Chapter four addresses the different elements of the research methods adopted for this research. It identifies the research gap based on the literature review in Chapters two and three and then it highlights the conceptual framework that was driven from the existing theory in the literature. The chapter then defines research philosophy, approach, strategy, data collection, and data analysis techniques. Finally the chapter clarifies the process of conclusion drawing and verification.

Chapter five explores the two selected studies, Egypt and UAE, starting by a brief background on both countries and their telecommunication market. The chapter then analyses these two countries' national policies in terms of four main elements: service allocation, technology selection, usage rights, and assignment type. The chapter also examines the interaction of each country with the ITU-R. Finally the chapter ends with exploring the ITU-R as an international organisation.

Chapters six, seven, and eight address the three main questions of the research. Chapter six handles the radiocommunication service allocation concept. It starts with the perceptions of the interviewees from Egypt and UAE on the concept and the applicability of the concept in these two countries. The chapter then explores the interaction between the international spectrum management regime and national spectrum management policies with regard to radiocommunication service allocation flexibility from the perspectives of the Egyptians, Emirates, and international interviewees. The chapter also examines the main elements of the international service allocation framework: a priori planning, decision making procedures, footnotes, MIFR, and the three regions system.

The second research question is addressed in Chapter seven, which handles the technology neutrality concept. It starts with the perceptions of the interviewees from Egypt and UAE on the concept its applicability in these two countries. The chapter then explores the interaction between the international regime and national policies with regard to decisions related to technology neutrality and technology selection from the perspectives of the Egyptians, Emirates, and international interviewees. Finally, the chapter addresses the influence of International Mobile Telecommunication (IMT) standardisation and IMT spectrum identification.

Chapter eight addresses the third question on opportunistic access concept in the TVWS. It starts with the perceptions of the interviewees from Egypt and UAE on the concept and discusses its applicability as well in these two countries. The chapter then explores the interaction between the international regime and national policies with regard to decisions related to adopting the concept from the perspectives of the Egyptians, Emirates, and international interviewees. The chapter also addresses the perceptions of the interviewees on the TVWS devices radiocommunication service status and the influence of the WRC-12 decision on Agenda Item (A.I.) 1.19. It then examines the similarity of the case of TVWS with the case of Radio Local Area Network (R-LAN) in the 5 GHz. Finally, Chapter nine presents the main findings of the thesis, research limitations, and future research to be undertaken.

1.4 *Main Findings*

This thesis has made a number of interesting findings in relation to the interaction between international regime and national policies. The main finding is that the international spectrum management regime does not prevent adopting radiocommunication service allocation flexibility, technology neutrality, or opportunistic access in the TVWS. However, there are different elements of flexibility (support) and restriction (opposing) that have an influence on regulators' flexibility regarding radiocommunication service allocation, regulators' tendency towards technology neutrality, and deployment of opportunistic access in the TVWS. These elements are dependent on the country's geographical position, country's relationship with neighbouring countries, perceptions on technology neutrality, perception on the TVWS concept, size of country market, being advanced in technology, interpretation of the international regulations, national telecommunication market status, and usage dependency on the international regime's elements (e.g. footnotes).

2 National Radio Spectrum Management Policy

2.1 *Introduction*

This chapter presents a literature review of spectrum management on the national level. Section 2.2 starts with a brief introduction on the radio spectrum per se. Section 2.3 presents an overview on spectrum management in general and how it has evolved around the world. Section 2.4 analyses spectrum management on the national level into its main elements: radiocommunication service allocation, technology selection, usage rights, and assignment type. Moreover, Section 2.5 discusses the different combinations of spectrum management elements, which formulate national spectrum management policies: command and control, spectrum market, spectrum commons, and spectrum easements. Finally, Section 2.6 concludes.

2.2 *Radio Spectrum*

The word spectrum itself means the distribution of a characteristic of a physical system or phenomenon or the range of values of a quantity or set of related quantities (Dictionaries, 2001). Radio is defined by the ITU as "*Electromagnetic waves of frequencies arbitrarily lower than 3000 GHz, propagated in space without artificial guide*" (ITU-R, 2008a:7). Electromagnetic waves include all possible frequencies of electromagnetic radiation including radio, visible light, X-Ray and Gamma ray. Radio spectrum is the distribution of the radio frequencies and each frequency represents a portion of the radio spectrum. The term 'spectrum' is usually used instead of 'radio spectrum' to indicate the same meaning.

Spectrum is a finite but non-exhaustible resource. It is finite because the range of radio frequencies that is suitable for wireless communications is limited to the spectrum bands from 9 KHz to 3000 GHz. It is non-exhaustible because it is infinitely renewable and not consumed by use. Moreover, spectrum is a non-homogenous resource as it has different characteristics according to the frequency band. For instance, the reusing of frequencies below 100 MHz is difficult because they are capable of propagating for very long distances. On the contrary, spectrum above 5 GHz propagates for short distances (Cave et al., 2007a). In addition, using the same frequencies by multiple users at the same place and time leads to usage distortion for all or some of the users in an effect called interference. The interference issue requires coordination between the different users.

Radio spectrum is a main component in delivering wireless services to the society. TV, radio, GPS (Global Positioning System), and Wi-Fi are all examples of benefits that spectrum can offer to the public. Spectrum was firstly utilised for wireless transmission in 1895 when Alexander Popov and Guglielmo Marconi transmitted a wireless signal for short distance in Russia and Italy. Shortly afterward, the first human voice was broadcasted in 1906 (Timofeev, 2006). In addition, one of the first commercial radio systems was built by the Marconi Wireless Telegraph Company and it linked coastal radio stations and board ships (Anker and Lemstra, 2011). The next section presents an overview on spectrum management in general and how it has evolved around the world.

2.3 *Radio Spectrum Management*

In general, spectrum management accommodates allocating the different spectrum bands to different radiocommunication services (e.g. fixed, mobile), authorising users to access particular parts of the spectrum, managing type approval and electromagnetic compatibility standards for wireless devices, and monitoring spectrum use to restrain unauthorised use (Cave et al., 2006). The way spectrum is managed has evolved with time until it has reached its current format. In particular, at the early day of wireless communications, spectrum was perceived as a new inexhaustible natural resource commonly and freely used by the public (Struzak, 2003).

However, the issue of interference became quite apparent for different reasons. Firstly, radios transmitted over a wide band of frequencies due to the lack of knowledge on how to tune transmitters and receivers. Secondly, measures of wavelengths could not be estimated before 1905. Thirdly, many operators preferred to transmit over wide range of frequencies to avoid precise adjustment of receivers. Finally, transmitters used to transmit with large power to reach long distances. All of these issues called for changing the view of spectrum from a commodity to a scarce resource that needs to be managed (Kruse, 2002).

At the beginning of the 20th century, diverse alternatives of spectrum management approaches were discussed (Kruse, 2002). For instance, in the US, one vision was to have the navy regulating and operating the wireless coasting stations while limiting the commercial wireless firms' activities to research and manufacturing. One other proposal was to have cooperative and mixed regulatory approach in which the navy and commercial firms operate the coastal stations while the final authority over civilian users is to the commerce department.

The debate outcome varied across the world. In particular, the first law to control the spectrum was issued in 1903 in New Zealand and it granted the government the sole rights over wireless communications (Lie, 2004). In the US, two laws were issued (the Wireless Ship Act of 1910 and the Radio Act of 1912) to regulate wireless communications. Half of the spectrum was reserved for governmental usage, and private users were required to acquire a license to operate by the Secretary of Commerce (Marcus, 2004). This was mainly motivated by the Titanic tragedy which led to allocating large portions of the spectrum to the US Navy (The IEEE – EMC Society, 2007).

In 1925, the Secretary of Commerce declared that there is no space in the spectrum for further assignments and therefore, stopped issuing new licenses. A year later, the US Attorney General declared that the Secretary had no authority to define any rights to spectrum. Surprisingly, instead of appealing against such decision, the Secretary decided to issue open access licenses without any fees. This led to a radio chaos that was not resolved until the issue of the Federal Radio Act of 1927. The Act envisioned the spectrum as a public property that is regulated by the Federal Radio Commission, which later became the Federal Communications Commission (FCC). In the UK, the Telegraph Acts of 1868 and 1869 regulated wireless communications. In 1904, the Post Office was considered as the wireless regulator and the government then nationalised the private wireless shore stations(Marcus, 2004).

Since then, spectrum has been strictly regulated by governments for several reasons including national security of radio applications especially wireless telegraphy and immaturity of radio technology in its early days. (Horvitz, 2013). As clarified by Horvitz (2013:8) "*Government regulation was another way to compensate for the hardware's inadequacy*". The third reason was the Marconi monopoly over wireless telegraphy, which motivated governments to establish national sovereignty over the radio spectrum. Freyens (2009) points out that the governmental approach was the conventional way to manage the spectrum from the early 1930s until 1994 where the FCC conducted its first spectrum auction ever (Cramton, 2002). The next section analyses spectrum management on the national level into its main elements.

2.4 *National Radio Spectrum Management Policy: An Analysis*

National spectrum management policies are not similar and vary around the world according to the local regulations and circumstances. For instance, in the US, NTIA is responsible of assigning frequencies to all federal government owned and operated radio stations (Cave and Morris, 2005). Moreover, in Tunisia, there is a separate entity from the regulator that is responsible for spectrum management (Agence Nationale des Fréquences (ANF), 2012). Therefore, it is not an easy task to determine common foundations for national spectrum management policies in general without considering particular cases.

However, there have been some attempts to analyse national spectrum management policies in terms of their main dimensions or elements. For instance, Chaduc and Pogorel (2008) argue that there are four elements that determine the type of spectrum management approach or policy: radiocommunication service allocation, technology selection, usage rights, and assignment type. Freyens (2009) adopts slightly different elements for categorisation such as usage flexibility, rights exclusivity, club membership, rules control, and rights assignment. This research will adopt the four elements categorisation system of Chaduc and Pogorel (2008) for its clarity and simplicity. In the next four sections, the four main elements are explored are discussed in detail.

2.4.1 Radiocommunication Service Allocation

The first element, service allocation, is the distribution of the spectrum to the different radiocommunication services (Foster et al., 2011) where a service is defined as transmission, emission and/or reception of radio waves for specific telecommunication purposes (ITU-R, 2012c). More specifically, it determines the use of a given frequency band by one or more terrestrial or space radiocommunication services or the radio astronomy service (ITU-R, 2008a). Service allocation could be flexible/neutral or harmonised. Harmonisation refers to the common designation of bands for particular radiocommunication services in different countries (Indepen and Aegis Systems, 2004). On the other hand, service flexibility or neutrality implies that any radiocommunication service can be offered in the frequency band of interest (Frullone, 2007).

Harmonisation is useful in mitigating interference, reducing cross-border coordination requirements, promoting international mobility, and decreasing equipment costs. In addition, spectrum liberalisation may reduce compatibility and interoperability and decrease values of harmonised spectrum (Friederichs and Mohyeldin, 2007). However, harmonisation could also lead to restrictions on use of underused or unused spectrum for alternative uses, and on the ability to re-farm spectrum for new services (Indepen and Aegis Systems, 2004, Chaduc and Pogorel, 2008). Therefore, Cave (2002) argues that harmonisation should be time limited until it enables manufacturers and operators to deliver a cost effective service. After that, the market should be opened for other services.

It should be noted that there are other types of allocating spectrum other than by service (ITU-R, 2001b, Eurostrategies and LS-Telecom, 2007). For instance, spectrum could be allocated based on grouping services that have similar characteristics together or by categorising services according to the service area of the radio system application (e.g. terrestrial point to point, space earth to space). Spectrum could also be divided into bands where low, medium and high power services existed or divided on the basis of the amount of interference one could expect to encounter in using a specific band of spectrum.

2.4.2 Technology Selection

The second element of spectrum management policy is technology selection. Selection of technologies could be neutral, restricted to standardised technologies, or selective of specific technologies. Standardisation refers to the level of specification of allocated services such as transmitter power, channelisation, and interoperability. On the other hand, technology neutrality is defined by Foster (2008) as the minimum applied constraints while ensuring that interference is appropriately addressed. Whittaker (2002) argues that true technology neutrality implies defining conditions without any biased assumptions.

An important element of technology selection is channel planning which is defined by Chaduc and Pogorel (2008) as the intermediate stage between harmonisation of service allocation and technology standardisation. Channel planning accommodates two types of channel: duplex mode, frequency division duplex (FDD) and time division duplex (TDD), and the width of the channel (e.g. 10, 20 MHz).

The main advantage of standardisation is that it allows large production scale, which reduces the cost of the equipment. Benefits of standardisation include also avoiding harmful interference and promoting interoperability between terminals and networks. Anker and Lemstra (2011) argue that national regulator usually prefers to select a standardised technology because it obviates the need for specifying particular technology characteristics as part of the licensing process.

On the other hand, standardisation may lead to lock-in to an inferior standard and delays in the introduction of new equipment (Pogorel, 2007, Indepen and Aegis Systems, 2004, London Economics, 2008). An example of the failure of regulators in selecting the right technology is the enhanced radio messaging system (ERMES) which was an initiative to create a Europe-wide mobile messaging system that ended with no significant implementation (Cave, 2002).

2.4.3 Usage Rights

The third element of spectrum management policy is usage rights. Chaduc and Pogorel (2008) define three categories of spectrum usage rights: exclusive , exclusive with easement, or collective (non-exclusive). In order to understand the concept of property rights in spectrum, it is useful firstly to understand what property rights mean in general. Demsetz (1967) points out that property rights develop to internalize externalities when the gains of internalization become larger than the cost of internalization. In other words, property rights are developed only when their benefits exceed their expenses. Furthermore, Hazlett (2006) defines four categories for property in terms of access rights: open access property in which there is no restriction on usage, state property where access rules are determined by the state, common property where access rules are determined by owners, and private property where access rules are determined by a single owner.

Exclusive property rights in spectrum entails licensing clean spectrum, free of interference to the licensee. While this encourages operators to take financial risks and invest in establishing wireless networks, it may create market entry barriers and decrease competition (Chaduc and Pogorel, 2008). Secondly, an easement is a certain right to use the property of another without possessing it. Hence, exclusive spectrum property rights with easements entails allowing other users to access a spectrum that is owned or licensed to a particular entity without causing harmful interference. Easements exist in many cases but with different extents. For instance, some spectrum bands accommodate sharing between fixed terrestrial and satellite radiocommunication services with both users of the two services have exclusive property rights (Chaduc and Pogorel, 2008). The third type is collective usage rights and it entails common access to the spectrum without having exclusive property rights in the spectrum by a particular entity. While this has the benefits of decreasing entry barriers and promoting innovation, it adds significant technical constraints and increases the risk of interference (Chaduc and Pogorel, 2008).

It should be noted that there are differences between the type of usage rights and the type of spectrum access. Exclusive property rights entail that spectrum be exclusively owned by an entity that has the right to determine access rules to the spectrum. This access could be individual or collective. To elaborate, let's consider three different cases. The first case represents a company that have a license to use a single frequency in the VHF band for internal communication within the company. The second case is a mobile operator that has an exclusive license to wide frequency band to provide services to the end users. The third case is common frequency band that is open for usage for public (e.g. 2.4 GHz). While in the first case access to the spectrum is for individuals, in the second and third cases access is on collective basis. Moreover, the first and second cases represent exclusive property rights in terms of usage rights while the third case entails collective usage rights.

2.4.4 Frequency Assignments

The fourth element of spectrum management policy is frequency assignment where there are three categories: administrative, market-based, or license exempt (Chaduc and Pogorel, 2008). Administrative assignments could be conducted through first-come first-served basis, beauty contest, comparative bidding, or lotteries (ERC, 1998). In the former, the license applications are dealt with in the order of their receipt and the license is granted when the applicant fulfils the application criteria. Additionally, while in beauty contest applicants submit their proposals (e.g. population coverage, service speed) to be assessed by national regulator, in comparative bidding applicants submit a cash bid in addition to their proposals. In lotteries, regulators choose randomly from the applicants.

There are two types of assignments within the market-based approach: spectrum auction and spectrum trading (secondary market). Firstly, auctions are transparent flexible means of employing price mechanism to the spectrum (Cave and Valletti, 2000). Secondly, spectrum trading is a way of applying free market of spectrum assignments where they could be transferred to other users as long as there is no harmful interference (ITU-R, 2004). It is worth mentioning that both of trading and auction are not mutually exclusive. Spectrum could be initially auctioned and then traded. Finally, in license exempt assignment, access to the spectrum does not require a license from the regulator. The next section discusses the different combinations of four spectrum management elements, which formulate national spectrum management policies.

2.5 *National Radio Spectrum Management Policy Approaches*

The different combinations of the four previously mentioned elements, service allocation, technology selection, usage rights, and frequency assignments formulate several approaches to spectrum management on the national level. Meanwhile, there is no common view on the number and naming of the different national spectrum management approaches. For instance, Pogorel (2007) has the views that there are nine spectrum management policies on the national level. Furthermore, he labels the 'open access' approach proposed by Noam (1995) by the term 'California dream' and the 'easements' approach proposed by Faulhaber and Farber (2003) by the term 'technical command and control plus mitigated market'. Therefore, it was decided to focus on the four main approaches that are considered in most of the literature: command and control, spectrum market, spectrum commons, and spectrum easements. The next four sections address each approach of them with more detail.

2.5.1 Command and Control

The command and control approach is based on allocation harmonisation, standardised technology, exclusive property rights and administrative assignment (Chaduc and Pogorel, 2008). Within such approach the regulator manages spectrum by designating appropriate uses, technologies and users (OECD, 2006). This traditional approach to spectrum management worked well for many years due to several reasons. Firstly, there was a small number of wireless services that evolved at a slow pace (Wellenius and Neto, 2005). Secondly, there were enough frequencies to accommodate most of the users (Wellenius and Neto, 2005). Thirdly, the command and control approach was and is still useful in achieving international spectrum harmonisation for a particular service, and adopting global technical standards to provide interoperability and economies of scale (OECD, 2006).

Besides, command and control is a main tool for national regulators to achieve public interest goals such as coverage requirements and ubiquity of services (Cave et al., 2007b). Controlling the use of the spectrum makes it easier to manage harmful interference as regulators would be able to model the interaction between neighbouring services and tailor license conditions (Cave et al., 2007b). Command and control is also argued to be suitable for services such as broadcasting where governments tend to control the number and identity of broadcasters (Cave, 2006). Finally, the telecommunications industry was perceived as a ‘natural monopoly’ that is not suitable for competition (Ratto-Nielsen, 2006).

Several issues have called for reviewing and reforming the command and control approach. The first issue is the movement of telecommunications market liberalisation that started in the US and spread around the world that resulted in a competitive market in the wireless industry (Ratto-Nielsen, 2006). Shortly after that, the FCC was the first regulator to adopted auctions in spectrum assignment in the US in 1994 (Kelly and LaFrance, 2012). The second issue is the rapid growth in wireless services, especially mobile phone services, which increases the demand for spectrum (Wellenius and Neto, 2005). In addition, most of the valuable spectrum has already been assigned in many countries to particular users or entities (Wellenius and Neto, 2005). Therefore, it has become difficult for new services to find vacant spectrum that can accommodate their needs.

Thirdly, operators have been facing shortage in spectrum needed for demand growth in broadband services. In particular, the growth in mobile data traffic is almost doubling every year (Cisco, 2012). In a study by Cisco, it is expected that global mobile data traffic will increase 18-fold between 2011 and 2016 (Cisco, 2012). Besides, the introducing of Fourth Generation (4G) services has generated more data traffic where a 4G connection generates 28 times more traffic on average than a non-4G (Cisco, 2012). It is argued also that the reason behind such growth in data is the increasing utilisation of video services such as movies on demand and the emergence of widely used internet social networks such as ‘Facebook’. Furthermore, operators need spectrum not only for capacity but also for providing new applications and services and to compete with the over the top service providers.

Fourthly, several technical studies have indicated that spectrum utilisation efficiency is quite low. For instance, a study by ‘Shared Spectrum’ shows that 62% of the spectrum band 30 MHz – 3 GHz is unutilized during peak hours in a dense urban area covering both civilian and military use (The New America Foundation and The Shared Spectrum Company, 2003). Another study shows that 95% of the government's spectrum in the US is not being used at any given time (Economist, 2004). Fifthly, innovation in technologies, such as spread spectrum, has called for reviewing the way spectrum is managed (Wellenius and Neto, 2005).

In addition to all of the previous issues, there are several deficiencies associated with the command and control approach. For instance, such approach could create artificial scarcity that is due to spectrum underutilisation and inefficient use rather than shortage in the available spectrum (Wellenius and Neto, 2005). Moreover, Lehr (2005) points out how this artificial scarcity distorts the opportunity cost of spectrum[1]. More specifically, the opportunity cost is high for new users who desire to adopt new technologies and services because of the high spectrum fees and restricted access to spectrum. On the other hand, opportunity cost is low for governmental agencies and incumbents as they face little incentive to invest in enhancing their spectrum usage by adopting new technologies or other means.

Furthermore, Cave et al. (2006) explain that regulators traditionally have been focusing on promoting the public interest while delaying the introduction of new

[1] Opportunity cost is the value of something in its best alternative use.

technologies and services and artificially increasing services' cost. Hazlett (2001) asserts that the public interest concept is vague which allows the regulator a maximum degree of freedom to restrict access to the spectrum. He further explains that regulators usually tend to monitor inefficiency resulted from over-utilisation rather than those associated with under-utilisation. Opportunities for new services and technologies are usually under-weighted by the regulator comparing to existing ones. Furthermore, Marcus (2004) argues that the radio history proofs that government suppressed more technology than it promoted. For instance, although spread spectrum technology was invented back in the 1940s, it was classified by the government until it was reinvented in the 1960s. It is also argued that regulators usually favour inaction, as they do not face tangible deficits if new entrants are blocked. Furthermore, they cannot anticipate or measure the benefits and cost provided by the market.

The previous issues have motivated several regulators to revise their spectrum policy. For instance, in the US, the National Telecommunications and Information Administration (NTIA) reviewed the fundamental spectrum policy objectives in 1989 (FCC, 2002). Following that, the Spectrum Policy Task Force (SPTF) was established in 2002 and one of its recommendations was that the spectrum policy should balance between granting of exclusive spectrum usage rights through market-based mechanisms and spectrum commons while using command and control in limited circumstances (FCC, 2002). In addition, it recommends applying flexibility in selection of services and technologies while allowing secondary market in spectrum rights.

In Europe, the European Commission (EC) issued a green paper in 1998 on radio spectrum policy requesting comments on issues such as harmonisation of radio spectrum allocation and radio spectrum assignment and licensing (European Commission, 1998). In the UK, Professor Martin Cave was appointed in 2001 to lead an independent review of radio spectrum management (Cave, 2002). Cave (2002) calls for a market-based approach that enables spectrum trading into commercial use of spectrum and gradually extend the market mechanism to other public services. The next three sections explore the three main potential alternatives to the command and control approach: spectrum market, spectrum commons, and spectrum easements.

2.5.2 Spectrum Markets

The market approach is based on radiocommunication service allocation flexibility, technology selection neutrality, exclusive property rights and market-based assignment (Chaduc and Pogorel, 2008). In such approach, it is argued that private operators are more knowledgeable of the market and will choose the optimum service to the consumers (Hazlett, 2001). The origin of market approach could be traced back to the dilemma that the FCC faced in choosing between three different standards for transmitting systems of colour television signals in 1951 (Herzel, 1951). The FCC performed what can be called a technical beauty contest and adopted only one standard. Herzel (1951) suggests a revolutionary solution at that time to use an auction to choose among the competing standards.

Herzel (1998) explains afterwards that his main concern at that time was not using auction as much as having packages of spectrum rights and obligations. Smythe (1952) defends the FCC position at that time by explaining that the different spectrum users should be treated differently according to their activities (especially governmental agencies) and therefore bidding cannot be used as the mechanism to choose among them. Herzel (1952) responds by arguing that radio spectrum is similar to any other object (e.g. equipment) that users compete for.

Coase (1959) supports Herzel's argument in his seminal contribution 'the federal communications commission' and suggested that spectrum assignments should be treated in a way similar to property rights. Coase also argued that the aim of the regulator should be to maximise the output and not to minimise the interference and that interference should not be an issue as long as the gain from it is much more than the harm it produces. Coase (1960) generalises his argument afterwards in his Nobel Prize article 'the problem of social cost' and suggests an approach toward dealing with harmful effects on others that is based on comparing the total social product yielded by alternative social arrangements. Therefore, interference by one user against the other could be allowed if society benefits are much more rather than in the case of delimiting interference.

Rothbard (1982) opposes that view and argues that the first user of a resource has the property rights so that the user who last operates would be responsible of resolving the interference. By applying Coase's view into the issue of interference in wireless communication, Cave and Webb (2003) suggest that interference could be allowed into neighbouring bands if the value of the increase in capacity and/or reduction in equipment cost is greater than the value of the loss at the neighbour side due to the interference.

In general, Baumol and Robyn (2006) define three main elements of the market-based approach. The first is to design exclusive property rights to the use of the spectrum in a specific geographic area and applying technical rules to limit the interference between licensees. The second is using auction method for the initial allocation of spectrum rights and applying a secondary market method. The third is allowing maximum flexibility to the types of commercial services that can be provided in the licensed spectrum. In the next sections each of these elements is closely examined.

2.5.2.1 **Spectrum Property Rights**

The first attempt to design spectrum property rights was made in 1969 when Vany et al. (1969) proposed a spectrum property right package called 'TAS' that stands for time, area, and spectrum. However, the proposal was abandon by the FCC. Following that, many scholars attempted to find alternative designs for spectrum property rights but none of them were implemented in practice (Cave and Webb, 2003, Cave and Webb, 2012, Vries and Sieh, 2012). The practice of spectrum property rights has varied around the world with no case of significant success. For instance, the Ofcom developed a model called 'spectrum usage rights (SUR)' as a way of defining spectrum property right. SUR specifies the maximum level of interference that can be caused, rather than the power that can be transmitted (Ofcom, 2008). There were some difficulties associated with SUR (Eurostrategies and LS-Telecom, 2007), and accordingly the approach has not been widely applied. In addition, the FCC studied an approach to define spectrum property rights called 'interference temperature'. In this approach, transmission is permissible as long as the resulting interference at any unintended receiver does not exceed a certain level (Evci and Fino, 2005). The approach was quite complex that the FCC decided in 2007 to abandon it as it is not practical and may increase the interference levels (Weiser and Hatfield, 2008).

Furthermore, Guatemala applied in 1996 a private property rights approach to spectrum management. In such approach, spectrum rights are called 'titulo de usufructo de frecuencia (TUFs)' and they define ownership by specifying parameters such as the band or frequency ranges, hours of operation, geographical coverage area, maximum effective radiated power by the TUF holder, and maximum field strength or signal strength on the border of the coverage area (Hazlett and Muñoz, 2006). Another approach that was adopted in Australia is called space centric management and is based on defining maximum transmit power at the antenna rather than maximum field strength away from the antenna (Whittaker, 2007). It is worth mentioning that while there is no much literature on the assessment of the influence of these approaches, Deffains (2013) clarifies that the concept of property rights has helped solving some interference situations without referring explicitly to the concept but rather by adopting it implicitly (e.g. interference from 4G base stations into radars systems and TV receivers in France).

2.5.2.2 **Auctions**

Spectrum auctions were firstly introduced in the US in 1994 and since then, there have been calls to expand the FCC's auction authority to encompass new frequency bands and new wireless services including unlicensed services (Kelly and LaFrance, 2012). The FCC was also the first to use simultaneous multiple round auction design that allows participants to bid for spectrum at different territories at the same time (Oranje et al., 2008). The success of spectrum auctions have encouraged Kwerel and Williams (2002) to suggest the FCC to auction spectrum voluntarily offered by incumbents and any unassigned spectrum in a large-scale two-sided[2] 'band restructuring' auctions, in what is called 'big bang auction'.

Arguments in favour of auctions include being transparent flexible means of employing price mechanism to the spectrum while achieving policy objectives (Cave and Valletti, 2000). In addition, auction bids reflect anticipated services' prices and therefore, higher auction fees do not imply higher prices for the end users (Hazlett, 1998b). On the other hand, auctions may create barriers to small entrants and to cut down free and non-profitable services. Noam (1998) also argues that auctions are used mainly to raise revenues for governments.

[2] Auctions are classified as either one-sided or two-sided. In two-sided auctions both bids and asks are allowed. Bids are the amounts offered by the potential buyers to purchase the item. Asks are prices offered by the seller. A transaction is created when the bid and ask prices match. One-sided auctions, however, only allows bids and the auction goes to the highest bidder.

Auctions have been widely used around the world since the FCC auction in 1994 and were used to sell over 100 billion$ around the world (McAfee et al., 2010). However, Cave and Foster (2010) explain that the practise of spectrum auction has not proved successful in some cases due to several reasons including: political interference (preferences and reserve prices), the failure to perceive the importance of the interaction of auctions among different countries, high opening bid prices set by the regulator, inadequate spectrum packages, inappropriate reserve prices, unrealistic expectations by bidders, flawed bidding rules, collusion by participants and excessive service obligations. In addition, there are concerns that auctions usually result in raising the value of a license and in delaying the deployment of services (Cave, 2002a).

2.5.2.3 **Trading**

Spectrum markets are argued to enhance the utilisation efficiency of spectrum provided that property rights are fully and precisely defined and there are no transaction costs (Cave and Webb, 2003). Cave (2008) points out that although auctions are useful in initially allocating the spectrum to those who have the highest value for it, trading of spectrum between the different users ensure that this is the case even if the valuation of spectrum change over time. Argument in favour of spectrum trading is that it creates incentives for users to apply their spectrum to the highest-valued uses as determined by the market (OECD, 2006), and that it also removes artificial scarcities arising from the administrative allocation of the spectrum (Wellenius and Neto, 2005). Spectrum trading offers auction bidders a safety net in case their business proves to be unsuccessful and could also provide companies that lost out in an auction with the opportunity to acquire a license, possibly at a reduced price (WIK, 2006).

On the other hand, there are concerns that trading might increase interference among users and constrain harmonising services in adjacent spectrum bands (OECD, 2006). In addition, trading might allow spectrum hoarding by incumbents seeking to restrict competition (Wellenius and Neto, 2005). Trading cannot be adopted in cases where current spectrum fees do not reflect spectrum economic value (Falch and Tadayoni, 2004). Moreover, users may not be aware whether they will be affected by interference until the transmission begins (Cave and Webb, 2012). Trading could also lead to extensive fragmentation of spectrum assignment where extensive negotiations between users and many guard bands are needed (Indepen, 2001).

In general, the practice of trading has not proven to be widely successful for several reasons in the UK and US (Benkler, 2011, Akalu and Arias, 2012, Cave et al., 2007b). In particular, it is argued that the nature of spectrum services limits the effectiveness of trading as there are generally three types of spectrum licenses (El-Moghazi et al., 2012). The first one includes large number of licensees with small band of spectrum, such as Private Mobile Radio (PMR). In such case, trading is part of merging, or change of ownership. For instance, the percentage of PMR trading transactions in the UK, the pioneering country in spectrum trading, comparing to total number of licenses is 4.3% (Electronic Communications Committee (ECC), 2011).

In the second type, there is a small number of licensees with large band of spectrum, such as mobile operators. In such case, market is relatively stable and spectrum is a precious asset so that number of trading transactions is almost none. In the third type, spectrum license is customised for the licensee’s business. For instance, a fixed link license is used to connect two sites of the licensee. In such case, license is only critical to the licensee and of no importance to the others. This is evident in France where there are 30000 fixed link licenses and although trading is allowed, no transaction ever happens (Electronic Communications Committee (ECC), 2011). In addition, the nature of wireless services in terms of dominance of mobile service, convergence of several applications on the IP platform, uncertainty associated with interference resulted from incompatible services or technologies, economies of scale resulted from harmonised technologies, existence of a long roadmap for current technologies limit the effectiveness of spectrum trading or spectrum property rights.

2.5.2.4 Flexibility

Spectrum flexibility entails that the holder of spectrum property rights has the right to determine the use of the spectrum rather than the regulator in the case of command and control approach. The practise of introducing flexibility has varies across the world. One example of flexibility was when the FCC auction spectrum for multipurpose ‘wireless communications service’ in 1997. However, the auction resulted in little revenue due to the uncertainty regarding the potential spectrum use (Goodman, 2004). In Europe, a concept called Wireless Access Policy for Electronic Communication Services (WAPECS) was introduced to enable more flexibility within the EU spectrum management framework by allowing using the spectrum on a technology and service neutral basis within certain technical requirements to avoid interference.

The initiative was based on replacing traditional service and technology combination by what is called ‘electronic communications services’ where mobile, portable, or fixed access could be provided under one or more frequency allocations (mobile, broadcasting, fixed), deployed via terrestrial and/or satellite platforms using a variety of technologies. The industry response to the WAPECS approach was that they prefer harmonised frequency arrangement and that the cost associated with a more flexible use of spectrum in terms of band plan neutrality is high (CEPT, 2010).

Furthermore, in El Salvador, a liberal approach to spectrum management was applied in 1997 where spectrum assignments are technology neutral. In addition, although the regulator allocates specific service to each spectrum band, users can deviate from such allocation without a penalty. Assignments extend for 20 years and are auctioned in case of multiple applicants, and can also be transferred or subdivided in frequency, geographic, and time dimensions without regulatory approval (Hazlett and Muñoz, 2006).

2.5.3 Spectrum Commons

Before examining the spectrum commons approach, it is useful to explore the commons concept per se. More specifically, a commons is a resource to which no single decision making unit holds exclusive title. The term ‘commons’ was firstly used in medieval times when woodland and pasture were set aside for the joint use of villagers (Vogler, 2000). Benkler (2003) perceives commons as a particular type of institutional arrangement for governing the use and disposition of resources whether they could be opened to anyone or only to a defined group and whether it is regulated or not. Chaduc and Pogorel (2008) define the spectrum commons as an approach that is based on service flexibility, technology neutrality, collective use and license exempt assignment.

Several scholars address the concept of commons in spectrum but from different views. Firstly, Gilder (1994) opposes auctioning exclusive spectrum rights as it will impede technologies that do not need exclusivity. Furthermore, he calls for handling spectrum as public property as advanced technologies will render spectrum not scarce but abundant. Baran (1995) shares similar views and explains that spectrum is not used most of the time and this unused spectrum could be utilised if technology could determine empty slots in time and place. The issue attracted more attention when Noam advocates the ‘open access’ paradigm where users could get access to the spectrum without having an exclusive license by buying access tickets whose price varies with congestion and automatically determined by the demand and supply conditions at the time.

Noam anticipates that license exclusivity would be technologically obsolete and economically inefficient in the future and he argues that spectrum policy should focus on controlling the traffic among the equipment rather than controlling the spectrum (Noam, 1995, Noam, 1998). Benkler (1998) joins the discussion and argues that spectrum management should focus on regulating the use of equipment rather than the spectrum in a way similar to the internet regulatory model which adopts decentralised commons structure. The discussion was further developed by other scholars such as Lehr (2004) and Lehr and Crowcroft (2005) which calls for a ‘dedicated unlicensed spectrum’ where all unlicensed devices are considered primary users. Moreover, Werbach (2004) proposes a new approach for spectrum management called ‘supercommons’ that refocuses wireless regulation away from the ownership of spectrum and toward the rights to use devices for communication

On the other hand, scholars such as Hazlett (1998b) argues that the open access model could conversely render spectrum worthless and uninhabitable if the transaction costs of aggregating spectrum equities prove substantial. Hazlett (2001) also criticises spectrum commons as once an unlicensed operator creates killer applications and services, other operators will copy the business model, which may increase congestion and degrade service quality. Moreover, Hazlett (2006) opposes the views that the regulator should set aside spectrum for unlicensed use to add social value and argues that having private property right will enable the regulator to create spectrum commons. Hazlett and Leo (2010) argue that spectrum commons approach could destroy spectrum value as it usually results in distributing a huge number of small overlapping spectrum rights that cannot be re-aggregated. They argue also that spectrum commons is itself a rejection of open access as it might exclude and restrict certain wireless applications and services. Moreover, lack of spectrum ownership could cause market failure, as it would discourage incumbents to invest in technology and infrastructure.

It should be noted that the term ‘spectrum commons’ is used by some scholars to point to different technologies such as short range devices, Wi-Fi, or cognitive radio systems (CRS), or to different spectrum management approaches such as unlicensed bands, overlay, or underlay. However, this study uses the term ‘spectrum commons’ to point to specific spectrum management approaches which include ‘spectrum open access’ (Noam, 1995), ‘dedicated unlicensed spectrum’ (Lehr, 2004), ‘private commons’ (Webb and Cave, 2003), ‘California dream’ (Chaduc and Pogorel, 2008), and ‘supercommons’ (Werbach, 2004). Spectrum management approaches that accommodate unlicensed devices such as Wi-Fi or short range devices such as RFID are usually called ‘restricted commons’ in case that technology is standardised or ‘standard commons’ in case that technology selection is neutral (Chaduc and Pogorel, 2008).

2.5.4 Spectrum Easements

An easement is a certain right to use the real property of another without possessing it. Easements in spectrum were mainly proposed by Faulhaber and Farber (2003) who suggest an approach based on allowing other users rather than the spectrum owner to use the owner spectrum as a non-interference easement. Faulhaber and Farber (2003) explain that this easement creates a non-interfering commons at all frequencies and in all locations. In general, there are two main types of access within spectrum easements: overlay (opportunistic) and underlay access.

Overlay devices access the spectrum at the geographical, time or frequency gaps of the licensed users’ transmission as long as not causing harmful interference (e.g. TVWS). On the other hand, underlay access implies that a secondary user will transmit at low power levels, within the noise floor of licensed spectrum (e.g. UWB) (Cave and Webb, 2012). In other words, underlay access entails easements in power (Cave and Webb, 2003). For instance, short-range devices (SRD) could operate as secondary users along with the primary users as they transmit in small bandwidth and power for short distances. Moreover, equipment such as ultra wide band (UWB) can transmit over a large bandwidth with very low power levels.

Overlay or opportunistic access is promoted by technologies such as CRS that are capable of measuring the radio environment and learning from experience in order to transmit dynamically in the temporal unused frequencies without the need of exclusive allocation (Mitola, 2000). One of the main candidate spectrum bands for CRS operations is the TVWS, which refers to the geographical interleaved vacant frequencies in the TV spectrum. These frequencies were allocated for broadcasting but were not used in particular area or frequency because of the need of spectrum guard band and geographical separation between TV channels to avoid interference (Freyens and Loney, 2011b). TVWS could exist also in areas where spectrum is not used for broadcasting due to limited supply or demand in broadcasting services (Freyens and Loney, 2011a). It is worth highlighting that TVWS exist regardless whether the broadcasting services are analogue or digital.

CRS usually use technologies such as software-defined radio (SDR) to adjust automatically their behaviour (IEEE, 2008). SDR is defined by the Institute of Electrical and Electronics Engineers (IEEE) as a type of radio where some or all of the physical layer functions are software controlled (IEEE, 2008). Another concept that is associated with CRS and SDR is what is called Dynamic Spectrum Access (DSA). DSA is a technique by which a radio device can dynamically select operating spectrum to use. DSA could be cooperative-based in which the secondary user may only use a band with permission of the primary user, or non-cooperative where the secondary user does not require permission from the primary user (Chapin and Lehr, 2007).

Several scholars criticise the easements approach including Werbach (2004) who refutes deploying underlay or overlay within an exclusive property rights. Firstly, the owners could prevent other users from accessing its frequencies even if they do not interfere with him. Secondly, it would be difficult to determine the price and terms for such access. Werbach (2004) explains further that the easement concept that is based on non-interference restrictions on the secondary users enable the primary users or the spectrum owner to put up artificial limits on the easement or claim interference.

Furthermore, Cave and Webb (2012) explain that deploying overlay with full protection to the primary users would result in inefficiency due to the required large guard bands. Therefore, they suggest applying the same methodology for interference determination used for underlay to overlay along with using database that contains maximum transmitted power for overlay users according to their position. A supplementary measure to database is to use spectrum monitoring system (QinetiQ, 2005). Furthermore, Werbach (2010) proposes a mechanism, called spectrum networking database (SND), to facilitate the management of dynamic access to the spectrum in a way similar to the domain name system (DNS) used in the internet management.

In practice, one of the first steps of the implementation of an easement in spectrum was when the FCC paid attention to CRS in 2003 when it initiated a proceeding to facilitate opportunities for deploying such technologies (FCC, 2003). In 2006, the FCC allowed fixed unlicensed devices to operate in the TVWS, excluding channel 37, and prohibited personal/portable devices from operating on channels 14-20 that are used by public safety operations in some cities (FCC, 2006). The FCC decided then in 2008 to allow both fixed and portable devices to operate in the TVWS on the condition that they deploy geo-location capabilities and access a database that provides a list of available TV channels that may be used at their location (FCC, 2008).

Another update was in 2012 when the FCC decided to slightly increase the maximum permissible power spectral density (PSD) for each category of TV bands device among other actions in order to decrease operating cost for TVWS devices and to enable them to provide greater coverage (Yang, 2014). In fact, we should highlight, in this respect, Marshall (2010)'s argument that while the TVWS was firstly adopted in the US, this may not be useful for the concept of DSA. This is due that the US is a special case for DSA deployment due to the existence of huge areas with low population and large spectrum assigned to the military.

In Europe, the Radio Spectrum Policy Group (RSPG) within the EC recommends that introducing the CRS could be considered on the national level taking into account border coordination issues (RSPG, 2011b). Moreover, the EC is funding a project, COGEU (Cognitive radio systems for efficient sharing of TVWS in European context), that proposes a national geo-location database that has bands for commons usages that do not need guaranteed quality of service (QoS) and bands for secondary trading for usages that need a guaranteed QoS (Mwangoka et al., 2011).

On the standardisation level, the IEEE founded the group 802.22 in 2004 (IEEE, 2004). The group aims to develop a standard for a cognitive radio-based access interface for use by license-exempt devices on a non-interfering basis in spectrum that is allocated to the TV broadcast service. The IEEE 802.22-11 standard was finalised in 2011 and it provides broadband wireless access over a large area up to 100 km from the transmitter with data rate up to 22 Mbps per channel without interfering with reception of TV broadcast stations (IEEE, 2011). Moreover, the IEEE is developing the IEEE 802.11af standard to modify the current IEEE 802.11 standard of Wi-Fi to meet the legal requirements for channel access and coexistence in the TVWS (Baykas et al., 2010). This Wi-Fi standard will enable larger range and better indoor coverage because of the nature of the UHF spectrum. In addition to the previous two standards, there are activities on other standards that incorporate CRS techniques such as dynamic frequency selection (DFS)[3] and transmit power control (TPC)[4] (e.g. 802.11h, 802.16a) and also that incorporate full CRS techniques (e.g. 802.16h) (Sherman et al., 2008).

In addition to the TVWS concept, manufacturers, Qualcomm and Nokia, have proposed a new approach called ‘authorised shared access (ASA)’ to allow dynamic overlay usage of the mobile operators’ spectrum (Standeford, 2011). ASA is suggested to operate on shared and non-interference basis in bands allocated to the mobile service and identified for IMT (ECC, 2014). The ASA concept presents a further step from the CRS in the TVWS. Firstly, it enables licensed secondary access rather than unlicensed. Secondly, ASA is provided by an operator and through a manufactures that sell equipment capable of access the spectrum on opportunistic basis. Thirdly, ASA does not provide a best effort service but services under a predictable QoS (Qualcomm and Nokia, 2011).

It is worth mentioning that the concept is currently considered in the EU under the term ‘licensed shared access (LSA)’ (RSPG, 2011a). LSA is different from ASA in that sharing rules must be approved by the regulator and incorporated in operators’ licenses (Forge et al., 2012). One significant advantage of LSA is that it targets spectrum that offers a clear potential for global harmonization such as the spectrum already identified for IMT (DIGITALEUROPE, 2012).

[3]In DFS all radio resources are available at all RLAN nodes. A node (usually a controller node or access point (AP)) can temporarily allocate a channel and the selection of a suitable channel is performed based on interference detected or certain quality criteria, e.g. received signal strength, C/I.

[4]For data transmission, some standards use higher power spectral density for initialisation and control the transmit power according to evaluation of the RF link quality.

Another similar approach has been suggested in the US in the President's Council of Advisors on Science and Technology (PCAST) report (President's Council of Advisors on Science and Technology (PCAST), 2012). Marcus (2012) considers that the PCAST report is considered as the equivalent of LSA with a focus on the case of sharing national government spectrum with private sector users. One other concept for easement is called 'Plurastic licensing' where licenses are awarded under the assumption that opportunistic secondary spectrum access will be allowed (Holland et al., 2012). Moreover, Faussurier (2014) notices that there is a shift in CEPT from focusing on CRS and TVWS towards spectrum sharing in general. Besides, in the Commonwealth of Independent States (CIS), there has been some work on principles of coordination in the border areas for CRS using national geo-location database (Kokotov, 2014). Additionally, the Asian Pacific countries established a task group on CRS and SDR in April 2009 to facilitate the study on these systems in their countries.(APT/AWG Task Group on SDR & CRS, 2014).

On the other hand, there have been some concerns associated with these spectrum easements models. For instance, the mobile industry giant, GSMA, has been sceptic about the TVWS concept for several reasons. Firstly, TVWS may disturb the existing market through inappropriate regulations such as eliminating the cost of acquiring licensed spectrum. Secondly, TVWS may influence the mobile allocation process to be considered at the WRC-15. Thirdly, there is a lack of coexistence studies to evaluate interference effects between mobile broadband systems using TV white space and digital TV reception (GSMA, 2013a). Moreover, the use of techniques such Single Frequency Networks (SFNs) where several transmitters can use the same frequency channel without interference decreases the TVWS opportunities (Gomez, 2013).

Moreover, Forde and Doyle (2013) clarify that there have been high expectations on the CRS technologies which may have led to market and regulatory uncertainty. Another criticism to CRS is related to the hidden terminal problem where CRS may identify spectrum as vacant upon measurements while the spectrum is used by another user behind an adjacent building (Webb, 2007). Furthermore, studies by CEPT have shown that the amount of TVWS is limited due to the tight digital broadcasting planning and because the TV bands is heavily used on opportunistic basis by devices called Program Making and Special Event (PMSE) (Anker, 2010a). Meanwhile, this may contradict with other studies which show that 56% of the TV channels are unused in Europe, when averaged over the whole geographic area (Cui and Weiss, 2011). In general, the amount of TVWS is highly dependent on the density of TV transmitters (Jantti et al., 2011).

2.6 *Conclusions*

This chapter has presented an overview on spectrum management on the national level from the theoretical and practical viewpoints. Firstly, it has shed light on the radio spectrum resource per se while clarifying its main characteristics that make it different from other natural resources. The chapter has shown then how the perception of radio spectrum changed from being a new inexhaustible natural resource commonly and freely used by the public to a scarce resource that needs to be managed for several reasons. Meanwhile, while the practice of spectrum management on the national has evolved differently around the world, spectrum has been strictly regulated by the governments in most of the world.

The chapter has also analysed national spectrum management into its main elements: service allocation, technology selection, usage rights, and frequency assignment. The first element, service allocation, is related to the distribution of the spectrum to the different radiocommunication services and it could be harmonised in different countries or let flexible according to the user. The second element, technology selection, could be neutral, restricted to standardised technologies, or selective of specific technologies. The third element, spectrum usage rights could be exclusive, exclusive with easement, or collective (non-exclusive). The fourth element is frequency assignment where there are three categories: administrative, market-based, or license exempt.

The chapter has then addressed the different combinations of these four elements, which formulate national spectrum management policies while focusing on four main approaches that are considered in most of the literature: command and control, spectrum market, spectrum commons, and spectrum easements. The command and control approach is based on allocation harmonisation, standardised technology, exclusive property rights and administrative assignment. This traditional approach to spectrum management worked well for many years. However, several issues have called for reviewing and reforming the command and control approach.

Three main approaches are usually discussed as alternatives to the command and control approach. The first approach is spectrum market, which is based on allocation flexibility, technology neutrality, exclusive property rights and market-based assignment. There are three main elements of the market-based approach: designing exclusive property rights to the use of the spectrum, using auction method for the initial allocation of spectrum rights and applying a secondary market afterwards, and allowing maximum flexibility. Furthermore, the practice of spectrum property rights, spectrum trading, and spectrum flexibility has varied around the world with no case of significant success.

Spectrum commons is an approach that is based on service flexibility, technology neutrality, collective use and license exempt assignment. Spectrum commons refers in this research to approaches such as spectrum open access or dedicated unlicensed spectrum. Besides, spectrum management approaches that accommodate unlicensed devices such as Wi-Fi or short range devices such as RFID are usually called 'restricted commons' in case that technology is standardised or 'standard commons' in case that technology selection is neutral.

Easement in spectrum is an approach that is based on allowing other users rather than the spectrum owner to use the owner spectrum as a non-interference easement. In general, there are two main types of access within spectrum easements: overlay (opportunistic) where spectrum is accessed at the geographical, time or frequency gaps of the licensed users' transmission as long as not causing harmful interference and underlay access which implies that a secondary user will transmit at low power levels, within the noise floor of licensed spectrum. While underlay access entails easements in power, opportunistic access is promoted by technologies such as CRS that are capable of measuring the radio environment and learning from experience.

In general, this chapter has surveyed the different approach to spectrum management on the national level. In particular, it illustrates how the command and control was until recently the dominant approach. Meanwhile, while there have been three alternatives suggested to overcome the deficiencies of such traditional approach, none of them shows wide adoption or significant success with the exception of technologies such as Wi-Fi and measures such as auctions. The next chapter discusses in detail spectrum management on the international level by analysing the international spectrum management regime in terms of the four main elements that have been used in this chapter to examine national spectrum management policies: service allocation, technology selection, usage rights, and frequency assignment. The purpose of such analysis is to identify elements of interaction between national spectrum management policies and activities related to spectrum management on the international level.

3 International Radio Spectrum Management Regime

3.1 *Introduction*

The previous chapter has presented an overview on the different approaches to spectrum management on the national level. In addition, it has highlighted the radio spectrum policy reform process from the command and control approach towards spectrum market, spectrum commons, and spectrum easements. Meanwhile, this chapter tends to investigate how spectrum is managed on the international level in order to highlight the main elements of interaction between national spectrum management policies and activities related to spectrum management on the international level.

The chapter starts with a brief overview on the international spectrum management regime and its foundation in Section 3.2. In addition, the section examines the international regime in terms of its main principles, norms, rules, and decision-making procedures. Section 3.3 then analyses the international regime in terms of the four main elements that constitute national spectrum management policies: service allocation, technology selection, usage rights, and frequency assignment. Finally, Section 3.4 concludes.

3.2 *International Radio Spectrum Management Regime: An Overview*

Before analysing the international spectrum management regime, it is highly significant to explain what international regimes are in general. Young (1982) defines regimes as social institutions governing the actions of those interested in specifiable activities. He further defines international regimes as regimes pertaining to activities of interest to members of the international system.

Regimes can also be defined as sets of implicit or explicit principles (beliefs of facts, causation, and rectitude), norms (standards of behaviour defined as rights and obligations), rules (specific prescriptions and proscriptions for action), and decision-making procedures (prevailing practices for making/implementing collective choices) around which actors' expectations converge in a given area of international relations (Krasner, 1982). While principles are general standards of behaviour, norms are the most general prescriptions and proscriptions relevant to an issue area and they are implemented at lower level by rules and decision-making procedures (Zacher, 1996).

The international spectrum management regime was created in line with the formulation process of national spectrum management policies. At that time, the regime conveyed the domestic preferences of the countries that participated in creating it. In particular, two issues necessitated managing the spectrum at the international levels. The first is the phenomena of interference, which became a major problem at the early days of wireless communication as radios transmitted over a wide band of frequencies and radio emissioned crossed frontiers. This caused interference in neighbouring countries. The second issue was Marconi company's refusal to relay messages received from competing operators (Anker and Lemstra, 2011). These two issues called for conducting a conference in Berlin in 1903 to address the Marconi company monopoly over radio telegraphy and to enable international interconnection (Codding, 1991). The final protocol of the conference established that wireless stations should operate in a way as not to interfere with other stations (Codding and Rutkowski, 1982).

Following that, the first international conference on radio communications was held in Berlin in 1906 and it established the first international table of frequency. It also established the principle of compulsory intercommunication between land and vessels at sea (Timofeev, 2006). The conference resulted also in creating the International Radiotelegraph Union, which aimed at developing international regulations for use of the spectrum. This Union merged with the European International Telegraph Union to form the current International Telecommunications Union (ITU), which became one of the United Nations agencies in 1947.

Following that, the interest of many entities, such as military and broadcasters, in spectrum started to grow, which, in turn, motivated governments to heavily regulate spectrum usage (Ryan, 2012). This was in line with the national policies at the turn of the twentieth century which sought to enforce government control over radio spectrum for political purposes such as national security and for economic benefits derived from controlling the industry (Cowhey, 1990). In addition, by the mid-1920s, the issue of harmful interference became more apparent as Europe and North America were full of broadcasting stations using unregulated frequencies (Savage, 1989). Accordingly, the 1927 International Radiotelegraph Conference witnessed a shift from focusing on the regulation of the radio traffic towards allocating the spectrum to separate services (Woolley, 1995), and the concept of ‘common use of common frequencies’ was gathering more momentum (Levin, 1971).

While several scholars analyse the international telecommunication regime in general (Zacher, 1996, Ratto-Nielsen, 2006), no common agreed analysis on the specific case of spectrum management was found. Therefore, it was attempted to analyse the international spectrum management regime in terms of its main principles, norms, rules, and decision-making procedures.

Firstly, the ITU-R is the administrative cooperation body responsible for setting the regime’s rules through the ITU-R Radio Regulations (RR) and the ITU-R resolutions, recommendations and reports. The ITU-R is one of three organisational sectors that constitute the ITU in addition to the Standardisation Sector (ITU-T) and Development Sector (ITU-D) (Gregg, 2009). The RR have international treaty status and they are binding for all the ITU-R countries (Maitra, 2004). On the other hand, ITU-R recommendations do not have legal status similar to the ITU-R RR unless they are incorporated by reference in the RR (McLean Foster & Co., 2013).

The main principles of the regime could be driven from the principles which the RR are founded on (ITU-R, 2008f). There principles include limiting the number of frequencies and the spectrum used to the minimum essential to provide in a satisfactory manner the necessary services, using spectrum rationally, efficiently and economically to enable equitable access to the ITU-R countries, and not causing harmful interference to other countries or recognised operating agencies. The main norms of the regime could be assumed on the basis of the rights and obligations of the ITU-R countries which include the rights to participate in conferences of the ITU and having one vote in these conferences (ITU, 2011a). The regime’s rules and decision-making procedures are discussed in the next sub-sections.

It should be noted that there has been an increasingly prominent role of industry in the international spectrum management regime, especially since the ITU Plenipotentiary Conference of 1995 formally recognised the rights of the private sector (MacLean, 1995). Private sector membership in ITU requires direct or indirect connection with a relevant state member (Lyall, 2011). In addition, participation of the private sector in the ITU meetings could be in direct way or within the delegates of their country (Manner, 2003).

While the private sector has equal rights with national regulators in ITU-T and ITU-D, national regulators are the ultimate decision makers in the ITU-R (McCormick, 2007). Meanwhile, the private sector can participate and lobby in the ITU-R to obtain support for their interests (Irion, 2009).

Although national regulators are the decision makers for treaty instruments, their decisions are developed based on the studies of the ITU-R study groups where the private sector conducts much of the technical work (McCormick, 2007). There has been also an increasingly role of regional organisations especially at WRCs (U.S. Congress Office of Technology Assessment, 1993). In particular, there are six regional organisations that follow the activities of spectrum management in the ITU-R: Asia Pacific Telecommunity (APT), Arab Spectrum Management Group (ASMG), African Telecommunications Union (ATU), European Conference of Postal and Telecommunications Administrations (CEPT), Inter-American Telecommunication Commission (CITEL), and Regional Commonwealth in the Field of Communications (RCC) (ITU-R, 2012g).

3.3 *International Radio Spectrum Management Regime: An Analysis*

In the next sections, the international spectrum management regime is analysed in terms of the same four main elements that constitute national spectrum management policies: radiocommunication service allocation, technology selection, usage rights, and frequency assignment.

3.3.1 Radiocommunication Service Allocation

In general, the principles underpinning radiocommunication service allocation have not been changed since the first Radio Telegraph Conference in Berlin in 1906 (ITU-R, 2012h). In particular, dividing the spectrum according to the type of service and global harmonisation of spectrum allocations are the ITU historical methods to mitigate harmful interference. More specifically, the level of protection required by one type of service, may not be suitable for another type of service (ITU-R, 1995b). Service allocation is also essential for interference management due that these service definitions provide information on the application types and generic technical characteristics of the stations under each service type. For instance, fixed service implies having stations that operate at specified fixed points in a point-to-point architecture, utilising antennas with a narrow beam width and with a specific azimuth and tilt (ITU-R, 2012a).

The ITU-R table of frequency allocation divides the frequency band into smaller bands that are allocated to more than 40 radiocommunication services (ITU-R, 2001b). The first radiocommunication service was established in 1906 under the name ‘maritime service’ in 1906 (Ard-Paru, 2012). Currently, there are three types of radiocommunication services: broadly defined services (e.g. fixed, mobile), narrowly defined services (e.g. maritime mobile), and normally defined services (e.g. broadcasting, amateur) (ITU-R, 1995b). Furthermore, each spectrum band could be allocated to one or more radio services with equal or different rights (primary and secondary). This is based on the results of compatibility and sharing studies that are usually technology dependent (Louis, 2011). Stations of a secondary service cannot cause harmful interference to stations of primary services and cannot claim protection from harmful interference caused by stations of a primary service (ITU-R, 2008c).

The ITU-R divides the world into three regions in terms of spectrum allocation[5] as shown in Figure 3-1 (ITU-R, 2012d). Such division was introduced in WRC-47 (Ard-Paru, 2012). It is worth mentioning that the number of worldwide allocations is only 12.8 % of total frequency band allocations (ITU-R, 2011a).

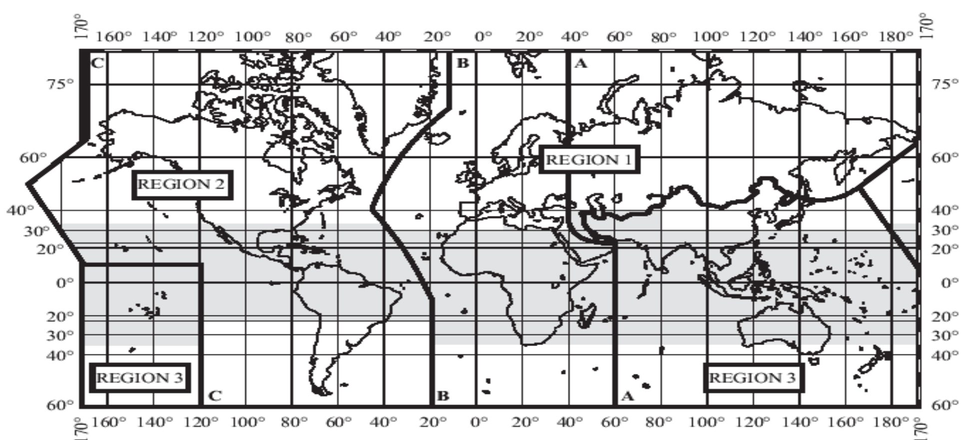

Figure 3-1: The ITU-R Three Regions

[5] Region 1 comprises Europe, Africa, the Middle East west of the Persian Gulf including Iraq, the former Soviet Union and Mongolia. Region 2 covers the Americas, Greenland and some of the eastern Pacific Islands. Region 3 contains most of non-former-Soviet-Union Asia, east of and including Iran, and most of Oceania.

Decisions related to spectrum allocation are taken during ITU-R WRCs. Within WRCs, four main aspects of the spectrum are discussed: type of service (e.g., fixed, mobile), type of access (primary and secondary), allocation geographical areas (globally or regionally), and technology characteristics (e.g., maximum transmitted power). The WRC decision-making process creates technical and operational certainty for new and existing users and maximises the global harmonisation of the spectrum resource (Abernathy, 2004). WRC resolutions have binding status unlike WRC recommendations (Ard-Paru, 2012). Significantly, the agenda of the current conference is determined by the previous one. Items that could be included in the agenda include revisions to the RR and any other question of a worldwide character that falls within the remit of the conference (ITU, 2011b).

During the WRC, negotiations are conducted between member states of the ITU, which effectively involving them trading support on different issues between one another (Manner, 2003). Observers that are sector members of the ITU-R, that are, from the private sector, can attend WRCs in a non-voting capacity, while each member state is entitled to one vote (ITU, 2011b). Regional organisations usually present common proposal to the WRC on behalf on their member states. In general, those countries that do not share the view of the others regarding a WRC decision are expected to agree to the opinion of the majority. Otherwise, they can record their reservations (Jakhu, 2000). Regarding the status of new spectrum use on the national level with respect to service allocation in the RR, Table 3-1 presents the possible different cases (Indepen, 2001).

Spectrum Use on the National Level	Status regarding the RR Service Allocation
Use is in conformity with the primary services in the ITU-R table of spectrum allocation.	Use is protected against interference from primary and secondary services allocated in the same band.
Use is in conformity with the secondary services in the ITU-R table of spectrum allocation.	Use is protected against interference from secondary services but cannot claim protection from primary services in the same band.
Use is not in conformity with the primary or secondary services in the ITU-R table of spectrum allocation.	Use cannot claim protection from primary or secondary services in the same band. In addition, it should not collide with

	neighbouring countries' spectrum allocation (Foster et al., 2011).

Table 3-1: Status of Spectrum Use on the National Level with respect to Service Allocation in the RR

If a country wants to protect this new use against interference, it may add a footnote to the ITU-R RR stating this particular use. However, other neighbouring countries may block such use if it will restrict their own use. Footnotes indicate additional or alternative allocations (ITU-R, 1995a). More specifically, a band could be indicated in a footnote of the ITU allocation table as allocated to a particular service on a primary or secondary basis in an area smaller than a region, or in a particular country. Footnotes can also determine services priority and technical conditions associated with allocation (Ard-Paru, 2012).

In addition to footnotes, countries can register their important frequency assignments in the ITU-R where there are two types of registration (Ryan, 2005). The first one is a priori planning which enables a guarantee of access to the spectrum where each country submits its requirements at a world or regional planning conference. Such concept emerged in 1919 with aeronautical service (Zacher, 1996). Although the advantage of such type of planning is that it guarantees equitable access to the spectrum, valuable spectrum is pre-allocated and may not be in use. However, it is argued that priori planning conferences such as Geneva-2006 (GE-06) allow flexibility as it allows services other than broadcasting on the condition that they are not causing interference and because it is flexible in terms of the location of transmitters within the service area (Foster, 2008).

One example of a priori planning is the ITU Regional Radio Conference in 2006 (RRC-06) which planned the process of switchover of terrestrial broadcasting services for radio and television from analogue to digital in Europe, Africa and the Middle East (Irion, 2009). The RRC-06 resulted in the Geneve-2006 (GE-06) agreement or plan, which planed the analogue and digital broadcasting services in the bands 174-230 MHz and 470-862 MHz. The GE-06 plan determined the end of the transition period of the analogue broadcasting services in the UHF band to be 17th June 2015 (GSMA, 2012). It is worth mentioning that at the WRC-47, there were suggestions by the US and other countries to conduct priori planning to the entire spectrum in one step (Savage, 1989).

However, this was dropped for the fear of the dominant of the developing countries on the ITU-R (Zacher, 1996).

The second type of assignment registration is in the non-planned bands on a first come, first-served basis in the ITU-R Master International Frequency Register (MIFR). Such registration requires conformity with the ITU-R service allocation table and not causing harmful interference to existing assignments in other countries (Lyall, 2011). More specifically, registration procedures require ensuring potential assignments would not cause interference to assignments already registered in the MIFR. MIFR has been criticised for accommodating declarations and not factual data which may give the impression of scarcity in spectrum (Struzak, 2007).

There have been several criticisms to the ITU-R service allocation. For instance, Cave (2002) argues that international co-ordination is a constraint on the ability of a single country to introduce more flexibility into its spectrum use. However, this varies according to the geographical characteristics of such country in terms of area, coastal line length, and number of neighbouring countries. Applying flexible spectrum use that is not in conformity with the ITU regulations would require extensive coordination with neighbouring countries (Indepen, 2001). Furthermore, there have been calls to perceive spectrum as an infrastructure asset used to deliver different applications to the end user instead of traditionally allocate spectrum exclusively for particular services (Legutko, 2008).

Furthermore, international harmonisation may also impose constraints on changes in spectrum use which would delay introduction of new services and technologies (Lie, 2004). Louis and Mallalieu (2007) highlight the influence of convergence on radiocommunication service allocation where the differences between hitherto standalone services become increasingly blurred (e.g. unidirectional fixed point-to-multipoint system and broadcasting system). For instance, Wi-Fi equipment operating in the 5 GHz are categorised under the mobile service in the RR while they provide fixed broadband access (Radiocommunication Bureau, 2007). Besides, advancements in mobile technologies have enabled them to provide similar services to broadcasting such Multimedia Broadcast Multicast Service (eMBMS) in LTE (Watson, 2013). Louis (2011) argues that there is a need to study alternatives to service harmonisation as broadly defined services may not be adequate to handle convergence.

On the other hand, there are several advantages related to the harmonisation of the ITU-R service allocation. In particular, harmonisation is important for the industry because the number of spectrum bands supported by devices is limited (Ercole, 2009). More specifically, supporting more spectrum bands by the handsets would make them less sensitive which would require more base stations (Christmas, 2007). Jones (1968) argues that international regulations do not restrict transfer of spectrum rights, as most domestic uses of the spectrum do not produce interference beyond countries' borders. Freyens (2010) highlights the importance of global harmonisation provided through the ITU-R RR and explains that only geographically isolated countries that are simultaneously large equipment manufacturers may afford the cost of ignoring ITU regulations. International harmonisation is also critical for services of international nature such as maritime (Cave, 2005).

There have been several attempts to revise the service allocation principles at the ITU-R with the most recent one is when WRC-12 discussed under agenda item 1.2 how to enhance the international spectrum regulatory framework (ITU-R, 2007c). In addition, prior to the WRC-12, the ITU-R studies approached the issue from two perspectives. The first focused only on convergence between fixed and mobile services, while the second addressed spectrum allocation issues more generally (ITU-R, 2011b). These studies showed that there are cases where it is difficult to distinguish between fixed and mobile services such as point to area or point to multi-point applications (ITU-R, 2011a). However, it was shown also that in most cases, there are joint allocations of spectrum across fixed and mobile services (ITU-R, 2011b). Eventually WRC-12 decided not to change current spectrum allocation practices with regard to the two issues (ITU-R, 2012n), and to continue the studies on revising the definitions of fixed service, fixed station and mobile station until WRC-15 (ITU-R, 2012k).

Following the WRC-12, the ITU-R has been studying the consequences of changes in service definitions on coordination, notification and registration of the frequency assignments of the stations in the fixed and mobile services and on the definitions of other services and stations (ITU-R, 2012b). Several proposals have been discussed such as defining a new category of service that does not convey any notion of physical mobility or signal content for those stations, which may operate under more than one service (ITU-R, 2012a). Eventually, due to the lack of contributions on the issue (ITU-R, 2013a), the draft Conference Preparatory Meeting (CPM) report to the WRC-15 indicated that the discussions resulted in retaining the current definitions for the fixed service, fixed station and mobile station as they have been able to adapt to technology evolution and that there is sufficient flexibility within the present RR (ITU-R, 2014a).

3.3.2 Technology Selection

In general, the ITU has been involved in the issue of telecommunications standards compatibility since its early days in order to handle the issue of Marconi monopoly (Savage, 1989). In addition, the ITU-R did not succeed to agree on one standard for coloured TV in the 1960s and therefore, three standards were approved (Zacher, 1996). Savage (1989) argues that multiple standards have been viewed by the ITU as a policy of last resort. With regard to personal mobile communication systems, the ITU-R has been involved in two aspects: defining the standards and frequency identification related to these systems (ITU-R, 2007f). The involvement of the ITU-R in the standardisation process was mainly in response to the formulation of several national and regional standards bodies that were perceived as a threat to the role of the ITU in setting international telecommunications standards (Besen and Farrell, 1991).

Regarding personal mobile telecommunication systems, the lack of interoperability between second generation (2G) mobile standards motivated the ITU-R to become more involved in the standardisation process of mobile systems (ITU, 1998). In addition, it was clear that the mobile market became quite large and more worldwide rather than national or regional (Funk, 1998) which called for a global effort towards a worldwide third generation (3G) standard.

The first step of the ITU standardisation activities on mobile technologies was in the 1980's where the concept of FPLMTS (Future Public Land Mobile Telecommunication System) was discussed in the ITU-R (Formerly International Radio Consultative Committee (CCIR)). That was mainly due to the support of the European countries which seek to have successor to the Global System for Mobile Communications (GSM) system (U.S. Congress Office of Technology Assessment, 1993). More specifically, the ITU-R Task Group 8/1 was formed in 1985 to define a framework for FPLMTS services (Callendar, 1994). The name FPLMTS was renamed IMT-2000 by the Radiocommunication Assembly (RA) prior to the WARC-97 (ITU, 1997). WARC-92 also adopted resolution 212, providing the general framework for IMT-2000 standards development and system implementation (Leite et al., 1997).

The ITU established a procedure for submitting and evaluating the IMT-2000 radio interfaces proposed by the national/regional standardisation bodies (ITU-R, 2010b). Following that, the ITU-R invited applicants for IMT-2000 radio transmission technologies in 1997 and ten terrestrial proposals were submitted in 1998 (Engelman, 1998). Among these proposals, five radio interfaces were approved to be part of the IMT-2000 standards: WCDMA, CDMA 2000, TD-SCDMA, EDGE, and DECT (ITU-R, 2009a). The main key requirements of IMT-2000 were set to provide data rates up to 2 Mbit/s (ITU-R, 1997). A few years later in 2006, the IEEE submitted a proposal to include the WiMAX standard named as IP-OFDMA into the IMT-2000 family of standards (WIMAXForum, 2007).

While the WiMAX proposal was approved as a new terrestrial radio interface for IMT-2000, there were oppositions from China and Germany and several industry bodies (WP 5D Chairman, 2007a). More specifically, several industry bodies (mostly from competing technologies) expressed that compliance of WiMAX with the minimum performance capabilities of IMT-2000 needs to be further handled. Therefore, a special meeting was held in August 2007 to meet the concerns related to the inclusion of WiMAX (WP 5D Chairman, 2007b). The meeting ended up with Germany and China still having some concerns but with the majority of the attendants supporting the inclusion. The ITU-R RA-07 agreed in October 2007 to officially include WiMAX to the IMT-2000 family (Sims, 2007b).

Regarding 4G standards, the ITU–R announced its invitation for the submission of proposals for candidate radio interface technologies for the terrestrial components of IMT-Advanced in 2008 (ITU, 2008a). The main key feature of IMT-Advanced was set to be providing enhanced peak data rates up to 100 Mbit/s for high and 1 Gbit/s for low mobility (ITU-R, 2007a). There were six different proposals containing two main technologies: IEEE (IEEE 802.16m) and 3rd Generation Partnership Project (3GPP) (LTE Release 10) (WP 5D Chairman, 2009). Later, these six proposals were consolidated into the two IMT-Advanced technologies: LTE-Advanced and WirelessMAN-Advanced (ITU, 2010a). These two technology standards were submitted to the RA-12 and were agreed by the ITU-R member states (ITU, 2012b). The LTE-Advanced standard was identified as LTE Release 10 and beyond, while the WirelessMAN-Advanced standard was identified as IEEE 802.16m (ITU-R, 2012e).

It is worth mentioning that the ITU-R is currently working on what can be called '5G' by developing the framework and overall objectives of the future development of IMT for the year 2020 and beyond (Osseiran, 2013). In addition, the ITU-R has recently provided a global perspective on the future spectrum requirement estimate for terrestrial IMT (ITU-R, 2014b). Furthermore, the ITU-R has assessed the global mobile broadband deployments and forecasts for IMT systems over the next decade (2012-2022) (ITU-R, 2011e). The ITU-R, recognising the importance of the timely availability of spectrum for the deployment of IMT systems, will also discuss in the coming WRC-15 the potential additional candidate frequency bands (ITU-R, 2012j).

The IMT standardisation process has been associated with identifying spectrum for the use of IMT standards by the ITU-R. The first step with this regard was when the European countries called for spectrum allocation for FPLMTS in the mobile WARC of 1987 but the issue was postponed until WARC-92. During WARC-92, countries such as the US opposed allocating new frequencies for FPLMTS (U.S. Congress Office of Technology Assessment, 1993). Eventually, the conference identified the bands 1885-2025 MHz and 2110-2200 MHz for countries wishing to implement FPLMTS (ITU, 1992).

At WRC-2000, more frequency bands were identified for the use of IMT-2000 including 806-960 MHz, 1710-1850 MHz, 2500-2690 MHz (ITU-R, 2001c, ITU-R, 2001d). In addition, at the WRC-07, the following frequency bands were identified for IMT 450-470 MHz, 698-806/862 MHz, 2.3-2.4 GHz, and 3.4-3.6 GHz (ITU-R, 2007g, ITU-R, 2007b). WRC-12 decided also to allocate the 694-790 MHz frequency band in Region 1 to mobile service on a co-primary basis with broadcasting service (ITU-R, 2012l).

Regarding the impact of IMT standardisation on technology selection on the national level, there are different cases. For instance, in Europe where the GSM standard was mandatory for operators (Cowhey et al., 2008), there was a discussion over whether bands identified for IMT-2000 could be used for technologies other than IMT-2000. This was mainly due to the pressure made by EC to apply technology neutrality.

Furthermore, the Electronic Communications Committee (ECC), which is one of the CEPT bodies, explained that designating a band for a particular use does not preclude adopting other technologies (Sims, 2005). Eventually, the EC countries could not reach consensus on whether to allow non IMT-2000, including WiMAX at that time, to access IMT-2000 identified spectrum in Europe (e.g. 2.5 GHz) (Sims, 2006a).

Another case is related to Japan which took the position that the 2.5 GHz band will be reserved for non IMT-2000 technologies (Sims, 2006b). Other countries were more specific regarding the selection from the IMT standards. For instance, in Hong Kong, the award of a standard specific CDMA-2000 license was announced (Sims, 2007a), while in China, the government has assigned each of the three operators a particular IMT-2000 standard (TD-SCDMA, CDMA-2000, and WCDMA) (Newlands, 2009b).

The IMT standardisation process has shown also that the industry and ITU-R have different perceptions on the categorisation of technologies in terms of being 2G, 3G or 4G. More specifically, while according to the ITU-R, IMT-2000 is supposed to be equivalent to 3G, this is not necessarily the case for industry. For instance, although EDGE is part of the IMT-2000 family of radio interfaces, it is not considered by the industry as a 3G technology (ITU-D, 2009b). Moreover, the first releases of CDMA-2000 was considered by some as not one of the real 3G technologies although it is part of the IMT-2000 family of standards (Saugstrup and Henten, 2006).

The emergence of the IMT-advanced family of standards caused a similar debate on the categorisation of 3G and 4G technologies. The issue is that IMT-2000 standards encompass their enhancements and future developments (ITU-R, 2007e) and some of the IMT-2000 radio interfaces have evolved to achieve capabilities that are similar to the IMT-Advanced (ITU, 2010b). For instance, LTE Release 10 is part of the IMT-2000 radio interfaces and it supports up to 3 Gbit/s in the downlink which is way beyond the initial capabilities of IMT-2000 (ITU-R, 2013d). Additionally, LTE Release 10 and 11 are also part of the IMT-Advanced radio interfaces (ITU-R, 2013c). It is worth mentioning that the IMT Advanced standards have been called by the ITU as 'the true 4G technologies' (ITU, 2009).

With regard to the influence of IMT spectrum identification, it should be noted that it is rare in the ITU-R radio regulation to allocate spectrum bands to specific applications or technologies. Furthermore, in the early stages of IMT development, there was a debate at the WARC-92 on whether to allocate or identify spectrum for FPLMTS. The use of the word ‘identify’ was opposed by several countries, as it would give strong indication of allocation. Eventually, the words ‘identified’ and ‘allocated’ were replaced by ‘intended for use’ (U.S. Congress Office of Technology Assessment, 1993).

Furthermore, the name ‘IMT-2000’ was chosen to denote and reflect that the IMT-2000 standards would use the 2 GHz spectrum band and be available in the 2000’s (Jho, 2007). Besides, the ITU-R made an important step in enabling the re-farming of spectrum in bands perceived by many as being 2G related. That was when the WRC-2000 resolved to identify the band 806-960 MHz which was already allocated to mobile service to IMT-2000 (ITU-R, 2001a). The decision aimed at encouraging the evolution of first and second generation mobile systems to IMT-2000 in their operating frequencies (ITU-R, 2001c).

The ITU-R has also contributed to the attainment of a long delayed harmonisation between the ITU-R three regions in the UHF band when the WRC-12 allocated the 694-790 MHz band to the mobile except aeronautical mobile service in Region 1 (ITU-R, 2012l). This would resolve the historical incompatible deployment of CDMA and GSM networks in the UHF band globally (ITU-D, 2012). Furthermore, ITU-R made the differentiation between IMT-2000 and IMT-Advanced become less distinct when WRC-07 decided to combine the identification of spectrum for IMT-Advanced and IMT-2000 into a single category: IMT (ITU-R, 2007e). In other words, the decision allowed both of IMT-2000 and IMT-advanced radio interfaces to get access to the entire spectrum identified for IMT. Therefore, in theory, operators should be able to introduce technologies such as LTE in bands licensed for 3G services.

3.3.3 Usage Rights

With regard to the existence of the concept of spectrum easements in the ITU RR, there are three cases. The first case is the co-existence of primary and secondary services where secondary services operate in the same spectrum bands with primary services without causing interference or claiming protection against interference from primary services. For instance, underlay devices, such as SRD, are perceived to operate on secondary basis as mobile service (RSPG, 2011a)

While there is no explicit mention of why and how the concept of secondary service was initiated, this research attempted to seek the origin of the concept of secondary service in the ITU-R. In particular, it was found that the concept could be traced back to the general radiocommunication regulations that were approved at the WRC-1932, which stated that "*A fixed station may as a secondary service transmit to mobile stations on its normal working frequency subject to the following conditions: (a) the Administrations concerned consider it necessary to use this exceptional method of working; (b) no increase of interference results*" (ITU-R, 1932: 19). The concept of secondary service was used in another instance in the WRC-1938 where the U.S.S.R. stated that they are using broadcasting service as a secondary and supplementary to the basic allocation of aeronautical service in certain spectrum bands (ITU-R, 1938).

In addition, starting from WRC-1938, differentiation was associated with some services by indicating some priority to them. For instance, the radiocommunication regulation approved by the WRC-1938 stated that in ITU-R region 3, the maritime mobile service has priority in the band 510-525 kc/s (ITU-R, 1938). In WRC-1947, it was added that a land station may communicate, on a secondary basis, with fixed stations or other land stations of the same category (ITU-R, 1947). The current form of primary and secondary service appeared in WRC-1959 where the definition of primary and secondary services were stated explicitly (ITU-R, 1959).

The second case could be considered as the operation on non-interference basis according to Article 4.4 from the RR. Such article states that "*Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations*" (ITU-R, 2008b: 33).

One example of that is the WLAN devices which operate on a non-protection, non-interference basis and with low powers (Anker and Lemstra, 2011). These devices usually operate in the what is called Industrial, Scientific and Medical (ISM) spectrum bands such as 2400-2500 MHz and 5725-5875 MHz (ITU-R, 2012d). These bands are designated for ISM applications, and radiocommunication services operating within these bands must accept harmful interference which may be caused by these ISM applications (ITU-R, 2012d). These bands were firstly determined by the Radio Conferences of 1947 and 1959 which identified several frequency bands to the ISM applications excluding applications in the field of telecommunications (ITU-R, 1979). Such allocation requires that radiation from equipment used for ISM applications is minimal, and that outside the bands designated for ISM equipment, radiation is at a level that does not cause harmful interference to a radiocommunication service (ITU-R, 2008d). It is worth mentioning that the ITU resolution was taken shortly after the USA adopted similar decision (USA, 1948).

A major change in the use of these ISM bands was made when the FCC decided in 1985 to open up three ISM spectrum bands (915 MHz, 2.4 GHz and 5.8 GHz) for Wireless Local Area Network (WLAN) (Lemstra et al., 2011a). The decision led to a similar approach in the band 2.4 GHz in Europe (Lemstra et al., 2011b). Moreover, in 1992, the spectrum band 5.150-5.350 GHz was allocated in Europe for WLAN (CEPT, 1992). The industry in the USA was triggered by that decision and called in 1995 for a similar allocation in the 5 GHz band in the USA for WLAN. Consequently, the FCC allocates the spectrum bands 5150 to 5350 MHz and 5725 to 5825 MHz for the operation of the unlicensed national information infrastructure (U-NII) devices[6] (Anker and Lemstra, 2011). The decision was also motivated by the need for higher data rates that may not be achieved under the ISM band regulations and crowding conditions (Negus and Petrick, 2009).

The third case is the sharing between WLAN, which categorised as primary mobile service, and other primary services in the 5 GHz band. Such allocation of mobile service in the 5 GHz for WLAN operations was initiated by the European countries which proposed in the WRC-2000 to have an agenda item in WRC-03 to consider additional spectrum allocation to mobile service in the frequency ranges 5150-5350 MHz and 5470-5725 MHz to gain global harmonised frequency allocations for radio local area networks (R-LAN) (CEPT, 2000). The European countries’ argument was that the global mobile service allocation would give R-LANs an appropriate ITU allocation status. Additionally, the ISM band at 5 GHz is not preferred due to the expected

[6] The higher U-NII band coincided with part of the already assigned ISM band.

significant increase of the use of other applications in this band and the high quality of service requirement for R-LANs (CEPT, 2000). However, it was recognised that such allocation would require sharing with other systems such as radar systems and therefore, the ITU studied the technical restrictions necessary to allow such sharing (Horne, 2003).

It is worth mentioning that the move of the WLAN to the 5 GHz band was motivated by perception that the lower bands are congested (e.g. 2.4 GHz) and by the need to achieve higher data rates (Negus and Petrick, 2009). Eventually, WRC-03 decided to allocate the bands 5150-5350 MHz and 5470-5725 MHz on a primary basis to the mobile service for the implementation of wireless access systems (WAS), including R-LANs (ITU-R, 2003b). WRC-03 agreed also on allowing sharing of the 5 GHz bands between radiolocation service (radar systems) and mobile service (R-LAN) on a primary basis upon using DFS and TPC to facilitate spectrum sharing (ITU-R, 2003a, ITU-R, 2011c). In particular, DFS measure determines the timeline for radar sensing, usage, abandoning the channel, and a non-occupancy time after detection (Zhao et al., 2007).

In addition, relatively high transmitted power limits and wide frequency bandwidth were allowed in contrast to the case of WLAN operating in the ISM bands (ITU-R, 2003b). Horne (2003) argues that it was unusual for the ITU to determine technical restrictions in terms of behaviour-based mechanism such as DFS. In particular, it was the first time that mandated sharing conditions associated with an allocation include cognitive features. Sung (2003) clarifies that while international allocations were not necessary for WLANs, they are needed to harmonise WLAN frequency use throughout the world and to legitimise unlicensed WLAN operations in developing countries that are not familiar with the concept of unlicensed services.

In addition to the previous three forms of non-exclusive access, the ITU-R has recently discussed technologies such as CRS that enable DSA at WRC-12 under agenda item 1.19 which addresses the regulatory measures that could enable deployment of CRS (ITU-R, 2007c). The issue was firstly raised in the ITU-R when the RA-07 formulated several questions on CRS for study in the ITU-R SGs focusing on its definitions and technical specifications (Anker, 2010b). Following that, the WRC-07 invited in resolution 956 the ITU-R to study measures such as the need for a worldwide harmonized cognitive supporting pilot channel (CPC) or a database that can assist in the determination of local spectrum usage (ITU-R, 2007d). However, the interest in CPC had reduced following the WRC-07 (Ofcom, 2012).

One of the main outcomes of the ITU-R with this regard was the issuance of formal definitions of CRS and SDR (ITU-R, 2009b). CRS are also mentioned in ITU-R reports related to IMT as enablers of more dynamic and flexible radio resources management and optimisation (ITU-R, 2011d). It is worth mentioning that before WRC-12, there were perceptions that there may be needed changes for CRS similar to the case of DFS for WLAN in the 5 GHz in the WRC-03 (RSPG, 2011b). In addition, during WRC-12, some concerns were expressed regarding interference between CRS and space, passive and safety services (RCC, 2011). Countering this, however, others argued that national regulators can set operating parameters for CRS devices through equipment authorisation requirements to ensure they will not cause interference (CITEL, 2012, CEPT, 2011). Several regional organisations called for the development of a WRC-12 resolution to provide a framework for guidance on the study of CRS as well as guidance regarding how the use of CRS should be administered (ASMG, 2011b, ATU, 2011a, APT, 2011).

Eventually, WRC-12 did not decide on any particular measure with regard to CRS. Moreover, no spectrum was allocated to CPC as it was recognised that CRS are technologies and not radiocommunication services. It was also agreed that the examination of the implementation and use of CRS in radiocommunication services should continue without the need for consideration in next WRC (ITU-R, 2012f). In addition, WRC-12 recommended that any radio system implementing CRS technology should operate in accordance with the provisions of the radio regulations and that the use of CRS does not exempt administrators from their obligations with regard to the protection others operating in accordance with the RR (ITU-R, 2012i). There are current studies in the ITU-R SG 5 and WP 5A regarding CRS use for the mobile service (Costa, 2014). On whether the international regime restricts the use of CRS, Medisis and Holland (2014) argue that there is nothing to restrict utilising CRS in two cases. The first is to use CRS under any service as defined in the RR. The second is to operate on non-interference basis where there is no caused harmful interference and no claim from protection from harmful interference.

Regarding TVWS, there have been some work in the WP 1B to produce ITU-R report on TVWS (Chairman of Working Party 1B, 2013). In addition, TVWS are defined in one of the ITU-R reports as "*a portion of spectrum in a band allocated to the broadcasting service and used for television broadcasting that is identified by an administration as available for wireless communication at a given time in a given geographical area on a non-interfering and non-protected basis with regard to other services with a higher priority on a national basis*" (ITU-R, 2011f:3). However, the TVWS definition is not yet formally defined by the ITU-R Coordination Committee for Vocabulary (CCV) similar to the case of CRS and SDR (ITU-R, 2013b).

Regarding the status of TVWS, one perception from CEPT is that they should operate on non-interference basis (Newlands, 2009a). Besides, the US has clarified during the WP 1B meetings that they are using the TVWS on non-protection, non-interference basis (Chairman of Working Party 1B, 2013). Moreover, concepts such as LSA are perceived to operate according to the RR service allocation (RSPG, 2011a).

3.3.4 Assignment

The ITU-R is not involved in the type of spectrum assignment and whether it is administrative, unlicensed or by auction. However, one article of the ITU-R RR states that "*no transmitting station may be established or operated by a private person or by any enterprise without a licence issued in conformity with the RR*" (ITU-R, 2008e: 235). Horvitz (2007) argues that such article may be the reason that some countries prohibited the unlicensed use of radio. In addition, an ITU-R report discusses the non-market based methods, such as comparative processes and lotteries, and market-based methods, such as auction and spectrum trading, for spectrum assignment (ITU-R, 2010a). Moreover, a survey by the ITU on international policies on license exempt shows that almost two thirds of 75 respondents countries do not enjoy full license exemptions (Best, 2006).

3.4 *Conclusions*

This chapter has followed the early development of spectrum management on the international level and how it was created in line with the formulation process of national spectrum management policies. In particular, two issues necessitated managing the spectrum at the international levels: the phenomena of interference and the refusal of the Marconi Company to relay messages received from competing operators.

The ITU-R is the administrative cooperation body responsible for setting the international spectrum management regime's rules through the ITU-R RR and the ITU-R resolutions, recommendations and reports. Dividing the spectrum according to the type of service and global harmonisation of spectrum allocations are the ITU historical methods to mitigate harmful interference. Each spectrum band could be allocated to one or more radio services with equal or different rights (primary and secondary) with the world is divided into three regions in terms of spectrum allocation. Decisions related to spectrum allocation are taken during ITU-R WRCs.

Spectrum uses on the national level that are in conformity with the primary services and secondary services in the ITU-R table of spectrum allocation are protected against interference from primary and secondary services, and from secondary services allocated in the same band respectively. On the other hand, uses that are not in conformity with the primary or secondary services in the ITU table of spectrum allocation cannot claim protection from primary or secondary services in the same band.

The ITU-R work on standardisation of 3G technologies started by inviting applicants for IMT-2000 radio transmission technologies in 1997. Five terrestrial radio interfaces were approved to be part of the IMT-2000 standards. Later on, the WiMAX was included after oppositions from several countries and industry bodies. Regarding the 4G standards, two technologies, LTE-Advanced and WirelessMAN-Advanced were approved as IMT-Advanced standards. Moreover, the IMT standardisation process has been associated with identifying spectrum for the use of IMT standards by the ITU-R.

With regard to the existence of the concept of spectrum easements in the ITU RR, there are three cases. The first case is the co-existence of primary and secondary services where secondary services operate in the same spectrum bands with primary services without causing interference or claiming protection against interference from primary services. The second case is the operation on non-interference basis according to Article 4.4 from the RR. The third case is presented in the sharing between WLAN, which categorised as primary mobile service, and other primary services in the 5 GHz band.

4 Research Methodology

4.1 *Introduction*

This chapter deals mainly with two issues: the research gap and the appropriate research methodology to address it. Section 4.2 starts with identifying the research gap emerging from the literature review in Chapters 2 and 3, and then states the research main questions. Section 4.3 displays the adopted conceptual framework adopted for this research that is based on the literature review in the previous two chapters. The research methodology adopted for this research is explored which refers to the various sequential steps adopted by a researcher in studying a problem with certain objectives in mind[7](UKessays, 2014).

Section 4.4 clarifies in detail the philosophical paradigm adopted for this research while highlighting the dominant paradigm. Section 4.5 points out the research approach and then Section 4.6 identifies the used research strategy and how it was designed to fit with the purpose of this research. Section 4.7 indicates the data collection methods used to fulfil the research strategy. Section 4.8 handles the data analysis process through three stages: data reduction, data display, and conclusions drawing and verification. Finally, Section 4.9 concludes.

4.2 *Research Gap*

The literature review in Chapter 2 has discussed in detail the traditional approach to spectrum management: command and control, which enforces government control over the radio spectrum through service allocation harmonisation, selecting standardised technology, exclusive property rights, and administrative assignment. In particular, such approach emerged at the early days of wireless communication in order to protect national security, handle wireless equipment inadequacy, and deal with interoperability.

[7] It was noted that there are different approaches to deal with research methodology. As a result, scholars usually use similar terms to point to different subjects. For instance, while Saunders et al. (2009) use the term research strategies to reflect the choice between case studies, action research and other strategies, Holden and Lynch (2004) refer to them as research approaches while Creswell (2009) uses the term strategies of inquiries. Therefore, it is quite important to use one model of terms and clarify each one of them. Upon examining the different literature on research methodology, this research follows mostly the sequence suggested by Saunders et al. (2009) in order to inform one type of terms.

Meanwhile, the command and control was until recently the only approach to manage spectrum on the national level. However, many issues have called for reviewing such approach such as telecommunication market liberalisation, data demand growth, shortage in spectrum, and low spectrum utilisation efficiency in addition to the deficiencies in the command and control approach.

As result, a number of countries have reformed or planned to reform their spectrum management policies to accommodate elements from the three main alternatives to command and control: spectrum market, spectrum commons, and spectrum easements. However, while auction has been widely accepted as an assignment method for mobile operators around the world, the practice of spectrum property rights, spectrum trading, and spectrum flexibility has varied around the world with no case of significant success. Furthermore, spectrum commons has been implemented partially in the form of Wi-Fi or SRD. Additionally, concepts such as TVWS, ASA, LSA, have recently emerged and their effect is not shown yet.

Meanwhile, in many countries, radio spectrum is still managed according to the main principles of the command and control approach due to different local factors such as the influence of the public sector, especially the military, the absence of political support for such reform, the difficulty to re-farm current spectrum assignments, security issues, rigidity of national telecommunication law, and geographical and demographic status. On the other hand, there are other international factors that may have an influence on reforming national radio spectrum policies including standardisation activities, regional mandates, technology development, and developed countries' policies.

For instance, Wi-Fi is an example of the advancement of technologies that motivated many countries to allow such technology considering the existence of global standards (IEEE 802.11). Moreover, changes on national level preferences in the developed countries could lead to parallel changes in the developing countries. In particular, the success of spectrum auctions in the US has encouraged other countries to adopt auctions in their spectrum policies. However, one external factor that is largely overlooked in the debate is the interaction of national spectrum policies with the international spectrum management regime, and how such interaction may influence national spectrum policies reform.

In particular, Chapter 3 has shown how the international regime accommodates several functions that may be related to the four main elements of spectrum management on the national level: service allocation, technology selection, usage rights, and frequency assignment. Firstly, allocating the spectrum according to the type of radiocommunication service and global harmonisation of these allocations are the ITU historical methods to mitigate harmful interference. Secondly, the ITU-R has been involved in two aspects of personal mobile communication systems: defining the standards and spectrum identification related to these systems. Thirdly, there are different forms of spectrum easements in the ITU-R RR via primary and secondary services and operation on non-interference basis. Fourthly, the ITU-R is not involved with spectrum assignment and whether it is administrative, unlicensed or by auction while advocating licensing in general.

However, it is still not clear how the international regime interacts with national spectrum management policy reform from command and control to market, commons and easements approaches. Having said that, the main question of the research is decided to be '**How do the international radio spectrum management regime and national radio spectrum management policies interact?'** In order to investigate such interaction, it is necessary to map the different spectrum management approaches as shown in Figure 4-1.

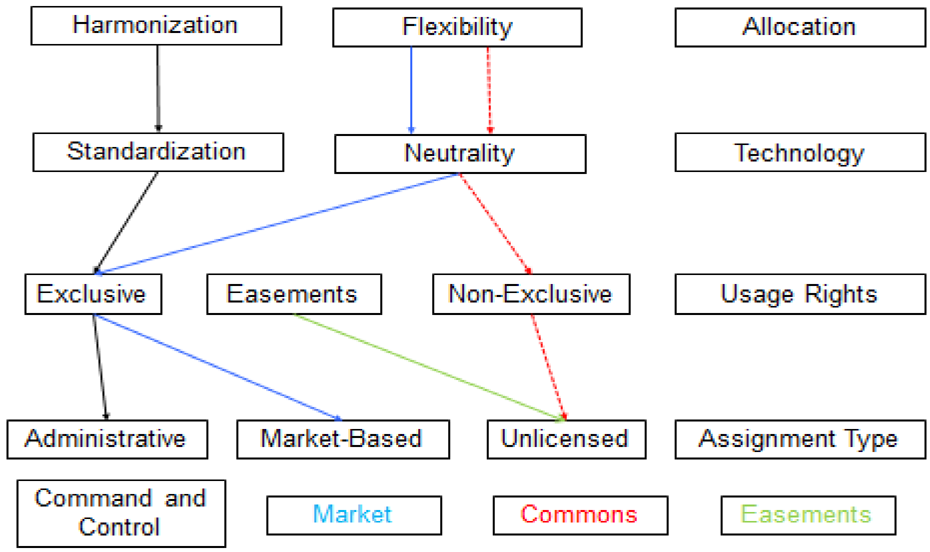

Figure 4-1: Spectrum Management Approaches

As shown in Figure 4-1, the main four approaches to spectrum management accommodate different elements. Firstly, the main difference between spectrum easements and other approaches is at the usage rights layer. Meanwhile, service flexibility and technology neutrality are not a condition for easements deployment. Moreover, although it is usually assumed that devices are license exempt in the spectrum easements approach; this depends mainly on national regulator. Secondly, the market approach is similar to the command and control in having exclusive usage rights. However, it is different in terms of having flexible service allocation and technology neutrality. Thirdly, spectrum commons is a complete deviation from the command and control approach.

Investigating the whole influence of the international regime on the different spectrum management approaches is beyond the time and resources available to this research. Therefore, it was decided to focus on some particular issues of an importance. Firstly, the market approach accommodates different elements such as radiocommunication service flexibility, technology neutrality, spectrum property rights design, auction design, and trading rules. It was decided to focus on the first two elements only: service allocation flexibility and technology neutrality. The decision is due to the fact that the ITU is not quite concerned with the assignment layer, and that the decision of spectrum assignment is related to national circumstances.

Secondly, with regard to the spectrum commons approach, the literature shows that the approach is still under discussion in the academia and under consideration by few national regulators while only standard or restricted commons is implemented in the form of Wi-Fi. However, spectrum commons shares also the two elements of service allocation flexibility and technology neutrality with spectrum market.

Therefore, two sub-questions are formulised as the followings '**How do the international radio spectrum management regime and national radio spectrum management policies interact with regard to radiocommunication service allocation flexibility?' and 'How do the international radio spectrum management regime and national radio spectrum management policies interact with regard to technology selection neutrality?'**

Thirdly, regarding the spectrum easements approach, the underlay type is implemented already by devices such as SRD. On the other hand, the overlay or opportunistic type, especially in the TVWS, is a new topic that is currently under consideration by many national regulators. Hence, it was decided to focus on the overlay (opportunistic) type of the easement approach in the TVWS. Therefore, the third sub-questions is formulised as the following **'How do the international radio spectrum management regime and national radio spectrum management policies interact with regard to opportunistic access in the TVWS?'**

There were several options for the focus of the research in terms of radiocommunication services. The first option was to address all of the radiocommunication services. However, this would require addressing more than forty services, which is beyond the resources and time available for the research. The second option was to address mobile services only. Nevertheless, the study would not be able to address issues such as service flexibility or overlay access in the TVWS. Therefore, it was decided to address three main radiocommunication services only: fixed, mobile, and broadcasting. That would enable addressing opportunistic access of devices categorised under fixed and mobile services in the broadcasting service spectrum. In addition, this would help focusing on the issues of technology neutrality in the mobile service bands and service allocation flexibility between the three radiocommunication services.

4.3 *Conceptual Framework*

According to Miles and Huberman (1994:18) "*A conceptual framework explains, either graphically or in narrative form, the main things to be studied-the key factors, constructs and variables-and the presumed relationships among them*". Such framework is helpful in determining which relationships to focus on and what data to be collected. In addition, conceptual framework can evolve and develop out of fieldwork itself (Miles and Huberman, 1994). It should be noted that while theory expresses a relationship among concepts, conceptual framework does not link concepts in a logically ordered deductive system. Instead, it is used mainly for theory development (Castro-Palaganas, 2007).

On the other hand, theoretical framework is defined as a set of theoretical assumptions that explain the relationships among a set of phenomena (Camp, 2001). The conceptual framework was quite useful in driving the main interviews questions. Figure 4-2 shows the conceptual framework for this study that was driven from the existing theory in the literature.

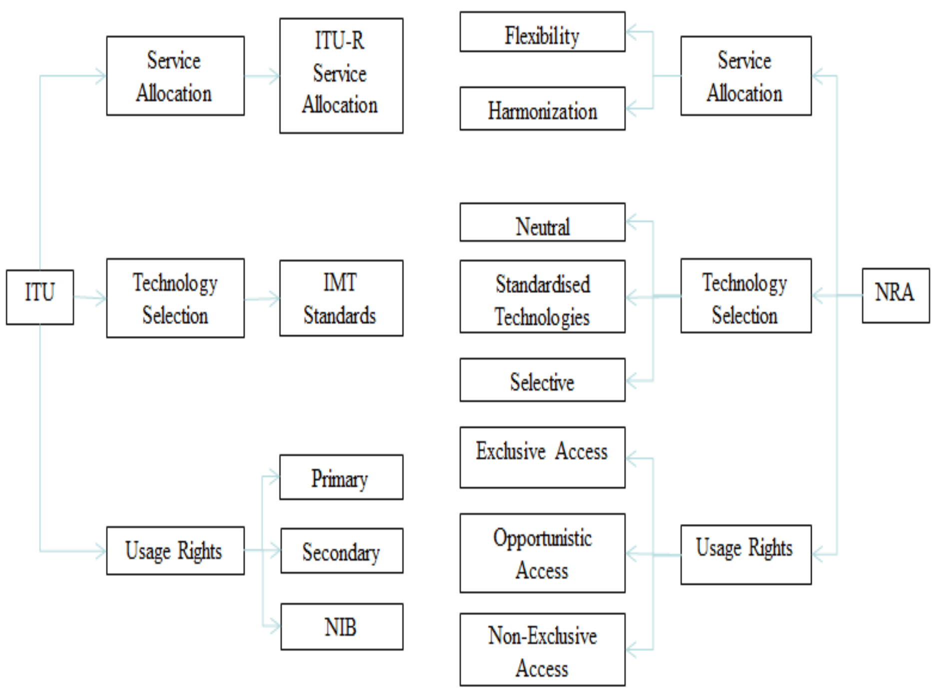

Figure 4-2: Conceptual Framework of the Research

As shown from Figure 4-2, the conceptual framework accommodates two sides. The one on the right side is based mainly on the literature review in Chapter two where national regulator authorities (NRAs) have different options with regard to the three elements of national spectrum management policies: service allocation, technology selection, and usage rights. Service allocation could be flexible or harmonised and technology selection could be neutral, limited to standardised technologies, or limited to specific technologies. Usage rights could be based on exclusive access, opportunistic access, or non-exclusive access. On the left side, the three elements of the international regime which are driven from Chapter three are displayed: service allocation according to the ITU-R table of service allocation, technology selection which is influenced by the IMT standardisation process in the ITU-R, and usage rights where there are primary, secondary, and access on non-interference-basis (NIB).

4.4 *Research Philosophy*

In general, research philosophy impacts the researcher's view of the relationship between knowledge and the process by which it is developed. In particular, Saunders et al. (2009) point out that the researcher's philosophical worldview or paradigm shows the researcher's view of the nature of reality or being (Ontology) and of what constitutes as an acceptable knowledge in a field of study (Epistemology). Scotland (2012) argues that the adopted paradigm would influence the choice of research strategy or plan and also the techniques used to collect and analyse data. Such philosophy is mainly influenced by the particular view of the relationship between knowledge and the process by which it is developed, and also by practical considerations (Saunders et al., 2009).

Before clarifying the philosophical paradigm adopted for this research, it is important firstly to understand what is meant by 'a paradigm'. Saunders et al. (2009) define paradigm as a way of examining social phenomena from which particular understandings of these phenomena can be gained and explanations attempted. While the literature accommodates many philosophical paradigms, this research focuses on four main types: positivism, interpretivism, realism, and pragmatism, which are mostly mentioned.

Firstly, the positivism position advocates the use of the methods of the natural science to the study of social reality (Bryman and Bell, 2007). In particular, it assumes that the social world exists objectively and externally, and that knowledge is valid only if it is based on observations of this external reality (Flowers, 2009). Secondly, the interpretivism position is a contrasting term to positivism and sometimes named as constructivism, anti-positivism, phenomenology, subjectivism, post-positivism, or social constructionism (Dissertation Writing Online, 2014, Holden and Lynch, 2004, Yuen, 2005, Schwandt, 1994, Mkansi and Acheampong, 2012, Flowers, 2009). Such position accommodates the subjective and socially constructed ontology. It also focuses upon the detail of a situation and the subjective meaning motivating actions (Saunders et al., 2009).

Thirdly, the realism position takes aspects from both positivism and interpretivism positions and holds that real structures exist independent of human consciousness, but that knowledge is socially created (Flowers, 2009). The fourth paradigm is called pragmatism which stands that the most important determinant of the adopted epistemology and ontology is the research question (Saunders et al., 2009).

This research attempts to find out the dominant philosophical paradigm within the research related to spectrum management. Upon searching many papers in the main journals in the field, it was found that it is rare to find the philosophical position of the authors explicitly mentioned. However, this does not indicate that such position does not exist. Instead, although research philosophy may not be apparent in the literature, it has great influence on adopted research methods. In particular, due to the multidisciplinary nature of spectrum management, researchers have been addressing the subject from three main aspects: technical, economical, and regulatory. This has called for adopting different epistemologies.

Firstly, with regard to the technical aspects to spectrum management, such research focuses on maximising the technical utilisation efficiency of spectrum usage (Burns, 2002, Webb, 2007). Therefore, what is considered as acceptable knowledge in the technical study of spectrum management is what can be generalised upon technical experiments or simulations. Secondly, while researchers of economic aspects of spectrum management address mainly other aspects of spectrum usage such as opportunity cost and auction prices, they also focus on observable values and measurable data of economic performance (Hazlett and Muñoz, 2006, Hazlett, 2006, Hazlett, 2001, Bazelon, 2009, Bayrak, 2008).

Having said that, it could be argued that the philosophical paradigm adopted in these technical and economic research is positivism. Regarding the regulatory aspects of spectrum management, researchers usually focus on national policies and the international regime (Codding, 1991, Savage, 1989, Cowhey and Aronson, 1991). As this particular research addresses largely the international spectrum management regime, it was inevitable to explore the field of international regimes in order to discover prevailing philosophical paradigms.

It was found out that there are three main theories for studying international regimes. Neoliberals envision that interdependencies and mutual interests of creating international technical standards could motivate increased international cooperation. On the other hand, neorealists consider that mutual interests are not sufficient for regime development as there should be a dominant state or group of states which has the power to impose acceptance of the regime and compliance on other states to acquire greater relative gains (McCormick, 2007). The third theory is constructivism where the learners construct their own knowledge (Kanselaar, 2002) and where the emphasis is on the collaborative nature of learning and the importance of cultural and social context (Open Educational Resources of UCD Teaching and Learning, 2014).

Regarding international regimes, constructivism seeks to demonstrate how many core aspects of international relations are given their form by on-going processes of social practice and interaction (Bledsoe, 2012). Furthermore, the three theories have different approaches with regard to regime analysis. While liberalism focuses on regimes' functions such as reducing transaction costs, realism studies the influence of a hegemonic power. Constructivism analyses regime in terms of cognitive frameworks that influence how actors define problems and their solutions (Cowhey, 1990).

While the neoliberal and neorealist embrace different views with regard to regime analysis, both of them adopts the positivisms paradigm (Lee, 1996). This is supported by Steans et al. (2010) who point out that positivism sometimes is equated with liberalism and realism. This is not the case for the constructivism approach, which is influenced by the interpretivism paradigm. Under such paradigm, it is argued that state behaviour is shaped by elite beliefs and shared knowledge (Ratto-Nielsen, 2006). It is worth mentioning that the dominant approach in the research on international organisations has been that of the liberal and realist based approaches (Lee, 1996).

Adopting the positivist paradigm in studying international regulations have been criticised by many scholars such as Lee (1996) and Ratto-Nielsen (2006) which argued for adopting other approaches such as the constructivism. More specifically, Ratto-Nielsen (2006) criticises employing the neorealism/realism perspective when studying the international telecommunication regime and explains that they do not justify the creation and maintenance of the ITU. Furthermore, liberal and neoliberal approaches do not consider the changes in domestic preferences (Ratto-Nielsen, 2006). Moreover, both approaches have failed to take into account the emergence of new policy actors and to explain changes within the regime.

Having said that, this research adopts the interpretivism paradigm as the philosophical position for this research for several reasons. Firstly, this research embraces the subjective ontological position which holds that social phenomena are created from the perceptions and consequent actions of social actors (Saunders et al., 2009). More specifically, it is argued that the regulatory aspects of spectrum management are socially constructed by the policymakers' views and beliefs where these views are not constant and may change according to the complex and relatively unique circumstances of each country. These views vary across the different stakeholders' position. Secondly, with regard to the epistemological position, this research aims to investigate the subjective meanings of a situation where the focus is on the detail (Saunders et al., 2009). In other words, it is believed that it is more important to focus on the detail of national regulations with regard to spectrum management and the particular views of national policy makers towards the international regulations.

In addition, although interpretivism is not the dominant paradigm in the field of study, such paradigm is adopted for its capabilities to accommodate the subjective views of the different stakeholders and to take into account the changes in domestic preferences of the selected case studies of Egypt and UAE. Besides, the subjective ontology of the interpretivism accommodates that an organisation is a socially constructed product so that it could be explored through the viewpoints of the individuals who work within such organisation (Burrell and Morgan, 1979). This is aligned with the researcher's belief that the discussions related to spectrum management on the international and international levels are formulated through the perceptions of the main stakeholders.

Furthermore, this research approaches the spectrum management issue under examination from the regulatory rather than technical or economic aspects. Hence, quantitative methods adopted by paradigms such as positivism would be limited in effect in the social world where it is might be difficult to quantify and measure the different issues (Mingers, 2006). It should be noted that there are criticisms to the interpretivism approach which include that one theory cannot be held as more valid than another (Holden and Lynch, 2004). This is due that research that is based on the interpretivism approach cannot be judged using the same criteria as applied in the positivism approach (Scotland, 2012). However, this research does not target generalisation but rather aims to examine closely specific context in order to answer the research questions. Therefore, such concern would not be an issue.

4.5 *Research Approach*

In general, there are two main research approaches in terms of theory: deductive and inductive. In the former, a theory is developed and then data is collected and the findings of the research are investigated to confirm or reject the theory's hypotheses. In inductive research, the theory is developed upon the observations or the findings of the research (Bryman and Bell, 2007). This research adopts inductive research approach for the following reasons. Firstly, developing hypotheses covering the research topic would be quite difficult as there is little literature addressing the issue. Secondly, the research addresses the spectrum policy domain that has a complex set of relationships and interactions between different categories of actors. Hence, the induction approach would provide more flexible structure to permit changes of research emphasis upon the research progress (Saunders et al., 2009).

Thirdly, deductive approach is found not to be suitable under the interpretivism paradigm adopted by this research as it is usually based on developing causal model that explains past and predict future observations. This is more valid for subject matters of natural science and not for the subject matter of social science (Gill and Johnson, 2002). On the other hand, inductive research is more suitable when this research tends to understand the nature of a problem and is concerned with the context in which events have taken place (Saunders et al., 2009).

It is worth highlighting Creswell (2007)'s argument that one of the implications of inductive approach is that the research procedures are shaped by the researcher's experience in collecting and analysing the data. Therefore, research questions could be changed during the study to reflect in a better way the types of questions needed to understand the research problem. In fact, the main research question was changed at the early days of the research from 'How does the international radio spectrum management regime influence national radio spectrum management policy reform?' to 'How do the international radio spectrum management regime and national radio spectrum management policies interact?' in order to reflect the dynamic bi-directional relationship.

4.6 *Research Strategy*

Selection of the research strategy is influenced by the research questions, philosophical underpinnings, extent of existing knowledge, and amount of time and resources (Saunders et al., 2009). The strategy adopted for this research is case study. Such strategy requires conducting detailed investigation to a specific case(s) in order to get a closer insight into the context and processes involved in the research subject (Meyer, 2001). Using case studies can ensure accuracy and alternative explanations and can bring out more detail by using multiple sources of data (Tellis, 1997). Intensive analysis of a typical case of a certain type would allow generalisations that could be applicable to other cases of the same type (Kumer, 2005).

The nature of the question and spectrum policy process has called for utilising such strategy. Case studies could be used with the interpretivism philosophical paradigm adopted by the researcher (Holden and Lynch, 2004). National policy process accommodates different stakeholders and the interaction between those stakeholders varies according to the national circumstances. Therefore, it is quite important to adopt a research strategy that focuses on the context of the research. Case studies are also preferable when the investigator has little control over events and when the focus is on a contemporary phenomenon within real life context (Yin, 2003). In particular, national regulators have the sovereign right to plan their spectrum according to any management approach. Therefore, spectrum policy development is an on-going process that this research has no control on.

Several criticisms associated with case study such as the difficulty to generalise conclusions in case of focusing on a single case and resulting in a massive amount of documentation (Yin, 2003). This research took some measures to overcome these shortcomings. As explained before, this research is not seeking generalisation but rather focusing on specific context. However, it was decided to address multiple case studies in order to add confidence to the findings (Miles and Huberman, 1994). Secondly, the collected data have been passed several stages of reducing and focusing in order to overcome the issue of large amount of documentation , which would be explained later.

It should be noted that other research strategies were considered for this research. Firstly, regarding ethnography method, the use of such methodology was precluded due to the time limitation of the research as it involves long period of participant's observation (Bryman and Bell, 2007). Action research was also omitted because of the nature of the spectrum policy process, which is built up in years and usually involves local citizens only. Survey is usually used with deductive approach, which is not the case for this research. In addition, all of the data collection methods associated with survey does not provide the research with the required flexibility and may have low response rate. Finally, grounded theory precludes using theory or conceptual categories that guide the research and analysis of data which may lead to spending significant time gathering basic information with regard to the research subject (Meyer, 2001).

4.6.1 Case Study Design

The second step after selecting case study as the research strategy is to design such strategy and to define its main elements. In general, there are four types of case studies: single-case (holistic), single-case (embedded), multiple-case (holistic), and multiple-case (embedded) (Yin, 2003). The difference between holistic and embedded case study is that the former handles each case as one unit of analysis, while the later may address more than one unit of analysis in the same case study. Holistic design is useful when no subunits can be identified. However, it may miss examining any particular issue in the case with more detail. Embedded design, on the other hand, enables extensive analysis to the case. Nevertheless, there is a potential of missing the whole picture of the case.

Single case study is suitable when it represents the critical case in testing a well-formulated theory or when the case represents a unique or extreme case. However, it has the risk of misrepresentation of the issue. On the other hand, it is argued that evidences driven from multiple-cases design are more compelling than single-case although multiple-cases require extensive resources and time (Yin, 2003).

The type of case study that is used in this research is holistic multiple-case where the unit of analysis is a country's national spectrum policy eco-system. The reason for selecting holistic case study is that although spectrum policy is the decision of national regulator, it is the output of complex interactions between the different actors and perspectives within the national spectrum policy domain. These actors include national regulators, national actors (e.g. national operators, national broadcasters, and public sector), and international actors (e.g. standardisation organisations, and industry forums). Therefore, the research should focus on the whole country and treat it as one unit rather than focusing on each actor.

In the case study selection process, several options were considered: the world, developing countries, or the Arab countries. While the first option is way beyond the available time and resources for the research, the option of the developing countries does not represent a homogenous case study. Firstly, not all the developing countries adopt the command and control and some of them have adopted the spectrum market (e.g. Guatemala and El Salvador). Furthermore, this is option is still not feasible considering the limitation in the research time.

With regard to the third option, the Arab countries, it was found that the dominant spectrum management regime in the Arab countries is command and control where services and technologies are selected by the regulator and trading is not allowed (Horton, 2012). Moreover, none of the Arab countries announces plans related to deployment of DSA in the TVWS or in other spectrum bands, and it would be useful to understand the perceptions of the Arab countries with this regard. Therefore, although the Arab countries is a mix of developed and developing countries with a diverse range of population, Gross Domestic Product (GDP) per capita, and ICT Development Index (IDI) [8] (The World Bank, 2012, UNData, 2012b, UNData, 2012a), they present a homogenous case study with regard to spectrum management.

[8] The ICT Development Index (IDI) is a composite index made up of 11 indicators covering ICT access, use and skills (e.g. Mobile broadband subscriptions per 100 inhabitants, Mobile cellular telephone subscriptions per 100 inhabitants). The country with the higher IDI is Hong Kong-China with score of 9.06.

The second factor that supported the choice of the Arab countries is their active participation in the ITU. In particular, the Arab countries have a regional group, the Arab Spectrum Management Group (ASMG), that is responsible for coordinating Arab States position in ITU-R meetings (ITU-R, 2010b). The ASMG has active participation and several contributions in the ITU-R meetings especially WRCs (Debbagh et al., 2012). Most recently, the Arab countries called in WRC-12 for allocating additional spectrum in the 694-790 MHz band for mobile service in ITU Region 1 (Standeford, 2012a, Standeford, 2012c).

Furthermore, the Arab countries participated in supporting the diversity within the IMT technologies within the ITU through supporting the inclusion of the FDD and TDD versions of WiMAX into the IMT family of standards (Egypt, 2007, Egypt, 2009, Lebanon, 2009, UAE, 2009). With regard to CRS, the Arab countries called for the development of a WRC-12 resolution to provide a framework for guidance on the study of CRS as well as guidance regarding how the use of CRS should be administered (ASMG, 2011b).

One other factor that encourages focusing on the Arab countries is their dependency on wireless rather than wire-line networks. For instance, the fixed-telephone penetration rate in the Arab countries is 9.6 % while the mobile telephone penetration rate is 97.6% for the year 2012 (ITU, 2012a). Therefore, spectrum management issues are critical for the Arab countries as spectrum is an essential component in delivering wireless services. In addition to that, there are few publications on the Arab countries in general, as they tend to be closed society. Therefore, they are largely overlooked in the academic research.

Finally, the choice of the Arab countries is also guided by practicality. The researcher is currently an employee in the spectrum management sector at the national telecom regulatory authority of Egypt (NTRA) and a member in the ASMG. In addition, the researcher is the representative of NTRA in the ITU-R for different issues. This would facilitate the process of accessing the data with regard to the Arab countries' spectrum policy and the ITU-R.

Due to the limitation in research time and resource, the study cannot cover all of the twenty-two Arab countries. Therefore, a sampling strategy was applied in order to select which case studies to focus on. Miles and Huberman (1994) suggest several sampling strategies such as maximum variance, critical case, or extreme case. It was decided to choose two strategies: convenience and criterion. While the former intends to select practical cases in terms of time and money, the latter refers to all cases that meet some criterion (Miles and Huberman, 1994).

The convenience sampling strategy resulted in excluding several Arab countries that have difficult circumstances in terms of practicalities. For instance, Palestine is denied access to most of the radio spectrum over Palestine territories by Israel (Palestine National Authority, 2012a, Palestine National Authority, 2012b). In addition, the recent local disorder in countries such as Iraq, Syria, Libya, Somalia, Tunis and Yemen would make it quite difficult to obtain data with regard to their spectrum policy and to conduct interviews with policy makers. Furthermore, some Arab countries such as Djibouti, Comoros and Mauritania have their published information on spectrum management in French only.

The second sampling strategy was selecting countries that have interaction with the ITU-R. This element is quite essential as the study aims to investigate the interactions and relationships between the international regime and the national spectrum policy. Three measures were used to assess this element: participation at the WRC level[9], participation at the study group level[10], and participation at the working group level[11]. While all of the Arab countries participated at the WRC level, only four countries participated at the level of study groups (Syria, Egypt, UAE, and Saudi Arabia) and five countries participated at the working group level (Syria, Egypt, UAE, Tunis, and Saudi Arabia).

After applying the criteria above and after excluding Tunis and Syria according to the first sampling strategy (convenience), three countries were selected as cases studies:

[9] Only the last four WRCs were considered, WRC-2000, WRC-03, WRC-07, and WRC-12, for the issue of data availability on previous WRCs.

[10] The participation at study group 1 (SG1) between WRC-03 and WRC-12 was considered. SG1 addresses spectrum management principles and techniques, general principles of sharing, spectrum monitoring, long-term strategies for spectrum utilisation, economic approaches to national spectrum management, automated techniques and assistance to developing countries in cooperation with the Telecommunication Development Sector.

[11] The participation at working party (WP 1B) between WRC-03 and WRC-12 was considered. WP 1B focuses on spectrum management methodologies and economic strategies. More specifically, WP 1B was responsible of two important agenda items (AI) prior to the WRC-12, AI 1.2 which addresses enhancing the spectrum management regulatory framework and AI 1.19 which addresses regulatory measures to enable CRS.

Egypt, Saudi Arabia, and UAE. Unfortunately, after several attempts to conduct the Saudi Arabia case studies, it was not possible to get the approval from the Saudi authorities.

4.7 *Data Collection Methods*

The choice of the data collection method is mainly influenced by the research strategy. Moreover, several methods were considered for this research such as questionnaires, and participant observation. Participant observation was excluded because it is time consuming and requires high level of access to the organisations under investigations (Saunders et al., 2009). Secondly, Questionnaires have the disadvantage of potential low response rate (Saunders et al., 2009).

The third method that was considered is interview, which is also favoured by the interpretivism philosophical paradigm adopted by this research for several reasons. Firstly, conducting research through interviews reflects that the researcher values personal interaction with the respondents more highly than their anonymous views expressed through a questionnaire (Saunders et al., 2009). Secondly, within interpretivism, reality is individually constructed and varies according to the number of individuals, and such reality is understood through interaction between the researcher and the individuals (Scotland, 2012).

The second step was to select which type of interviews to be used in this research. It is found that there are two types of interviews: quantitative (structured), qualitative (semi-structured, and unstructured). There are several reasons that favour the choice of qualitative interviews in this research (Saunders et al., 2009). Firstly, personal contact assures achieving more response rate than structured interviews. This is mainly because interviewees may hesitate to provide sensitive data or to spend time explaining their answers. Secondly, qualitative interviews provide an opportunity to modify particular questions in case the interviewees would not provide an answer.

On the other hand, quantitative interviews have a rigid structure that cannot be easily modified (Bryman and Bell, 2007). In addition, they require knowing all the answers to each question, which is not the case for this research. Qualitative interviews also provide the researcher with more flexibility and control in determining the interview questions. The difference between unstructured and semi-structured interview is that the former is similar to a conversation and could contain one question, while the later compromises a list of questions on specific topics (Bryman and Bell, 2007). As the research adopts a conceptual framework, there are particular topics that the interview needs to focus on. Therefore, semi-structured interviews are selected as the data collection method for this research.

The primary data was backed up with secondary data that was acquired through journals, consultant reports, and the website of national regulators. The researcher has an active TIES[12] (Telecommunication Information Exchange Service) account to access all ITU-R publications and countries' contributions. In addition, the researcher has access to two spectrum management specialised journals: 'Policy Tracker-Spectrum' and 'World Radiocommunication Reports'.

4.7.1 Data Sources

Identifying data sources was conducted with the help of the research conceptual framework and the analysis of the case studies. The main data sources are the ITU-R representatives and the main actors in the national spectrum policy eco-system. In addition, interviewees were selected based on the following criteria. At the national level, interviewees were selected from the national regulator, broadcaster, mobile operators and fixed incumbent on the basis that they should have knowledge on the country spectrum policy and should be aware of the international spectrum regulations.

On the international level, interviewees were selected from representatives at the ITU-R, mobile operators, mobile manufactures, industry forums, consultant firms, broadcasters, national regulators, regional organisations, and standardisation organisations. Appendix II provides detail on the interviewees selected for this research. Table 4-1 below shows the data sources for each of the research questions.

Data Sources
Service allocation flexibility • National stakeholders (regulators – mobile & fixed operators – broadcasters) • International stakeholders (regulators – mobile industry (manufactures – industry forums – operators) – broadcasters – ITU-R representatives).

[12] TIES is the name of ITU account that is exclusive to ITU members.

Technology neutrality • National stakeholders (regulators – mobile operators) • International stakeholders (regulators – mobile industry (manufactures – industry forums – operators) – ITU-R representatives).
Opportunistic access • National stakeholders (regulators – mobile & fixed operators – broadcasters) • International stakeholders (regulators – mobile industry (manufactures – industry forums – operators) – broadcasters – ITU-R representatives - TVWS industry (industry forum – standardisation organisation)).

Table 4-1: Data Sources

4.7.2 Interview Questions

Interview questions were developed with the help of the conceptual framework. Table 4-2 below presents a list of the questions for each research question. The questions language was different according to the interviewees. For instance, regulators were asked whether they apply technology neutrality and operators were asked if their licenses are technology neutral. In addition, as the interviewees have different backgrounds, the list of questions was dynamic and specific to each interviewee to make the best use of the interviewees' expertise. Furthermore, additional questions were asked for particular interviewees who were involved in a specific activity.

Research Questions / Sub-Issues	Interview Questions
How do the international radio spectrum management regime and national radio spectrum management policies interact with regard to service allocation flexibility? • Perception on concept. • Influence of MIFR on	• What are your views with regard to the concept of radiocommunication service allocation flexibility? • Do you think the concept of service allocation neutrality between fixed, mobile and broadcasting could be accommodated within the current ITU RR? • What is your opinion with regard to the

service flexibility. • Influence of footnotes on service flexibility. • Influence of a priori planning on service flexibility. • Influence of decision-making procedures on service flexibility. • Influence of the three regions system on service flexibility. • Influence of the radiocommunication services definition on service flexibility.	influence of registering assignments in the MIFR on service allocation flexibility? • What is your opinion with regard to the influence of footnotes on service allocation flexibility? • What is your opinion with regard to the influence of a-priori planning conferences such as RRC-06 on service allocation flexibility? • What is your opinion with regard to the influence of the ITU-R decision-making procedures on service allocation flexibility? • What is your opinion with regard to the influence of the current three regions system on service allocation flexibility? What modifications do you tend to introduce to the three-region system? • What is your opinion with regard to the influence of the current ITU-R definitions of fixed, mobile and broadcasting services on service allocation flexibility?
How do the international radio spectrum management regime and national radio spectrum management policies interact with regard to technology selection neutrality? • Perception on concept. • Influence of IMT standardisation on technology neutrality and selection.	• What are your views with regard to the concept of technology neutrality? • What is the influence of the IMT standardisation process on the tendency towards technology neutrality? • Is being one of the ITU IMT-2000 and IMT-Advanced standards mandatory for introducing a mobile technology? • Do your define 3G and 4G services according to the ITU-R IMT-2000 and IMT-Advanced

• Influence of IMT standardisation on 3G and 4G generation definitions. • Influence of IMT spectrum identification on technology selection and neutrality.	standards? • What is the influence of having spectrum identified for IMT on technology selection and neutrality?
How do the international radio spectrum management regime and national radio spectrum management policies interact with regard to opportunistic access in the TVWS? • Perception on concept. • Influence of the RR on TVWS. • Influence of WRC-12 A.I. 1.19 on TVWS. • TVWS service status. • Similar measures to the Wi-Fi in the 5 GHz.	• What do you think of the concept of opportunistic access? • Do you think that the concept of opportunistic access in TVWS could be accommodated within the current ITU-R RR? • What do you think of the influence of WRC-12 decision on CRS (AI 1.19) on adoption of opportunistic access in the TVWS? • What do you think of the TVWS service status? • Do you think there should be some mandates such as DFS on Wi-Fi in the 5 GHz for the case of TVWS?

Table 4-2: Interviews' Questions

4.7.3 Fieldwork Interviews

Before conducting the interviews in the fieldwork, two pilot interviews were conducted with two spectrum management managers where one of them was not specialised in the topics of the research and therefore, was not involved in the actual interviews later on. The pilot interviews were quite useful in different aspects. Firstly, they showed that interviews are preferred not to be conducted fully in Arabic, as some ITU-R terms cannot be easily explained in Arabic. Secondly, it was shown that the period of the interviews could vary according to the interviewees themselves. Thirdly, it was clear that the interviewer should be careful regarding the language of the question to reflect a neutral tone in order not to guide the interviewee towards particular answer. Fourthly, the sequence of the questions was found to be suitable and coherent. In general, the pilot interviews were a good chance to prepare for the fieldwork interviews.

Moreover, a course on research ethics was attended to get insights on the required ethical procedures to conduct the research. Upon revising the code of practice of the University of Strathclyde, an ethics form was submitted to the University ethics committee explaining issues related to data handling, collection, and storage in addition to potential risks on the interviewees. An email was sent to the potential interviewees explaining to them the main research questions. In case the interviewee agreed to conduct the interview, participant information sheet and consent form were sent to them. Most importantly, the information sheet contains information on the nature of interviewee participation. Besides, each interviewee was requested to sign the consent form to make sure he agreed to be part of the project. Fontana and Frey (1994) highlight the importance of ethics in interviews and to have consent form informing the interviewees of the research topic.

Some considerations were taken into account regarding the interviews process (Ackermann, 2012). This includes balancing the number of questions with the available time with the interviewees. In case that the available time was short, either another session was conducted with the interviewee or only most important questions were asked. Whether to record the interview or to take notes was decided according to the decisions of the interviewees. It was also important to set open, positive and relaxed stance with the interviewees and to build trustful relationship with the interviewees as pointed out by Fontana and Frey (1994). Explaining to the interviewees that no information that identifies them will be made publicly available and that their views are anonymous encourages several interviewees to express their opinions freely and to speak openly.

Almost all interviews were conducted in the period from March 2013 until March 2014 in several countries (Egypt, UAE, Switzerland, Kenya, South Africa, Uganda, and Tunis). In addition, out of the 113 interviews, 27 were conducted by phone due to difficulty in setting the interview in person. In such case, the interviewee was let to decide which method to use to conduct the interviews (e.g. Skype, land or mobile phone).

While conducting interviews on the phone has the advantages of being less time consuming, easier to organise, and having quicker willingness to co-operate, it also requires good telephone manners (Lemon, 2007). Interviews were recorded as MP3 format via a specialised recording device upon the interviewees' permission and sent back to them for verification. Only three interviewees refused to record the interviews. In such cases, interviews were transcribed immediately by the interviewer during the interviews and then revised before sending them to the interviewees for verification.

Notes were taken during the interviews to get better understanding of the data before transcribing the interviews. This was also useful in enhancing the questions afterward. These notes were also used to enhance the quality of the transcription. Furthermore, during the interviews with the national case studies, the interviewees were asked if they prefer to speak in English or in Arabic. This was important for some interviewees to express their views easily in their native language. In order to have the data in a format suitable for analysis, all recorded interviews were transcribed verbatim. Appendix III provides a sample of an interview transcription. In order to verify the data preparation process, the transcribed interviews were revised twice by independent professionals in addition to the researcher. Appendix IV provides a brief over the data preparation verification process.

4.8 *Data Analysis*

Miles and Huberman (1994) define three stages of data analysis: data reduction, data display, and conclusion drawing/verification. Data reduction is the process of selecting and simplifying the data included in the filed notes or interviews transcription. Data display is organising and assembling information that permits conclusion drawing. The next three sub-sections address each stage.

4.8.1 Data Reduction

One of the reasons for data reduction is that qualitative research generates large amount of data due to its reliance on style of interview transcription or field notes (Bryman and Bell, 2007). Data reduction has been achieved in this research through coding. A code is an abstract representation of an object (Bazeley, 2007) and coding is defined as breaking data down into component parts which are given names (Bryman and Bell, 2007). Coding is used to links data to ideas and also to find out links between the different ideas (Bazeley, 2007).

While coding could be conducted manually on printed papers, there have been several software usually called Computer-Assisted Qualitative Data Analysis Software (CAQDAS) that could simplify the coding process and decrease the risks of manual coding (Bryman and Bell, 2007). In addition, using software in a qualitative data analysis has the advantages of saving time, dealing with large amounts of qualitative data, and having increased flexibility (St John and Johnson, 2000). This research adopted version 10 of QSR NVivo software[13] to conduct the coding process because it is available via the university facilities and because it is easy to use as it has a friendly user interface. Appendix V provides detail of the coding steps in NVivo.

Coding check or verification is an important process and accommodates revising the codes by more than one coder and it is considered as a good reliability check (Miles and Huberman, 1994). In order to verify the coding process, three independent coders were selected to double code some selected interviews. These coders were selected on the basis that they were not involved in any part of the research and that they have good knowledge of spectrum management and the ITU. Furthermore, one additional coder was chosen from outside the field of spectrum management in order to make the verification process more robust. Appendix VI provides detail of the coding verification process.

4.8.2 Data Display

Miles and Huberman (1994) define data display as a visual format that presents the information systematically in order to drive valid conclusions. In general, this research displayed the collected data after reducing it for several reasons (Miles and Huberman, 1994). Firstly, it is difficult to analyse dispersed data and the process of drawing conclusions for the readers from data display has much better chances that doing that from extended text. Data display helps also discovering new relationship and proposing explanation.

Miles and Huberman (1994) identify different types of data display namely, partially ordered display where there is some internal order to impose concept structure,

[13] For further details on the features of NVivo, please look at http://www.qsrinternational.com.

time-ordered displays where data are ordered by time, role order display where information are ordered according to the role of the stakeholders, and conceptually ordered display where display is ordered by concepts. The last type of display was found most suitable for this research, which focuses on the concepts and their relation rather than time or role.

The second step after selecting conceptually ordered display was to choose the display format. In general, there are two formats of data display: matrices with defined rows and columns, and networks with a series of nodes with links between them (Miles and Huberman, 1994). This research adopted the network format for this research, as there are different categories of concepts under examination under the three research questions that may have complex relationship that is difficult to be displayed via matrices.

The third step was to choose the type of network format to be used for data display. This research considers different type of network mapping such as mind mapping, concept mapping, and cognitive mapping. Regarding concept mapping, it was found that concepts are usually single word which is not suitable for the purpose of this research which is to extensively display the data to draw conclusions (Banxia Software, 2014). Regarding mind mapping, it has the same shortcoming of having concepts as single word and it based mainly on using images and having one central idea which is not the case (Brightman, 2003). Therefore, it would not capture relationship and complexity in the research.

On the other hand, cognitive mapping is a causal based mapping technique that encourages the mapper to note hierarchy in the represented ideas (Banxia Software, 2014). It was also found that cognitive mapping could be also useful when a second mapper double check the mapping process as the links are less subjective and more consistent than the case of concept mapping. Furthermore, two of the pioneers of cognitive mapping, Professor Fran Ackermann and Professor Colin Eden, are from the researcher’s university and they could provide their advice on the maps. Therefore, cognitive mapping was found as the most convenience method for data display.

Cognitive maps are defined as graphic tools that are used to represent concepts and ideas that individual associates with some specific issue (Albino, 2003). Moreover, causal map is defined as a specific form of cognitive map that incorporate concepts linked together by causal relationships (Prigenta et al., 2008). In causal maps, nodes represent concepts and arcs directional relationship between these nodes (Topcu, 2014). Cognitive mapping is used mainly to represent the subjective world of interviewees (Eden, 2004), and it is based on the Kelly's personal construct theory as it presents person's construct system which they are able to and willing to make explicit (Eden and Ackermann, 1998b). More specifically, Kelly proposed that in order to understand how individuals organise their environment, the individuals themselves should define the relevant dimensions of that environment (Chaib-Draa and Desharnais, 1998).

There are different formats of individual cognitive mapping representations such as those suggested by Ackermann et al. (1992), Laukkanen (1998), Langfield-Smith (1992), Sheetz et al. (1994). However, it was found that the former type is the most convenience and richest in terms of representation and displaying the data of this research. Furthermore, the technique is widely adopted in much literature.

As cognitive mapping represents individual cognition, it was required to map each interviewee's transcribed interview. However, the purpose of data display in this research was to map the collective data representing the views of all of the interviewees on each topic, rather than the views of each interviewee on all the topics. In addition, mapping the individual interviews separately would be a quiet time consuming process. Such process is not needed as interviews were already coded into main concepts during the data reduction stage. Moreover, the research is not concerned with individual but collective views instead. Therefore, this research tends to collectively map the interviews' views.

After considering different types of group cognitive mapping, it was found that they all are not practical for this research (Tatiana Bouzdine-Chameeva et al., 2001, Leonhardt Kjærgaard and Blegind Jensen, 2014, Tegarden and Sheetz, 2003, Theinera et al., 2010). Therefore, it was decided to use the graphical representation of causal cognitive mapping for the purpose of data display and relationship examination. It was recognised that this way of mapping does not represent a cognitive mapping of the interviewees but rather composite causal maps of the different views. This is due that cognition belongs to individual and not to organisations and that the attribution of cognition to a group is problematic (Eden and Ackermann, 1998a). Miles and Huberman (1994) argue that data displays can be adapted to meet the needs of a particular study.

There have been several criticisms of the concept of cognitive mapping, as it does not truly represent what stakeholders think. Instead, maps are graphical representations of these stakeholders' statements and therefore they should be perceived as instrument of representation that helps the analysis of particular concepts (Nicolini, 1999). However, this was overclocked by the fact that this research was not using causal mapping to represent the cognition of the interviewees.

A program called 'decision explorer' was chosen because it was designed specifically to support cognitive mapping[14] (Banxia Software, 2014). Moreover, there are different features in the decision explorer program that enabled the research to handle the complexity of the maps such as hiding some detail and focusing on groups of concepts. In addition, the developers of the programs are from the researcher's university.

One feature that was useful in the decision explorer software is the ability to have a style for each concept or user defined links. For reasons of simplicity, this research adopted three types of styles for the concepts as shown in Figure 4-3.

Concept (1) below is called a negative concept where interviewees perceive such concept adversely or unfavourably. Concept (2) is a main or key concept that was identified during the data analysis while concept (3) is a typical or normal concept. The black arrow represents a causal links of being related or leading to while the red arrow with the negative sign implies negative relationship or link (e.g. decreases, negatively influence). It should be noted that the decision explorer program creates automatic numbering system that does not convey specific meaning or order. Appendix VII illustrates the data display steps.

[14] For more information on the program, please visit http://www.banxia.com/dexplore/.

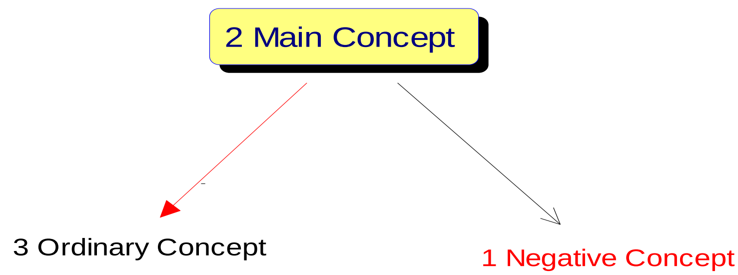

Figure 4-3: Link and Concept Styles

Figure 4-4 below represents an example of cognitive mapping on the need for conducting band-by-band study before introducing the concept of opportunistic access in general. The text that was displayed is as follows "*One view was that such task would be a long process requiring a lot of studies and may not help deploying such systems. The other view was that such studies would help countries to take decisions whether to use that technology or not*". As shown, arrows in red with the minus sign represent negative influence and blocks in red represent undesirable concepts. The numbers in the maps does not convey specific meaning but rather represents unique tag for the different concepts.

Figure 4-4: An Example of Cognitive Mapping

In order to verify the data display process, three independent mappers were selected to check the maps of some selected issues. These mappers were selected on the basis that they were not involved in any part of the research and that they have good knowledge of spectrum management and the ITU. Furthermore, one additional mapper was chosen from outside the field of spectrum in order to make the verification process more robust. Appendix VIII provides detail on the data display verification process.

4.8.3 Drawing and Verifying Conclusions

The third and final stage of the data analysis is drawing and verifying conclusions . In general, Miles and Huberman (1994) define thirteen tactics for drawing conclusions, and the researcher selected five of them that fit with the research strategy: noting patterns and themes, clustering, counting, making contrasts/ comparison, and noting relationship between variables. The first technique, noting patterns and themes, was used along the coding and mapping processes through organising nodes and concepts respectively. It enabled the researcher to make sense of the collected data and to note important findings. Such technique was also useful considering the large scope of the three research questions.

Secondly, the clustering technique was conducted with the help of the conceptual framework and it was used at different stages of the research. Firstly, it was used to cluster the different interviewees into categories. Clustering was used in the coding process through defining free, child, and parent nodes. Moreover, coding reveals the common areas between the different clusters as the program used for coding, NVivo, can code the same data by several nodes.

Thirdly, counting was useful considering the large number of data sources for each research question. In particular, it was used to clarify proponents and opponents for each concept. Additionally, counting is useful to mitigate researcher bias if any (Miles and Huberman, 1994). Fourthly, making contrasts was used to compare the different conclusions across the two case studies in addition to the international interviewees. Fifthly, noting relationship between variables was utilised extensively in the coding process to establish trees of parent and child nodes. Furthermore, noting relationship was an important factor in establishing the causal maps. Such technique was guided by the conceptual framework, which was slightly modified during the research.

The next step to conclusions drawing is conclusions verifying or confirming the findings. Miles and Huberman (1994) highlight the importance of conclusions verification in order to assess the plausibility and validity of the conclusions especially in the case of qualitative research where the researcher usually conducts most of the research by himself. Miles and Huberman (1994) suggest several tactics to increase the confidence in the research's finding and this research adopted four of them that fits with the research: checking for representativeness, checking for researcher effect, triangulation, and weighting the evidence. Appendix IX provides detail on the conclusions verification process.

The next step after drawing the conclusions and verifying them would be to examine the quality of the conclusions. Miles and Huberman (1994) identify five standards to assess such quality: objectivity (confirmability), reliability (dependability), internal validity (credibility), external validity (generalisation), and utilisation (application). Appendix X presents the assessment of this research conclusion in terms of these five standards.

Table 4-3 below concludes the different stages of research and their verification measures where applicable.

Research Stage	**Research Selection / Verification Measures**
Philosophy	• Interpretivism
Approach	• Inductive
Strategy	• Case Studies
Data Collection	• Semi-Structured Interviews
Data Preparation	• Transcription ○ Transcribed interviews were revised twice by two independent professionals and then by the researcher. ○ The transcribed verified interviews were then sent back to the interviewees to revise and verify their views.
Data Reduction	• Coding

	○ Four independent coders were selected to re-code some selected interviews
Data Display	• Cognitive Causal Mapping ○ Four independent mappers were selected to check the mapping of some selected concepts.
Conclusions Drawing	• Five measures were used to draw conclusions: ○ Noting patterns and themes ○ Clustering ○ Counting ○ Making contrasts/ comparison ○ Noting relationship between variables • Four measures were used to verify the conclusions: ○ Checking for representativeness ○ Checking for researcher effect ○ Triangulation ○ Weighting the evidence
Conclusions Quality Assessment	• Objectivity (confirmability) • Reliability (dependability) • Internal validity (credibility) • External validity (generalisation) • Utilisation (application).

Table 4-3: Research Stages

4.9 *Conclusions*

This chapter has handled two main issues: the research gap and the appropriate research methodology to address it. Regarding the research gap, the literature review in Chapters two and three has illustrated how the command and control approach to spectrum management was until recently the dominant approach. While there have been three alternatives, spectrum market, spectrum commons, and spectrum easements, suggested to overcome the deficiencies of such traditional approach, none of them show wide adoption or significant success with the exception of technologies such as Wi-Fi and measures such as auctions.

This is mainly due to several local and international factors. However, one external factor that is largely overlooked in the debate is the interaction between national spectrum policies and the international spectrum management regime, and how such interaction may influence reforming national spectrum policies. As a result, the main research question of the study is decided to be 'How do the international radio spectrum management regime and national radio spectrum management policies interact with regard to radiocommunication service allocation flexibility, technology selection neutrality, and opportunistic access in the TVWS?'

The chapter has displayed the conceptual framework adopted for this study that is driven from the literature review. This chapter has clarified in detail the philosophical paradigm adopted for this research while highlighting the dominant paradigm. This research adopted the interpretivism paradigm as the philosophical position for this research due mainly to its capabilities to accommodate the subjective views of the different stakeholders, and the inductive approach due to the suitability of such approach under the interpretivism stance. The strategy adopted for this research is case study as it fits with the research purpose and the interpretivism philosophical paradigm with a focus on the two case studies of Egypt and UAE.

The chapter has addressed the data collection method used in this research, which is semi-structured interviews while identifying data sources and interviews' questions. Three stages of data analysis were explored: data reduction, data display, and conclusion drawing/verification. Firstly, data reduction has been achieved in this research through coding using software called 'QSR NVivo'. Secondly, data display has been accomplished via cognitive causal mapping using software called 'decision explorer'. The third and final stage of the data analysis is conclusions drawing and verification. This research has adopted five tactics for drawing conclusions: noting patterns and themes, clustering, counting, making contrasts/ comparison, and noting relationship between variables.

5 Case Studies: Egypt, UAE, ITU-R

5.1 *Introduction*

While the previous chapter has shown that the research shall adopt a case study method with a focus on the two cases of Egypt and UAE, this chapter provides a brief overview on the two cases studies. In particular, Sections 5.2 and 5.3 address the two case studies. They start in Sections 5.2.1 and 5.3.1 with a background on Egypt and UAE respectively and then Sections 5.2.2 and 5.3.2 provide a brief on the telecommunication market in the two countries. Sections 5.2.3 and 5.3.3 investigate the spectrum management policies in Egypt and UAE in terms of the four main elements that have been used to examine national spectrum management policies: radiocommunication service allocation, technology selection, usage rights, and frequency assignment. Sections 5.2.4 and 5.3.4 then inspect the interaction of these two countries with the ITU-R. Section 5.4 addresses the ITU-R as an international organisation. Finally, Section 5.5 concludes.

5.2 *Egypt*

5.2.1 Country Background

Egypt is a developing country of lower middle income (The World Bank, 2014) that occupies the north eastern part of Africa with 2450 km coastal lines with the Mediterranean Sea and the Red Sea (The World Fact Book, 2014a). It has a republic system with 27 governorates including the capital, Cairo, and it has a population of approximately 87 million (estimate July 2014), a GDP per capita of 6600$, and the Egyptian pound (EGP) per US dollar equals 6.91 (estimate 2013) (The World Fact Book, 2014a). The area of Egypt is 1,001,450 sq. km and it has borders with Palestine, Sudan, Libya, and Israel as shown in Figure 5-1(wordtravels, 2014).

Figure 5-1: Egypt Map

5.2.2 Telecommunication Market in Egypt

Telecommunication services were introduced in Egypt in 1854 in the format of telegraph. In addition, the Arab Republic of Egypt National Telecommunications Organisation (ARENTO) was established in 1982 by the National Assembly law 153 to manage all infrastructure and services related issues to the telecommunications sector (Kamel, 2004). Egypt started liberalisation of the telecommunication market in line with the country’s economic reform program initiated in 1991 (Hassanin, 2007). Accordingly, the law 19 of 1998 established Telecom Egypt (TE) to inherit ARENTO and Telecommunication Regulatory Authority (TRA) as independent regulator (ITU, 2001).

In addition, the Ministry of Communications and Information Technology (MCIT) was created in 1999 as a second step in restructuring the telecom market in Egypt (Kamel, 2004). MCIT has been responsible of improving the telecommunication infrastructure and promoting the development of Egypt's information society (Reda, 2010).

Egypt has joined the Basic Telecommunication Agreement (BTA) in 2002 which implied removing governmental monopoly on the provision of telecom services (Reda, 2010). Accordingly, the law 10 of the year 2003 established the National Telecommunications Regulatory Authority (NTRA) as a replacement of TRA. In particular, according to Article 4 of the law "*The NTRA shall aim to regulate the telecommunication service and to enhance and deploy services in compliance with the most advanced technology means satisfying the users' needs at the most appropriate prices*" (NTRA of Egypt, 2003:4). While the NTRA is institutionally separated from the MCIT, the Minister chairs NTRA's board (Frontier Economics, 2007).

The fixed market is monopolised by TE who has 6.85 million fixed subscribers with penetration rate of 8.15% (August 2014) (MCIT, 2014). TE is 80% owned by the government and TE has 45% share in Vodafone Egypt (EBRD, 2012). TE uses CDMA2000-1X standards to establish WLL for providing fixed service in the rural area and it is using the 824- 849 MHz & 869- 894 MHz frequency bands (Telecom Egypt, 2007). TE uses also DECT standard for providing additional telephone capacity as WLL (DECTWEB, 2014). TE provides internet services and Internet Protocol Television (IPTV) through its subsidiary TE Data (Singh and Raja, 2008). Moreover, there were uncompleted plans to introduce second fixed operator in 2008 to end the monopoly of TE (Florin, 2008).

The mobile telephony market accommodates 95.84 million mobile subscribers with a penetration rate of 112.19% (August 2014) with 21.16% of them using mobile internet (MCIT, 2014). The first mobile operator was launched in 1996 by TE and then it was sold to Mobinil in 1998. The second operator was established in 1998 by Vodafone Egypt, formerly branded Click GSM (Kamel, 2004). The third mobile operator was awarded in 2006 to Etisalat Misr for 2.9 billion US dollars and the license was branded as 3G license (NTRA of Egypt, 2006b). It is worth mentioning that TE was one of the bidders of the third mobile license (Sutherland, 2011). Additionally, Mobinil and Vodafone have a total of 30 MHz in the 900 MHz, 1800 MHz and 2 GHz for each of them while Etisalat has a total of 35 MHz in the 900 MHz and 1800 MHz (Spectrummonitoring, 2014a). It is worth mentioning that one report indicates that Egypt has fewer frequencies assigned to mobile operators than other comparable countries (Miller et al., 2014).

NTRA decided that the cost for any other operator wishing to acquire a 3G license would be equal to 20% of the winning bid for the third mobile license (NTRA of Egypt, 2006b). Therefore, Vodafone and Mobinil paid 3.4bn Egyptian pounds (US$586m) to acquire the 3G license (GSMA, 2011). Mobinil is owned by France Telecom and Orascom, Vodafone Egypt is owned by Vodafone UK and TE, and Etisalat Misr is owned mainly by Etisalat. It is worth mentioning that a fourth mobile licence in the form of a Mobile Virtual Network Operator has been under consideration by NTRA since 2012 which TE indicated interest in (European Bank for Reconstruction and Development (EBRD), 2012). In 2014, MCIT announced that the unified license would provide mostly the state-owned TE the right to provide its own mobile services in exchange for a 2.5 billion Egyptian pounds fee. However, it was also mentioned that the final form of the license does not give TE the right to use its own frequency (Ahmed, 2014).

5.2.3 Spectrum Management in Egypt

Spectrum regulations in Egypt have started in 1953 by the law 471 which regulate the licensing of wireless and wire equipment and it was followed by the law 66 for the year 1979 which modified some parts in the previous law (ITU, 2007b). At that time, spectrum was regulated by ARENTO which is known now as TE (TE, 2007). In 1998, the spectrum management responsibilities moved from TE to TRA, which was replaced in 2003 by NTRA. In particular, one of NTRA responsibilities is to guarantee the optimum usage of the frequency spectrum and increasing its returns according to the provisions of law 10 for the year 2003 (NTRA of Egypt, 2003). One of the tasks of the NTRA board of directors is to approve, revise and modify the frequency spectrum usage plan whenever necessary in accordance with the resolutions and recommendations of the ITU.

Furthermore, the Law 10 established the frequency regulation committee to regulate the spectrum (NTRA of Egypt, 2003). While it is prohibited to use a frequency or a frequency band without obtaining a license from the NTRA, this does not apply to the Egyptian Radio and Television Union (ERTU) who has exclusive right to use the broadcasting spectrum allocated by the ITU according to article 51 in the telecommunications regulation law 10 for the year 2003 (NTRA of Egypt, 2003). ERTU is exempt from license fees according to the law number 10 for the year 2003 (NTRA of Egypt, 2003). The TV broadcasting occupies the band 470-862 MHz in the UHF band according to the Egyptian spectrum chart (NTRA of Egypt, 2008). 100% of the Egyptian population have TV sets and the majority of the population receive TV signals via satellite (e.g. Nile Sat) (Azzouz, 2014).

ERTU has been the sole authority governing all radio and television in Egypt since its establishment by decree in 1970 (Guaaybess, 2013). The exception to that is two private FM radio station located in Cairo: Nogoom FM and Nile FM (UNESCO, 2013). Interviews conducted in a report on media development in Egypt revealed that the ERTU has claimed that there are no frequencies available for private broadcasters and that there are number of obstacles to complete the switchover process including the lack of investment in this area due to low potential for profit (UNESCO, 2013). It was mentioned also that there were proposals to introduce a broadcasting law in 2008 but none of them were accepted and this is may be due to the fact that there are no private terrestrial broadcasters in the country (Mende, 2011).

5.2.3.1 Radiocommunication Service Allocation

The Egyptian response to an ITU survey on the information on national radio frequency spectrum allocations in the band 960 - 3000 MHz shows that NTRA follows the ITU-R radiocommunication service allocation. In particular, while most of the bands have several allocation in each band according to the ITU-R service allocation table in the RR, in most cases the NTRA response to the survey selects only one service in conformity with the ITU-R table (ITU, 2007b). Moreover, NTRA indicated in a response to ITU-D survey that they notify their service allocation assignments in the MIFR (ITU-D, 2009a). Additionally, Egypt was described in a 2009 presentation as a country with technology neutral but service specific mobile licenses while complying with ITU regulations (Chourbaji, 2008). It is worth mentioning that NTRA, in paper presented to the Global Symposium for Regulators in 2011 (GSR-11), recommended flexible use of spectrum in terms of allowing any specific service or technology to utilise the most suitable spectrum to it as one of the spectrum regulatory measures to promote wireless broadband (NTRA of Egypt, 2011b).

5.2.3.2 Technology Selection

It is stipulated in the Egyptian National Broadband plan that NTRA is technology neutral (NTRA of Egypt, 2011a:67). In addition, a survey by the ITU-D clarified that the NTRA is technology neutral in the mobile market and not in the fixed market (ITU-D, 2009a). Furthermore, former NTRA executive president expressed in a conference in 2012 that NTRA focuses its spectrum policy in the near future on encouraging radiocommunication liberalisation policies, and promoting technology neutrality in awarding spectrum (Badawi, 2012). However, it was found that earlier mobile licences granted by Egypt were specific to 2G technologies, and then the third mobile licence was technology-neutral. This has motivated the two other mobile operators to acquire the 3G licences (Aryani et al., 2009). It is worth mentioning that following the third license auction in 2006, there was a well-known case of conflict between NTRA and Mobinil where NTRA notified Mobinil to stop introducing EDGE until obtaining a 3G license.

In particular, while NTRA perceived EDGE as a technology capable of providing 3G services, Mobinil considered that EDGE is an improvement on the General Packet Radio Service (GPRS) networks and should not be classified as a 3G technology. GSMA sent to NTRA stating that EDGE is an improvement of GPRS and should not require a new license (Dardeery, 2006). The view of NTRA was that the air interface of EDGE is different than GPRS and that according to the ITU, EDGE was approved in 2000 as 3G standard (NTRA of Egypt, 2006e). Eventually, Mobinil postponed the promotion of EDGE services until disputes are settled with NTRA (NTRA of Egypt, 2006c). After almost a year, NTRA and Mobinil reached an agreement where Mobinil was granted a 3G license that allowed them to use UMTS, EDGE, HSUPA and HSDPA technologies and to acquire a 10 MHz frequency spectrum for providing 3G services (ITU, 2007a).

It is worth highlighting the discussion over WiMAX in order to shed some lights on technology selection approach in Egypt. In particular, NTRA has started experimenting with WiMAX since 2005 where a trial was initiated by MCIT and two WiMAX pilots were launched in 2007 (NTRA of Egypt, 2011a). Furthermore, NTRA initiated two hearing sessions in 2006 as a part of the consultation process regarding regulatory framework for Broadband Wireless Access (BWA) (NTRA of Egypt, 2006a). While the hearing session was supposed to address BWA technologies in general, special focus was given by NTRA on WiMAX (El-Moghazi, 2006, ElMaghrbel, 2006). It was indicated that it is possible for WiMAX systems to operate in the 5.725– 5.85 GHz bands on an uncoordinated and unprotected basis, the 2.5 – 2.69 GHz band is still under study, and the 3.4 – 3.6 GHz band is opened for the implementation of WiMAX systems (El-Moghazi, 2006).

Moreover, one of the hearing sessions focused on technology neutrality. The analysis of the responses shows that the majority were urging NTRA to impose standards on operators in order to guarantee a minimum level of harmonisation in the market as technology neutrality may lead to a fragmented broadband market (Badran, 2013). In addition, the consultation process revealed that the licensees would be permitted to provide voice, data and video services as fixed or nomadic services, but not as mobile services (NTRA of Egypt, 2006a). It is worth highlighting Intel response to the consultation as it addressed the issue of IMT and technology neutrality.

More specifically, it was pointed out that Intel is aware that there is a perception that the 2.5 GHz band is exclusively used by IMT-2000 standards. However, the company clarified that the IMT identification does not preclude the use of these bands by any other applications of the services to which they are allocated and does not establish priority in the RR (Intel, 2006). On the other hand, Ericsson highlighted the importance of having technology harmonised equipment in order to avoid having different channelling plans (Ericsson, 2006). TE supported the concept of technology and service neutrality subject to standards (Telecom Egypt, 2006). Vodafone Egypt requested limiting the license to nomadic standards (e.g. IEEE 802.16d) (Vodafone Egypt, 2006).

5.2.3.3 **Usage Rights**

In addition to the traditional exclusive usage rights adopted in the mobile licenses, NTRA approves Wi-Fi operations in the spectrum bands 2.4-2.4835 and 5.725-

5.850 GHz according to Egypt spectrum chart (NTRA of Egypt, 2008). In particular, unlicensed operation is allowed after registration in the 2.4 GHz band, and automatic licensing is approved upon payment of the requested fees in the 5 GHz band (The World Bank, 2006). It is worth mentioning that these two bands are designated to ISM application. Moreover, the 5.725 – 5.85 GHz bands have been used for Wi-Fi and Pre-WiMAX products and could be used for both indoor applications with Equivalent Isotropically Radiated Power (EIRP) up to 0.2 watt and outdoor applications with EIRP up to 4 watt (El-Moghazi, 2006).

Regarding technologies such as CRS, it was mentioned in the Egyptian national broadband plan that NTRA will support innovative spectrum access and that such support could be done through providing a specific spectrum band for unlicensed use for innovative research (NTRA of Egypt, 2011a). It was also mentioned that NTRA is participating effectively in the activities of the ITU-R to follow the regulatory measures needed to introduce CRS technologies and SDR. It is worth mentioning that Riley (2013) highlights the importance of technologies such as ‘Super Wi-Fi’ could decrease the chance of easily disconnecting the communication to the public similar to what happened in Egypt at the first days of the 2011 revolution.

Regarding the TVWS, NTRA presented a proposal to the 2nd African Spectrum Working Group (AfriSWoG) meeting in 2014 accommodating some views on the issue of TVWS (NTRA of Egypt, 2014b). NTRA recommended that commercial TVWS deployment should be postponed until the studies on sharing and compatibility with existing services in the UHF band are finalised. Commercial TVWS deployment should be postponed until the finalisation of the digital switchover (DSO) process to provide certainty for operators and end users. It was also recommended that commercial TVWS deployment should be postponed after WRC-15. This is due that the technical and regulatory measures of the allocation of the band 694-790 MHz for mobile service and identifying it for IMT to be defined in the WRC-15 should be taken into consideration before moving forward with TVWS deployment in portion of the UHF band 470-694 MHz.

In addition, NTRA expressed its concerns over several undermining forces that could influence the deployment of CRS in the TVWS including the difficulty to register CRS stations in the MIFR due to its dynamic nature, and the ducting phenomena in UHF band in some of the African countries that may deter the deployment of TVWS. The process of identifying some areas or spectrum bands for TVWS may be irreversible as it would be difficult to re-farm the band for other use later on, and that TVWS deployment may decrease opportunities for other applications within the UHF band. It was pointed out that traditionally, frequency assignments to end-users have been based on exclusive assignment over nationwide or regional areas, which may contradict with TVWS deployment.

5.2.3.4 **Frequency Assignment**

In general, NTRA is using three models for assigning spectrum according to the situation (NTRA of Egypt, 2006d). The first is 'first come, first served' and it is used mainly for bulk of fixed, microwave and mobile frequency assignments. The second is competitive licensing where there is more demand for spectrum than supply and it could use beauty contest or spectrum auction or hybrid of both. The third type is 'licence exempt'. Regarding license exempt use, a survey in 2005 on Wi-Fi licensing points out that users of Wi-Fi in Egypt are supposed to acquire a license while de-licensing has been under consideration (Horvitz, 2007). The Egyptian national broadband plan indicated that Wi-Fi users can operate under a class license (NTRA of Egypt, 2011a).

With regard to whether NTRA has created possibilities for secondary spectrum trading, the response to a 2009 ITU-D survey was 'no' (ITU-D, 2009a). While there is no available information on implementation of spectrum trading in Egypt, it seems that there is no legal objection against it. In particular, according to the Telecommunications Regulation Law for the year 2003, article 57 "*The licensee shall not have the right to waive his Frequency usage License to a third party except with a prior consent from the NTRA*", which means that limited type of spectrum trading is permitted in case that NTRA approves the trading process (NTRA of Egypt, 2003:21). There is one well known case where some sort of spectrum trading happened in Egypt (El-Bakry, 2004).

More specifically, TE purchased a spectrum license to establish a third cellular mobile operator in 2003 but the company failed to acquire an international partner, and also different studies at that time affirmed that third operator would weaken the market. Therefore, by the end of 2003, TE, Mobinil and Vodafone reached an agreement that allowed TE to return its GSM license to the NTRA for a full refund on its license fees.

In addition, Mobinil and Vodafone each paid 1 billion Egyptian pounds to acquire the spectrum of the proposed third operator network on the condition that no company is permitted to apply for a third mobile license before 2 years. It is worth mentioning that the conditional approval of NTRA to secondary trading was perceived as one of the barriers to trade in services in Egypt (Aboushady, 2013).

5.2.4 Interaction with the ITU-R

Egypt has been a member of the International Telecommunication Union (ITU) since 1876 and NTRA participated in all of the ITU three sectors (NTRA of Egypt, 2014a). More specifically, NTRA is an active player in the ITU-R and occupied several positions in its study groups and conferences including vice chairman of JTG 4-5-6-7, vice chairman of SG 1, vice chairman of SG 5, and vice chairman of SG 4 (ITU, 2014c). Furthermore, Egypt participated in the early days of ITU-R and even one of the WRCs was held in Cairo in 1938 (ITU, 2014a).

Regarding service allocation, NTRA was one of the supporters of the mobile allocation in the 790-862 MHz and 3.4-3.6 GHz in the WRC-07 (Bateson, 2009). In addition, Egypt, among other countries, greatly challenged the ITU-R system in terms of decision making procedures in the WRC-12 when Egypt submitted a statement entitled 'Motivations of getting an extension for mobile spectrum allocation in 700 band (698-790 MHz) during WRC-12 and not later' (ITU-R, 2012n). It is worth mentioning that in 2012, the NTRA executive president expressed his concerns over the process of allocating spectrum in the ITU-R being quite slow and usually taking about 8 years "*At this pace availing spectrum will always lag behind the technology developments*" (Badawi, 2012:8). He also pointed out the Arab and African countries' efforts in reducing the effect of the long-time process in ITU regarding the 700 MHz allocation (Badawi, 2012).

It is worth highlighting that while Egypt had the endorsement and support from the Arab and African countries present in the WRC-12 regarding the 700 MHz allocation, this was not the case in the previous WRCs. For instance, in WRC-97, Egypt submitted a request for its satellite system, NILESAT-1S, to be included in the category of successfully coordinated systems, although no such evidence was provided. Egypt's request was rejected after a formal voting not to compromise the ITU procedures (ITU, 1997). Regarding the GE-06, Egypt joined the plan and managed to achieve 95% assignments of the initial total requirements. In addition, two pilot projects were set in Cairo and Alexandria (Azzouz, 2014).

Regarding IMT technologies, NTRA submitted a contribution to the WP 5D (former 8F) indicating that NTRA has a neutral position with respect to all mobile technologies and does not give priority to any technology as long as it fulfils the IMT-2000 requirements and supporting the inclusion of any new candidate air interface as long as it fulfils the IMT-2000 requirements. Therefore, NTRA position was not to oppose the introduction of IEEE 802.16e-2005 specification (Mobile WiMAX) into Recommendation ITU-R M.1457 (IMT-2000) (Egypt, 2007). In 2009, NTRA submitted another contribution to the WP 5D clarifying that the inclusion of a TDD or FDD component to an existing IMT-2000 radio interface should be considered as an update rather than a new radio interface (Egypt, 2009).

5.3 *UAE*

5.3.1 Country Background

UAE is a high income country that lies in the Middle East, bordering the Gulf of Oman and the Arab Gulf, between Oman and Saudi Arabia with 1318 km coastal lines with the Arab Gulf (The World Fact Book, 2014b). It has a federal system with specified powers delegated to the UAE federal government and other powers reserved to the seven member emirates. UAE has a population of approximately 5.6 million (estimate July 2014), a GDP per capita of 29900$, the Emirati dirhams (AED) per US dollar equals 3.673 (estimate 2013) (The World Fact Book, 2014a). The area of UAE is 83,600 sq. km and borders with Oman and Saudi Arabia (The World Fact Book, 2014b) as shown in Figure 5-2 (Worldatlas, 2014). It is worth mentioning that UAE has a dispute with Iran over two islands which are occupied by Iran (The World Fact Book, 2014b).

Figure 5-2: UAE Map

5.3.2 Telecommunication Market in UAE

The state-owned Etisalat was the only authorised provider of public telecommunications networks and services in UAE until a new legislation was adopted to establish the telecom regulator, Telecommunications Regulatory Authority (TRA) (BMI, 2013d). In particular, TRA has been established according to the UAE federal law by decree No. 3 of 2003 as an independent public authority (TRA of UAE, 2014a). Accordingly, the second national public telecoms operator named Du was introduced in 2005 (BMI, 2013d). Moreover, the Ministry of Communication is responsible for setting national telecommunication policy while Telecommunications Regulatory Authority

(TRA) is responsible of day-to-day regulatory responsibilities (BMI, 2013d). More specifically, TRA is responsible of regulating the telecommunications market and digital broadcasting in UAE (ITU, 2012a). Unlike the case of Egypt, TRA of UAE is completely independent and not headed by the Minister of Communication (ITU-D, 2009a)

The fixed market accommodates two operators, Etisalat and du (ITU, 2012a) with 2.1 million subscribers and 25.3% penetration rate (TRA of UAE, 2014b). The mobile market composed of the same two operators, Etisalat and Du, with the government owning shares in both of them (BMI, 2013c). It is worth mentioning that the monopoly of Etisalat in the UAE mobile market ended when Du introduced mobile services in February 2007 (ITU, 2012a). In addition, TRA confirmed in 2012 that there are no plans to introduce a third operator. There are 17.1 million active[15] mobile subscribers with 203.7% penetration rate (TRA of UAE, 2014b).

Etisalat was established in 1976 as a joint stock company (Kovacs, 2014). The company is 39.5% owned by the UAE federal government (BMI, 2013b). Moreover, the company operates currently in fifteen countries in the Middle East, Asia, and Africa (Kovacs, 2014). Du stakeholders are the UAE government (50%), Abu Dhabi government through its investment unit Mubadala Development Company (25%) and the Emirates Company for Telecommunications and Technology (25%) (BMI, 2013a). Etisalat and Du have 79.6 MHz and 54.4 MHz respectively in the 900, 1800, 2100 MHz spectrum bands (Spectrummonitoring, 2014b).

The telecommunication market is exempt from the UAE competition law provisions considering that the two mobile operators are partially owned by the government. The UAE joined the WTO agreement in 1996; however, deadline for complete telecommunication market liberalisation was extended to 2015 (Kovacs, 2014). While there is no assessment of government ownership of both mobile operators, a survey on end users' satisfaction revealed that there is a perception that UAE's call rates are high and that offers provided by the two operators are artificial which call for enhancing the competition in UAE by introducing a third operator.

[15] 'Active' is defined by any subscriber who has made or received a voice or video call in the preceding 90 days, or has sent an SMS or MMS during that period.

5.3.3 Spectrum Management in UAE

The legislation for spectrum management in UAE accommodates the federal law no. 7 of 1973 for radio communications and law no. 3 of 2003 for spectrum fee policy (ITU, 2007b). In particular, TRA is responsible of managing the usage of the spectrum including assignment and allocation (TRA of UAE, 2009c). Broadcast operations in the UAE are licensed by the National Media Council (NMC) while TRA handle spectrum and frequency allocation (Ayish, 2013). Unlike the case of Egypt, there are seven terrestrial broadcasters in the UAE such as Abu Dhabi TV and Dubai TV (Ayish, 2013). The UAE population depends on broadcasting via cable and IPTV provided by Etisalat and du in addition satellite broadcasting. On the other hand, the number of households relying solely on terrestrial TV was 3% by end of 2009 (Sharif, 2011). Unlike the Egyptian case, there are annual fees on terrestrial sound and television broadcasting for each individual broadcasting station (TRA of UAE, 2009d).

5.3.3.1 Radiocommunication Service Allocation

In general, the UAE table of service allocation has been established in conformity with the ITU-R RR (TRA of UAE, 2005). However, the table shows that in some cases there is a deviation from the RR through footnotes. For instance, the band 1215-1300 MHz has an additional allocation to fixed and mobile services on a primary basis in UAE (ITU-R, 2012d). Moreover, while the band 1215-1240 MHz is allocated to radionavigation-satellite service on a primary basis in the ITU-R table of allocation, it is allocated to the same service on a secondary basis in UAE. In addition, the band 1215-1300 MHz is also allocated to the fixed and mobile services on a primary basis in UAE (ITU-R, 2012d).

Moreover, TRA indicated in a response to ITU-D survey that UAE notify its assignments in the MIFR (ITU-D, 2002). It is worth highlighting that TRA issued a white paper in 2013 discussing the future plans for the 800 MHz and 700 MHz spectrum bands. In particular, it was clarified TRA will release spectrum in these two bands for mobile broadband services by adopting the CEPT band plan in the 800 MHz and the lower portion of the APT plan in the 700 MHz band to maximise global harmonisation (TRA of UAE, 2013).

5.3.3.2 **Technology Selection**

In general, the TRA regulatory framework is technology neutral (TECHZone360, 2010). Regarding WiMAX, the technology was launched as a fixed service in September 2007 (ITU, 2012a). One issue that is worth highlighting in the context of technology neutrality is the dispute between Etisalat and Du over who is the first to launch 4G services in the UAE. In particular, Du made an advertisement campaign claiming it is the first to launch 4G services in the UAE by deploying HSPA+ technology, which provides speeds of up to 42Mbps, and argued that it is considered by the ITU as 4G services. Etisalat objected to that and argued that HSPA+ is a 3.75G rather than 4G according to the TRA standards (emirates247, 2011b). Eventually, TRA instructed Du to suspend its services and to modify its declaration in order to run these services. It was also mentioned that TRA found that the ITU did not issue a particular decision on the HSPA+ technology (emirates247, 2011a).

5.3.3.3 **Usage Rights**

In addition to the exclusive usage rights granted to the mobile operators, the use of 2400-2483.5 MHz (2.4 GHz) and 5470-5825 MHz (5 GHz) bands for outdoor Wi-Fi is allowed only upon obtaining frequency spectrum authorisation from the TRA. Operation of Wi-Fi is considered to operate on a secondary use basis (TRA of UAE, 2009e). DFS and TPC requirements are mandatory for the use of 5 GHz band (TRA of UAE, 2009e). The indoor use of Wi-Fi is exempt from fees (TRA of UAE, 2009d). Use of SRD is allowed on secondary basis as fixed and mobile stations for telecommunication applications and as ISM devices (TRA of UAE, 2009b).

Regarding the TVWS issue, TRA announced its views in 2014 (Almarzooqi, 2014). In particular, it was clarified that the UAE has decided to use the bands 700 and 800 MHz for mobile services which resulted in squeezing the terrestrial TV broadcasting in the lower band from 470-698 MHz and using SFN planning. Accordingly, the availability of TVWS would be reduced significantly. The two issues of the use of the band 470-698 MHz for low power devices mainly used in services ancillary to broadcasting and production, and high cross border interference due to the ducting phenomena decrease the TVWS chances. However, it was mentioned that the views that TVWS may not work is independent from the UAE support to the concept of CRS.

5.3.3.4 Assignment Modes

There is no available information on how TRA awarded the mobile licenses in UAE and whether there was a spectrum auction or not. In particular, it is only mentioned that assignment policy shall be referred to the UAE regulatory framework of spectrum authorisation. Such framework states that the use of spectrum requires obtaining authorisation from TRA (TRA of UAE, 2014c). Moreover, UAE regulations state that there shall be no unlicensed spectrum in the UAE. However, TRA may allow certain devices under class authorisation such as SRD, Wi-Fi and ISM devices (TRA of UAE, 2009c). Regarding spectrum trading, a recent survey by the ITU shows that none of the Arab countries adopt such approach (Horton, 2012). In particular, spectrum trading is not allowed in the UAE and spectrum authorisation does not confer any ownership right (TRA of UAE, 2008a).

5.3.4 Interaction with the ITU-R

The UAE joined the ITU in 1972 and was elected to its Council in 2006 (TRA of UAE, 2008b). According to the TRA executive president, UAE has evolved a solid relationship with the ITU where UAE host and support many of the ITU activities (The Gulf Today, 2014). In particular, UAE host a meeting of the WP 5D in 2008 (TRA of UAE, 2008b). UAE recently won the memberships of the ITU Council and Radio Regulation Board (RRB) (Emirates News Agency, 2014). Furthermore, the chairman of the WP 1B is from UAE (ITU, 2014c). It is worth mentioning that Etisalat and Du licenses contain a condition that both operators would assure that spectrum used across the borders is in compliance with the ITU procedures (TRA of UAE, 2006a, TRA of UAE, 2006b).

Regarding broadcasting services, TRA participated in the RRC-06 and managed to acquire 225 of assignments for digital terrestrial broadcasting. Moreover, it was planned to switch off the analogue TV transmitters by December 2013 (TRA of UAE, 2009a). However, till now, there is no available information on whether the switchover process has been finalised. Regarding service allocation, UAE led the discussion related to the 700 MHz mobile allocation in the WRC-12. More specifically, the head of spectrum management in the UAE explained that the 700 MHz originally started in the UAE where a national mobile allocation in the 700 MHz was decided (GSMA, 2013b).

The proposal was supported by few Gulf countries: Qatar and Kuwait (UAE et al., 2011). The proposal was then promoted by several entities from the industry in the ATU 1st African summit on digital dividend that was held in November 2011 (Kirkaldy, 2011, Lyons, 2011).

The summit recommended later the necessity of pursuing the allocation of the band 694-790 MHz to the mobile service on an equal primary basis with broadcasting for African countries at the WRC-12 (ATU, 2011b). The mobile industry lobbied regional organisations of the African and Arab countries prior to WRC-12 (Billquist, 2010b, Billquist, 2010a). The Arab countries then submitted contribution at the WRC-12 supporting the issue and calling for harmonisation of allocations in the range 698-790 MHz in the three regions of the ITU (ASMG, 2011a). The African countries promoted also the allocation and clarified that the band 790-862 MHz is partially allocated to other services in many African countries which increase the importance of the band 694-790 MHz (ATU, 2012).

In addition, Mr Al Awadhi, head of spectrum management in UAE, was elected by the WRC-12 as its chairman (ITU-R, 2012m) who was also elected in 2008 as the chairman of the ASMG (ASMG, 2008). The Chairman of WRC-12 had an important role in resolving the 700 MHz issue as one option for the chairman could be to decide that the issue is not on the agenda of WRC-12 or to call for a voting considering the imbalance between the Arab and African groups and the rest of the world (Standeford, 2012b).

Regarding IMT technologies, TRA made a contribution in 2009 to the WP 5D indicating their support to the inclusion of the TDD component of IMT-2000 CDMA MC and the FDD component of IMT-2000 OFDM TDD WMAN (WIMAX) into the IMT-2000 radio interfaces without being considered as a new submission "*The UAE is of the view that the addition of an FDD component to Section 5.6 will bring significant improvement, more choice and is based on the principle of technology neutrality*" (UAE, 2009:1).

5.4 *ITU-R*

This research examines the interaction between international regime and national policies. Therefore, it is perceived useful to examine the organisation of the ITU and specifically its radio sector per se in order to understand who is formulating the international regime. In general, the ITU-R is responsible of ensuring the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services (ITU, 2011a). The ITU-R is part of the ITU which is a specialised agency of the United Nations since 1947 (MacLean, 2007). The ITU-R is also the successive organisation to follow on the activities of the CCIR which was established by the International Radiotelegraph Conference in 1927 to study technical and operating questions related to radiocommunication (ITU, 2015a).

Besides, the ITU-R is an intergovernmental organisation where member states (countries) and sector members (industry, universities, etc.) have different rights and obligations (ITU, 2011a). The ITU instruments that are binding and regulate the use of telecommunications are International Telecommunication Regulations (ITR) and the RR (ITU, 2011a). The RR accommodate the complete texts as adopted by the WRC-95 and subsequently revised and adopted by WRCs, including all appendices, resolutions, recommendations and ITU-R recommendations incorporated by reference (ITU, 2014d). The ITRs regulate telecommunications services in terms of issues such as traffic between operators and quality of international services (Internet Society, 2012).

The ITU-R accommodates different entities: world and regional radiocommunication conferences (e.g. WRC, RRC) the radio regulations board (RRB), radiocommunication assemblies (RA), radiocommunication study groups (SG), the radiocommunication advisory group (RAG), and the radiocommunication bureau (BR) headed by the elected Director (ITU, 2011a). Figure 5-3 shows the organisational structure of the ITU-R (ITU, 2015b)[16].

[16] Space Services Department (SSD) - Terrestrial Services Department (TSD) - Study Groups Department (SGD) - Informatics, Administration and Publications Department (IAP).

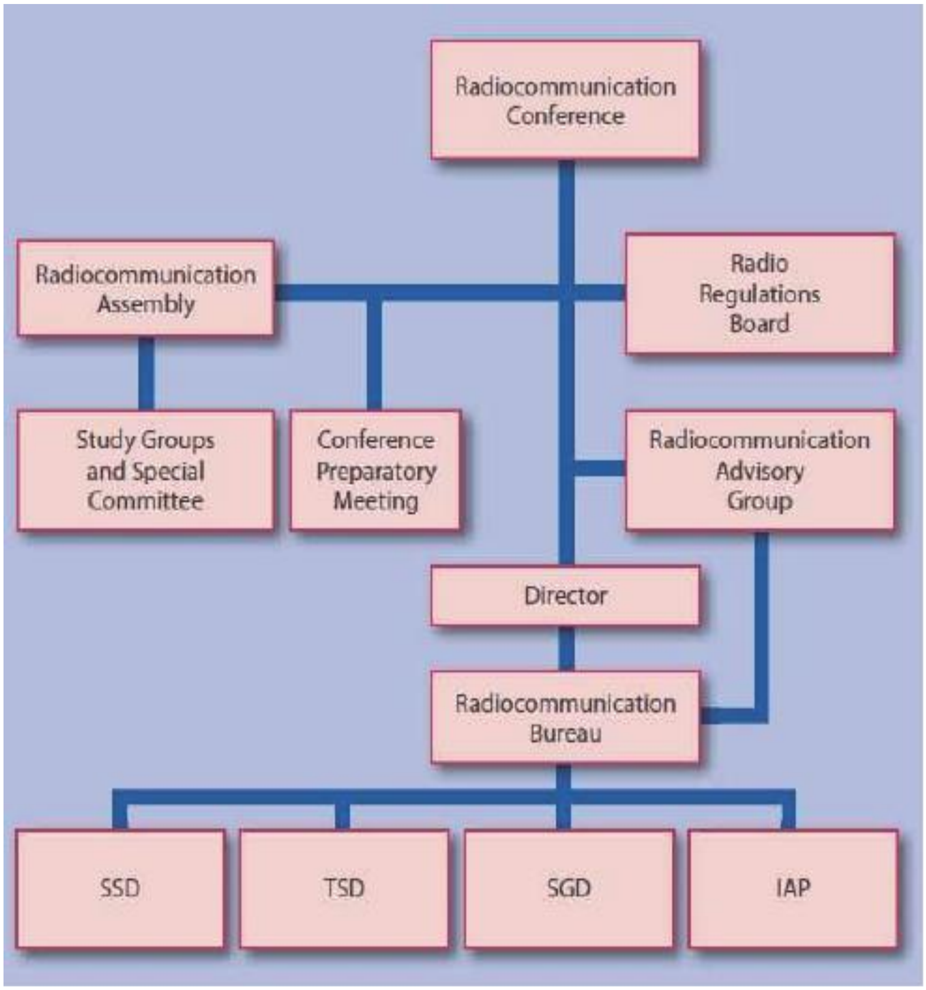

Figure 5-3: ITU-R Structure

Firstly, WRC may revise the RR and deal with any question of a worldwide character within its competence and related to its agenda (ITU, 2011a). Secondly, the RRB is mainly responsible of the approval of rules of procedure, which include technical criteria in accordance with the RR and its member are from the member states (ITU, 2011a). Thirdly, the RA provide the necessary technical bases for the work of the world radiocommunication conferences (ITU, 2011a). Fourthly, radiocommunication SGs are set up by the RA that shall study questions adopted in accordance with a procedure established by the RA (ITU, 2011b). SGs could be chaired by individuals from member states or sector members. Fifthly, RAG is also open to member states or sector members (ITU, 2011b). Sixthly, the radiocommunication BR is described as the executive arm of the ITU-R and it consists of the BR director and a team of technical and administrative staff (ITU, 2008b).

The ITU-R BR is mainly responsible for technical and administrative support of WRCs, RRB, RAG, RA, and SGs (ITU-R BR, 2014). Duties of the ITU-R BR director include coordinating the preparatory work of the study groups, participating as of right, but in an advisory capacity, in the deliberations of radiocommunication conferences, of the radiocommunication assembly and of the radiocommunication study groups and other groups, providing assistance to the developing countries in their preparations for radiocommunication conferences, assisting in the resolution of cases of harmful interference, and finally submitting to the world radiocommunication conference a report on the activities of the ITU-R since the last conference (ITU, 2011b). Furthermore, Chapter 3 analysed the ITU-R related activities in terms of the same four main elements that have been used to examine national spectrum management policies: service allocation, technology selection, usage rights, and frequency assignment.

This section has shown how the ITU-R as an organisation accommodates more than just the BR. More specifically, there are dynamic interactions between several entities within the ITU-R that formulate the output decisions whether it is in the form of the binding RR or voluntary ITU-R recommendations. These interactions involve countries exclusively in some entities (e.g. WRCs, RRB) or accommodate the private sector in some other cases (e.g. SGs). More specifically, the private sector can participate in the SGs and WPs meeting and can also submit written contributions. They can also hold the positions of chairman or vice-chairman of these SGs and WPs (Besnier, 2003).

Furthermore, while the ITU accommodates 193 member states or countries, the number of entities from the private sector is over 700 (ITU, 2014b). Even in some SGs or WPs such as the WP 8F (currently WP 5D), which was concerned with mobile technologies, the number of participants from the public sector is larger than delegates from countries (Chairman of Working Party 8F, 2007). Therefore, while the member states or countries are the final decision makers at WRCs, sector members or the private sector have a significant influence in the studies leading to these decisions at WRCs (McCormick, 2007).

5.5 *Conclusions*

In summary, this chapter has shown some differences and similarities between the two case studies as shown in Table 5-1. On the one hand, both of Egypt and UAE follow the ITU-R service allocation and adopt technology neutrality while being neutral within IMT. Moreover, they both have no implementation of trading and TVWS while allowing Wi-Fi in the ISM spectrum bands. Besides, both countries are part of the GE-06 plan and have public broadcasters. On the other hand, there is a contrast between the two countries in terms of area, population, and GDP. Moreover, UAE assigned more frequencies to the mobile operators than Egypt and the UAE government partially owned the two mobile operators. On the contrary, the Egyptian market enjoys competition between three private mobile operators.

Issue	Egypt	UAE
Country Background	Egypt is a developing country that has a republic system with an area of 1,001,450 sq. km and population of 87 million.	UAE is a high income country that has a federal system with an area of 83,600 sq. km and population of 5.6 million
Regulator Independency	Yes with Minister of ICT chairing NTRA board	Yes
Fixed Market	Monopolised by TE	Duopoly between government owned companies Etisalat and Du
Mobile Market	Competition between Vodafone, Mobinil, and Etisalat	Duopoly between government owned companies Etisalat and Du
Frequencies for Mobile Operators	Mobinil: total of 30 MHz Vodafone: total of 30 MHz Etisalat: a total of 35 MHz	Etisalat: a total of 79.6 MHz Du: a total of 54.4 MHz
Terrestrial Broadcasting	One government broadcaster – low view rate	Seven federal broadcaster - low view rate
Service Allocation	Follows the ITU-R service allocation	Follows the ITU-R service allocation

Technology Selection	Technology neutral	Technology neutral
Usage Rights	Wi-Fi operation in ISM spectrum	Wi-Fi operation in ISM spectrum
Frequency Assignment	First Come, First Served - competitive licensing – license exempt	Authorisation from TRA – class authorisation
TVWS	No implementation - Concerns	No implementation – Concerns
Trading	No implementation – allowed upon NTRA approval	Prohibited
IMT	Neutral within all IMT technologies	Neutral within all IMT technologies
Interaction with ITU-R	700 MHz mobile allocation – Concerns about decision making procedures	700 MHz mobile allocation
RRC-06 Plan	Joined the plan	Joined the plan

Table 5-1: Comparison between Egypt and UAE

In addition, this chapter has shown how the ITU-R as an international organisation accommodates more than just the BR, which has also more roles than just being a secretary to the ITU-R. More specifically, there are dynamic interactions between several entities within the ITU-R that formulate the output decisions whether it is in the form of the binding RR or voluntary ITU-R recommendations. In addition, these interactions involve countries exclusively in some entities (e.g. WRCs, RRB) or accommodate the private sector in some other cases (e.g. SGs).

6 Radiocommunication Service Allocation Flexibility

6.1 *Introduction*

This chapter handles the first research question concerned with the radiocommunication service allocation flexibility concept. It starts by exploring the perceptions of the interviewees from Egypt and UAE on the concept in Section 6.2 and applicability of the concept in these two countries in Section 6.3. Section 6.4 then explores the influence of the international regime on regulator flexibility regarding service allocation. Section 6.5 to Section 6.9 then examine the different main elements of the international service allocation framework: a priori planning, decision making procedures, footnotes, MIFR, and the three regions system. Finally, Section 6.10 concludes.

6.2 *Perception on the Concept of Radiocommunication Service Allocation Flexibility*

While the research focuses on the interaction between the international regime and national policies regarding the concept of radiocommunication service allocation flexibility, it was useful to examine the perceptions of Egypt and UAE interviewees on the concept per se in order to find out local factors that may have an influence on the adoption of the concept.

6.2.1 Egypt

In general, NTRA interviewees were mostly against the concept. In particular, it was expressed that the regulator should have the flexibility and not the operator. NTRA does not want the operator to take upper hand over the regulator. According to one of the interviewees "*I am the regulator, I know what the market is, I know what is tomorrow, I know the plan, I know everything, so I should consider first*". Interference is the main concern for adjacent and co-channel services and externally with neighbouring countries. The out of band emissions (OOBE) and protection values are different from one service to another and so the required guard band. Therefore, if the band is assigned to two operators while using two services, this would be difficult. It was felt that there is no tangible benefit to adopt the concept. Another concern is that spectrum is limited for some services such as mobile service so their spectrum cannot be used for other services. Security concerns were mentioned and also how to set service level agreement for the different services. It was also mentioned that nowadays there are equipment that are able to work as fixed, mobile or broadcasting so there is no need to have more than one service in the same band.

On the other hand, several advantages related to the concept were mentioned by interviewees from NTRA. Firstly, it would ease the allocation process for the regulator. Secondly, it was mentioned that this is good objective as potentially developing countries have a lot of spectrum that is used for broadcasting and not used by broadcasters. Moreover, there is a relationship between CRS and service flexibility as the technology would enable adopting that. One advantage raised by one of the interviewees is that service neutrality will bring more revenue to the regulator because the value of the spectrum will increase.

The Egyptian broadcasting interviewees were in general against the concept in Egypt for several reasons. It was felt that sharing between the broadcasting and the mobile in the same country is not possible. It was also pointed out that NTRA perceived the broadcasting to be less important than the mobile operators. The interviewees from the fixed incumbent (TE) were in favour of the concept for several reasons. In particular, it would enable TE to provide mobile services through their current technologies (CDMA). It was argued that the lines between fixed and mobile have been blurred a long time ago, and that the broadcasting service is diminishing.

The interviewees from the mobile community have different views. One view is that network characteristics are different between broadcasting and mobile service and if they are not regulated and harmonised, problems may emerge. Harmonisation is important to reduce equipment cost and to find handsets that are supporting your system. One other view is that while the concept is good in terms of addressing spectrum scarcity, it would need good coordination, which may not be well managed in Egypt. One third view is that it is preferable to have regulated flexibility with technical conditions because flexibility without border could lead to many technical problems such as interference from high power broadcasting service into mobile service. The forth view is that due to the scarcity of spectrum, having different services over the same band would be better.

6.2.2 UAE

The interviews with the TRA showed different views on the concept of service allocation flexibility. One view is that the Arab countries are not in favour of such trend at all, as cross-border coordination becomes a difficult task when there is uncertainty regarding the type of deployed service. Another perception on the service flexibility concept is that it is not widely adopted unlike the technology neutrality concept. One of the issues that were raised regarding harmonisation is that it is important to have unified equipment for the region. For instance, there is a lot of bandwidth allocated for mobile service but never used for mobile, because the equipment is not available. Interference is also a concern especially in the Gulf area where neighbouring countries are using different services and where the size of UAE is small comparing to others (e.g. Saudi Arabia). This is in addition to the high temperature, which makes the interference situation more difficult.

One interesting weakness of the concept is the difficulty of applying it especially if the size of the market is small. Therefore, it was argued that Europe was able to apply some sort of flexible allocation because they represent a huge block, which can harmonise its policies. On the other hand, there were several positive views on the concept from the perspectives of TRA interviewees. Firstly, the concept has a great value when the spectrum is auctioned and the market decides the service. It was also mentioned that the technology development might change this situation. In particular, CRS and SDR can enable flexibility by helping establishing the criteria for protection for the different services.

The broadcasting group did have two views. The first was that the concept would cause chaos, decrease utilisation efficiency, and result in difficulty of coordination. The other view was that the principle is good but the telecom sector may control it and acquire the broadcasting spectrum. The mobile operators' interviewees had different views on the issue. On the one hand, one view is that the concept would enable more flexibility providing that there is guaranteed protection against interference.

On the other hand, there was a view that flexibility may lead to the need of guard band, which will decrease the amount of frequencies in the band. Secondly, there are concerns related to its license fees difference between fixed and mobile. As explained by one interviewee "*Everybody will focus on the mobile services and accordingly, regulator will raise prices*". Another concern is protection against interference, which is perceived as essential in order to provide a proper service. Moreover, harmonisation is important in terms of the availability of the equipment.

6.3 *Applicability of the Concept of Radiocommunication Service Allocation Flexibility*

One other element that was perceived and considered important to focus on is the potential applicability of the concept in the selected case studies and to what extent flexibility is applied in radiocommunication service allocation. In particular, the research investigated whether there are legal or market circumstances that may prevent the introduction of the concept in Egypt and UAE.

6.3.1 Egypt

Regarding the applicability of service flexibility, it was indicated that in theory the concept could be applied within the Egyptian territories. Another interviewee from NTRA explained that the concept is not under consideration at all and that licenses are currently either for fixed and mobile. Other restrictions towards the applicability of the concept in Egypt include conflict with current legal framework, interference with neighbouring countries, and status of existing operators. Interviewees from the mobile operators explained that they are quite limited in their licenses in terms of the allowed services.

The fixed incumbent mentioned that regulations in Egypt are still service and technology specific. TE has spectrum band that is utilised by CDMA technology to provide fixed service but it is not allowed to use it for mobile. It was also mentioned that the spectrum is allocated in the ITU for mobile service and identified for IMT while it is used for WLL in Egypt. The broadcasters clarified that from the legal viewpoint, the TV Broadcasting Union (ERTU) is the sole provider of broadcasting service and their spectrum band is only used for broadcasting.

6.3.2 UAE

The head of spectrum management in UAE clarified that there are several restrictions against the applicability of the concept in UAE such as the governmental organisations, which are using the spectrum. Interviewees from TRA explained that the two mobile operators have the freedom to deploy any type of service without getting approval apart from broadcasting which is provided via the broadcasters only. It was also explained that licenses are technology neutral but not radiocommunication service neutral, which means that spectrum can be used for one service only (e.g. mobile or fixed).

The idea of allowing the broadcasters to provide radiocommunication mobile services was discussed with interviewees from UAE TRA who felt that mobile operators may be allowed to provide broadcast content but not the other way around. It was also explained that the different broadcasting applications provided through the mobile network is not considered to be a broadcasting service but a video streaming. Interviewees from the mobile operator explained that services in UAE are not neutral in terms of radiocommunication services as the license determines the services and accordingly the fees. It was also explained that the mobile operators in UAE provide fixed, mobile, internet services. Regarding the applicability of the concept, it was explained that big markets have flexibility but for UAE it is difficult to act against the international flow. Another issue that was raised with the operators is the use of the 3.5 GHz band for mobile service. It was mentioned that the band is licensed for Fixed Wireless Access (FWA) and cannot be used for mobile due to the differences in the spectrum fees.

6.4 *Interaction between International Regime and National Policies with regard to Radiocommunication Service Allocation Flexibility*

6.4.1 Egypt

Before discussing the main research question with the Egyptian interviewees, it was important to understand the NTRA dependence on and deviation from the RR service allocation. In general, it was mentioned that the RR are an important factor that influence Egypt spectrum policy. More specifically, the RR are mentioned explicitly in the Egyptian Telecom Law number 10 for the year 2003 in several articles. Most importantly, Article 50 states that "*The NTRA shall, in consideration of the issued publications of the International Telecommunication Union, set the frequency spectrum plan so as to realize its optimum use, the utmost yield of its usage and allow the provision of advanced Radio Telecommunication Services*" (NTRA of Egypt, 2003:20).

However, the RR are also among other factors such as national security requirements, which overwrite the RR. Additionally, one important issue that was raised during the discussion with the regulator is how often NTRA deviates from the ITU-R allocations. It was mentioned that in most cases there is no deviation except for some legacy systems. With respect to the interaction between the RR and national spectrum policy in Egypt regarding service allocation flexibility, the interviews with NTRA revealed that Egypt has the freedom to deviate from the RR to meet its interest as long as it does not cause interference to neighbouring countries.

In addition, while the regulator clarified that applying the RR is not mandatory, NTRA prefers to follow the RR for three main reasons. Firstly, the RR service allocations are based on sharing studies between the different services, and therefore, following the RR provides protection between the different services and countries. Secondly, there is no urgent need to deviate from the RR. Thirdly, Egypt is not a manufacturing country. As expressed by one of the NTRA interviewees "*you are not technology maker so that you have something that you made and you want to use it and you cannot wait for the ITU to adopt it*". NTRA interest is global harmonisation to allow compatibility between the different devices.

Besides, it was also revealed that there are no rules from the ITU-R to enforce the RR. One other point that was raised during the discussion with the regulator is that the ITU-R is ineffective when it comes to resolving cross border interference because there is no deterministic procedure over countries causing the interference. Therefore, Egypt follows the RR in order to avoid conflicts with neighbouring countries. It was also expressed that the RR can accommodate convergence between the different radiocommunication services as most of the bands are allocated to more than one service (e.g. mobile, fixed and broadcasting in the 700 MHz).

This was supported by another interviewee from NTRA who mentioned that service allocations were made basically to enable frequency sharing for more than a service inside the same band without harming each other. Therefore it was indicated that the RR do not constrain a regulator’s decision regarding service allocation. One example that was brought up by the regulator is the case of a company, which had a proposal that contradict with the RR. It was clarified that the idea itself was not rejected due to the contradiction with the RR but due to the non-availability of the frequencies. On the other hand, it was also recognised that the RR are not aligned with the concept of service neutrality as they still keep the principle of separating between services in the frequency bands.

One interviewee from TE clarified the ITU rules may prevent applying service neutrality as they indicate the type of service in each frequency band in each region. One other interviewee from TE explained that the RR do not restrict service flexibility as the RR are just recommendations except when it comes to neighbouring countries. The broadcaster explained that the ITU-R studies have proved that compatibility between the different services in the same band is impossible and that there must be exclusive band for the broadcasting as sharing it is not possible with other radiocommunication services (E.g. mobile, fixed).

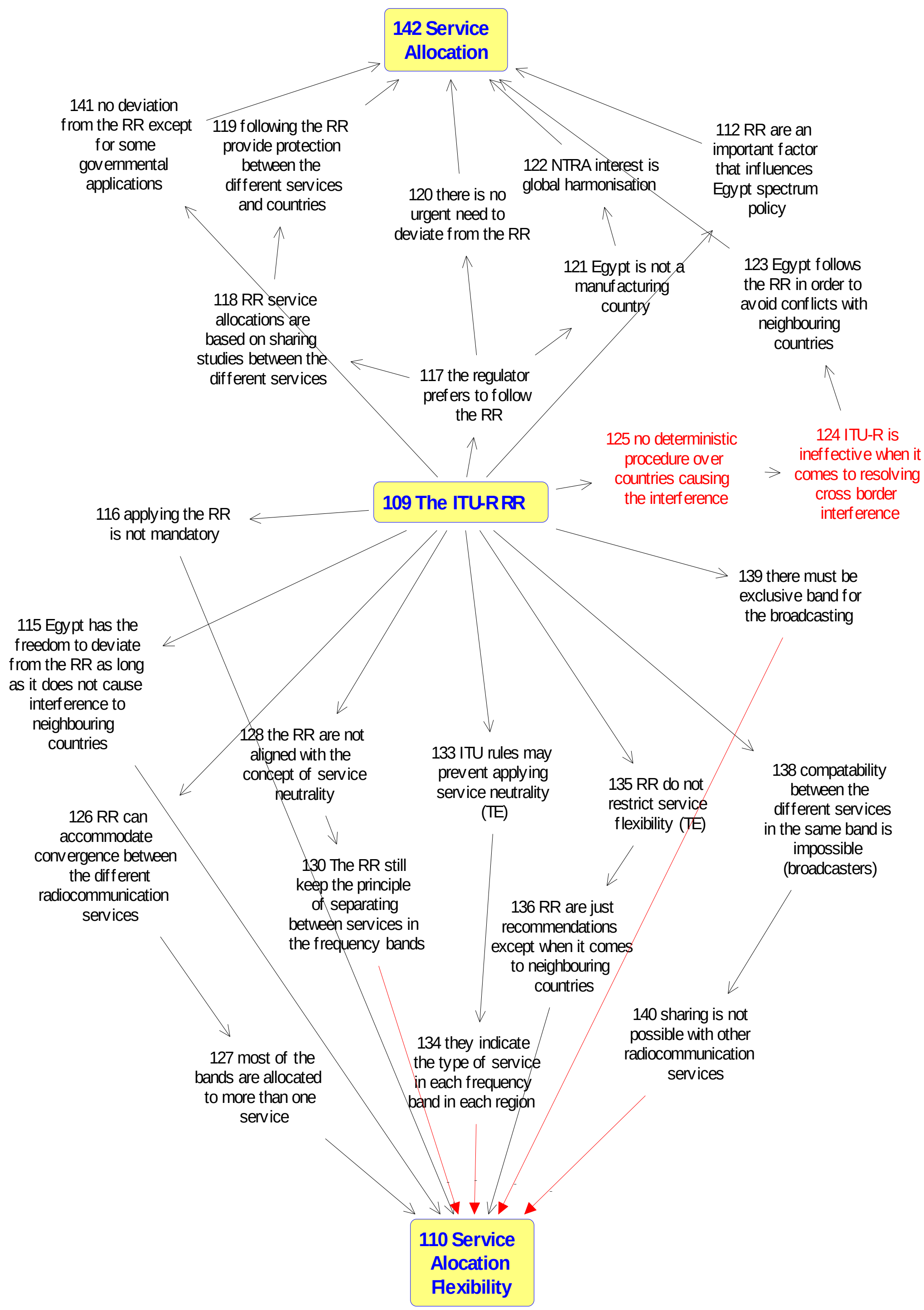

Figure 6-1: Interaction between ITU-R RR and Regulator's Flexibility regarding Service Allocation in Egypt

Figure 6-1 shows how the ITU-R RR interact with service allocation and service allocation flexibility on the national level. NTRA has a tendency to follow the RR for several reasons (concepts 112, 122, 119). Most significantly for Egypt, the map reveals how not being a manufacturing country (concept 121) and not being leader in technology adoption (concept 120) imply following the RR in terms of service allocation. In addition, following the RR is important for a country like Egypt, which has several neighbours in order to have protection against interference (concept 119). One of the reasons why Egypt follows the RR is the lack of effective interference resolution procedures (concepts 125, 124) so that NTRA prefers to follow the RR in order to avoid interference with neighbouring countries (concept 123).

Regarding the interaction with the RR with respect to NTRA flexibility on service allocation, the map shows that there are different flexible and restrictive elements. On one side, following the RR are perceived to be voluntary while not causing interference (concepts 115, 116, 136) and therefore, it does not restrict service allocation flexibility. In addition, the concept of having the spectrum allocated to more than one service accommodates the concept of service flexibility (concept 127). On the other side, there is a perception that the RR are not in conformity with the concept of service flexibility in principle as the RR determine services allocation in each band and separate between services (concepts 134, 130). The broadcasters specifically were against the concept arguing that the RR cannot accommodate flexibility with bands where there is a broadcasting allocation (concept, 138, 140, 139).

These findings show that NTRA has a tendency to follow the RR due to the advantages of the service harmonisation in the RR, deficiencies of the ITU-R in interference resolving, and not being leader in terms of technology development. Regarding the interaction with the RR with respect to NTRA flexibility on service allocation, there are different flexible elements such as RR being voluntary and having more than one allocation in the spectrum in the RR, and restrictive elements such as the RR not being in conformity with the concept of service flexibility and difficulty of applying the concept in broadcasting spectrum bands.

6.4.2 UAE

Regarding the dependence of TRA on the RR, it was explained that the TRA does not refer explicitly to the RR in their telecom law but rather in their spectrum policy recommendation. In addition, the UAE regulations are based on the obligation agreed at the international level. The regulator emphasised on the importance of the RR in terms of protecting their services, introducing new services, and creating harmonisation. Regarding the importance of harmonisation, interviewees from TRA pointed out that if the bands are not harmonised, this would increase the possibility of interference between the services, which will be used in this band. With respect to the deviation from the RR, interviewees from TRA pointed out that in general they avoid contradicting with the RR as they signed the treaty.

In addition, if there is a need for a new allocation, this can be obtained in the next WRC in three or four years. Moreover, it was clarified that there is no need to have a different allocation than ITU-R region 1 because there would be no benefit from the economy of scale and the mass production of the equipment viewpoints. Furthermore, having a service that is not allocated within the RR would be costly due to the customisation of the end user equipment. Regarding the deviation of UAE from the ITU-R table of allocation, it was explained that TRA of UAE does this only through footnotes.

Regarding the interaction between the RR and national UAE spectrum policy regarding service allocation flexibility, interviewees from the TRA clarified that new radio services may be delayed in UAE because the RR have not updated to include this particular radio service in that specific frequency, and then UAE needs to wait for a WRC so that new services are introduced through WRC under an agenda item. However, it was also explained that there are flexibilities in the RR where any country can introduce new radiocommunication services even it is not included in RR. This is by applying article 4.4 of RR, which allows operation while not interfering to and not claiming protection from neighbouring countries.

It was also indicated that most of the time the RR have multiple allocation at the same band so the band can be used by any service as long as it is in conformity with the ITU-R table of frequency allocation. In general, it was indicated that the RR are not a constraint and that modifying them should compromise between the industry and the government needs. One view from the operators highlighted the importance of coordination with the neighbouring countries through the ITU-R. One other view highlighted also the importance of harmonising services between neighbouring countries in order to avoid interference, and the issue of lack of enforcement of the RR in case of conflict between countries.

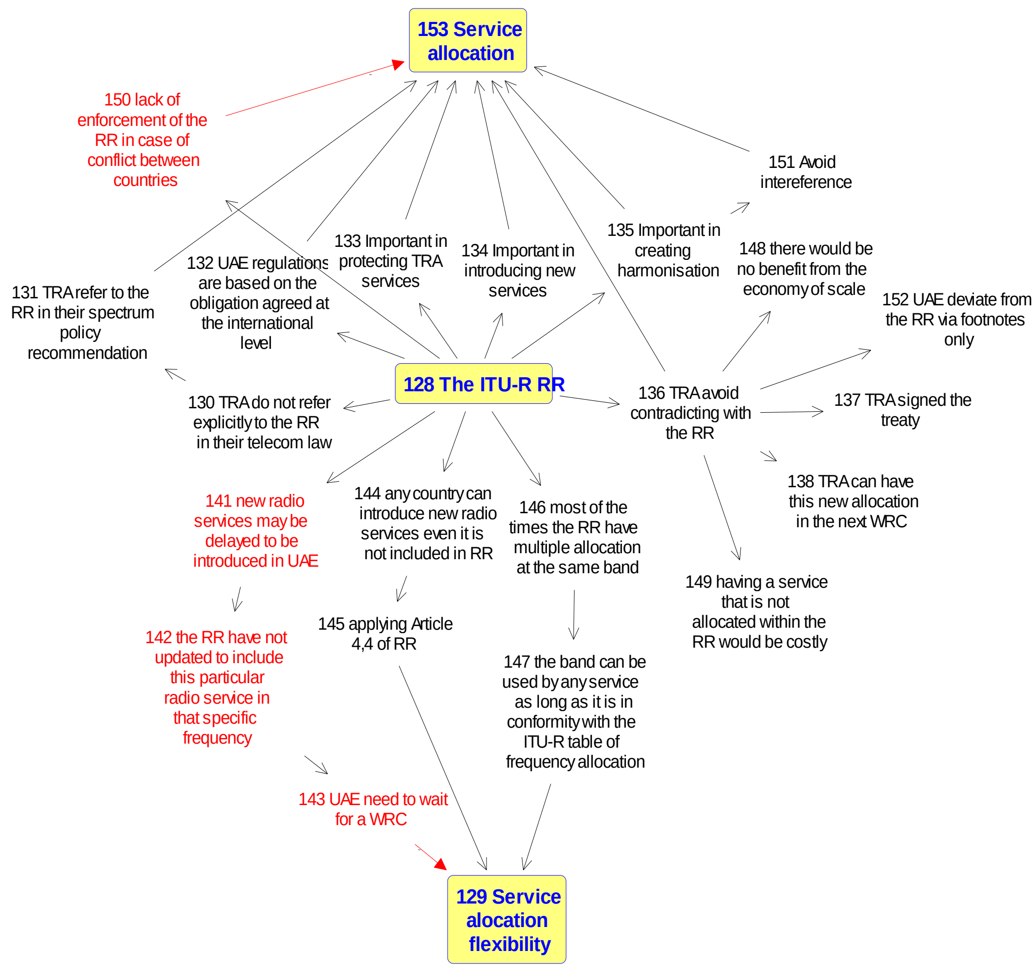

Figure 6-2: Interaction between ITU-R RR and Regulator’s Flexibility regarding Service Allocation in UAE

In general, Figure 6-2 shows that there are several positive issues that motivate

TRA of UAE to follow the RR including avoiding interference (concept 151), introducing new services (concept 134), creating harmonisation (concept 135), and protecting TRA services (concept 133). In addition, there are several reasons why it is disadvantageous for TRA not to follow the RR (concepts 149, 148, and 137). TRA can align with the RR even if there is no particular service allocation by having such allocation in next WRC (concept 138). With respect to the influence of the ITU-R RR on TRA flexibility regarding service allocation, it was perceived that there is flexibility in the RR by deviating from it as long as not causing interference (concept 145) and by having multiple allocations in the same spectrum (concept 146). On the other hand, the RR could be restrictive in case there is an urgent need to introduce specific service allocation in the UAE while it is not allocated in the RR so that TRA has to wait for next WRC (concepts 141, 142, 143).

These observations imply that TRA has tendency to follow the RR due to avoiding interference and creating harmonisation among other factors. Regarding the interaction with the RR with respect to TRA flexibility on service allocation, there are different flexible elements such as the freedom to deviate from the RR on the condition of not causing interference and having multiple allocations in the spectrum in the RR, and restrictive elements such as delay of having service allocation until next WRC.

6.4.3 International Interviewees

In general, forty interviewees commented on the issue of interaction between the RR and regulator’s flexibility regarding service allocation. On the one hand, thirty four of the interviewees were of the view that the RR are not constraining national regulator flexibility on radiocommunication service allocation due to several reasons. Firstly and most mentioned, it was indicated that a country can operate while contradicting with the RR on the condition that it will not cause interference to its neighbours. Hence, the RR are only constraining the administration with respect to its neighbours. As explained by one other interviewee, usage is a different issue than allocation and the ITU-R is concerned only with cross-border and not national issues.

Several interviewees from the ITU-R group supported such understanding and clarified that there is no restriction unless there is a potential interference with neighbouring countries. In particular, the RR have a lot of flexibility in the way that they do not aim at defining what every country should implement in detail at the national level. Instead, they make sure that what is or planned to be implemented at in a given country is compatible with what is planned to be implemented in its neighbouring countries. Secondly, the RR allow multiple radiocommunication services in the same spectrum band. Hence, introducing more service flexibility to the RR is possible through additional allocation similar to the case of the 700 MHz band where the band was originally allocated to broadcasting and then to mobile.

Thirdly, there is flexibility provided by having allocation on a secondary basis, footnotes or through the ITU-R article 4.4. Fourthly, flexible spectrum property right is related to issues such as licensing which is a national issue that is not addressed by the ITU-R. Moreover, a spectrum property right can be implemented within the RR service definition as service definition can be translated into spectrum mask to be adopted on the national level. Another interviewee explains that conditions associated with technical characteristics of spectrum property right at the national level could be incorporated in the RR by footnotes (e.g. WAPECS Block Edge Mask (BEM)).

It is worth mentioning that one interviewee from the regulator group clarified that defining spectrum property right within the ITU-R in detail may result in losing some of the flexibility already given by the ITU-R RR. It was also mentioned by one of the interviewees that there are many cases in the RR that are based on sharing conditions between the different radiocommunication services that provide more flexibility (e.g. PFD for the frequency band 21.4-22.0 GHz for Broadcasting Satellite Service (BSS) in regions 1 and 3). In general, the following quote from one of the interviews could be considered as a summary of the view that the RR provide enough flexibility "*The artist Picasso once said, 'form liberates'…so it creates certain constraints, but it also leaves a lot of freedom within those bounds*".

On the other hand, six interviewees were of the view that there are some elements of restriction within the RR. Firstly, the RR may be considered a restriction because the issue of radiocommunication service neutrality is not explicitly recognised in the RR. Secondly, it also has a great influence on national administration decision regarding service allocation as introducing a new service may cause a conflict with the neighbouring countries. Therefore, introducing new services should be done through an agenda item of a WRC. However, it was mentioned that if a country can reach agreement with its neighbour, the RR would not stop it. It was indicated that there could be restriction in bands where there are special radiocommunication services such as satellite or radiolocation. There was also a view that there is a shift in the paradigm of spectrum allocation from the ITU rigid hierarchy in term of service subdivision towards spectrum usage in a sense of what kind of content is to be delivered. The RR may constrain administrations, as they have to decide which services to deploy (e.g. broadcasting or mobile).

It was also evident during the interviews that the interaction between the RR and regulator decision on service allocation is different from one country to another. In particular, while some countries tend to make changes to the RR to get support for national changes, others go to the ITU when they have already introduced a new policy on the national level. More specifically, there was a view that some countries, especially the developing ones, would not do anything unless it is approved by the ITU. This is not because that they are forced to do so, but mainly because it is advantageous to them to follow the ITU-R radiocommunication service allocations. This is clarified further in the following statement "*I think people in developing countries are generally feel less powerful than people in developed countries, and so they see the ITU as being a body that recognised them on an equal status with other countries. And so they think we must respect this as an international agreement*".

Another perception on the issue is that the influence of the RR depends on how a country interprets the RR. As clarified by one of the interviewees "*The Japanese have a very literal interpretation of everything the ITU has ever written whether it's radio regulations or ITU recommendations. The 4.4 is a key issue in spectrum management in the US, whereas the Japanese do not even acknowledge RR 4.4 exists*". In addition, such influence is also related to the population distribution of the country. In an interviewee's own words "*There is very little population on either the US side or the Mexican side on the US - Mexican border, so that's not much of an issue. On the Canadian border it is more an issue because most of the Canadian population lives near the US border*".

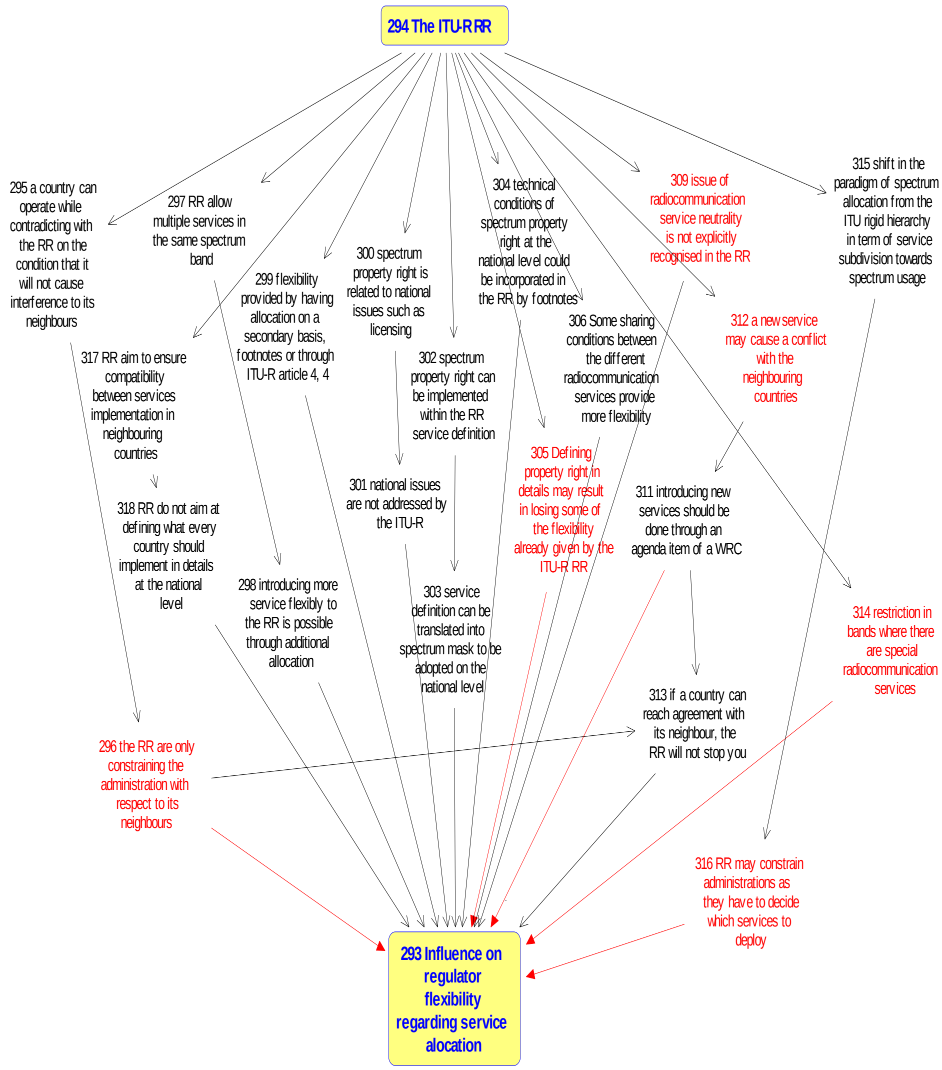

Figure 6-3: Interaction between ITU-R RR and Regulator's Flexibility regarding Service Allocation from Perspectives of International Interviewees

The causal map in Figure 6-3 has shown that the RR accommodate elements of flexibility and restriction as well. On one side, the RR are considered only constraining a country when it comes to the interaction with its neighbours (concepts 295, 296) as countries can operate while contradicting with the RR on the condition that it will not cause interference to its neighbours (concept 295). Therefore, new radiocommunication service allocations should be introduced through WRC (concept 311) because such new allocation may cause interference if implemented to neighbouring countries (concept

312). However, in case a country manages to reach an agreement with its neighbouring countries, the RR would not be a constraint (concept 313). The RR are not concerned with national usage (concept 318); instead, they address service allocation between countries (concept 318). Other elements of flexibility include having multiple services allocations in the same band (concepts 297, 298), and the possibility to have another allocation on secondary basis, via footnotes, or according to article 4.4 (concept 299). The concept of spectrum property rights could be considered as a national issue (concepts 300, 301) or it could be accommodated in the RR via different measures (concepts 304, 306) considering the risk of losing some of the flexibility already provided by the RR (concept 305).

On the other side, there are relatively restrictive elements in the RR in bands where there are special services (concept 314) and considering that the concept of service flexibility is not explicitly acknowledged in the RR (concept 309). Finally, there is a view that the concept of allocating the spectrum by service is absolute (315, 316). **These findings highlight that the RR restrict national regulators' flexibility regarding service allocation only towards neighbouring countries unless a country reaches an agreement with these countries. In addition, there are several measures in the RR that provide additional flexibility such as having multiple allocation and footnotes. Restrictive elements include depending on WRCs to have service allocation and being restricted in bands where special radiocommunication services operate.**

6.5 *A Priori Planning*

The general discussion on the service flexibility in the previous section has shown that some interviewees from the broadcasting industry perceive broadcasting as a special service that requires exclusive service allocation. In addition, as explained in Chapter 3, the broadcasting service in region 1 has special type of planning 'a priori planning' where each country has its requirements approved at a regional conference. This section closely examines the issue and investigates its influence on the concept of service allocation flexibility. It should be noted that while the concept of a priori planning is used for several radiocommunication services (e.g. satellite), the focus of this research was on the case of broadcasting.

6.5.1 Egypt

It was expressed by interviewees from NTRA that having a plan for the future is good in general. However, it was argued that the recent allocation of the band 694-790 MHz to mobile service by the WRC-12 called for re-planning the broadcasting service in the band 470-694 MHz on the Arabian and African levels. It was also explained that it would have been better for RRC-06 to be conducted after WRC-07 to meet the needs of broadcasting service and IMT, as at the time of the RRC-06 conference, new technologies such as DVB-T2 were unknown. As expressed by one of the interviewees from NTRA "*The conference was successful back then but afterwards the plan was changed in all countries*".

Regarding whether the RRC-06 met the requirements of the Egyptian administration, it was expressed that Egypt had 95% of the requirements, but there were over-needed or exaggerated requirements. This is due that the aim of NTRA during the conference was to attain the largest number of assignments similar to the other countries. This was clarified further by another interviewee from NTRA "*These requirements were imposed on you. Your commitments become mandatory on you. Meanwhile, the requirements may be much less and the commitment become much less*". It was also perceived by interviewees from NTRA that the planning conference was enforced by developed countries that wanted to introduce the technology of digital broadcasting. More specifically, the RRC was at a time when digital TV was about to be deployed in Europe. This was not the case for Egypt.

An evidence of such argument from the perceptive of the NTRA interviewees is the 800 MHz, 700 MHz allocations where many Arab and African countries changed their minds. Other concern related to RRC-06 conference is that not all countries were active when the GE-06 plan was made and that some dominant countries were more prepared. The Egyptian broadcaster did have positive views on the RRC-06 conference. Such conferences enable the reserving of frequencies for years and they also make the coordination process easier instead of meeting each country. Regarding the WRC-07 mobile allocation in the 790-862 MHz, the broadcaster agreed on the UHF allocation at the WRC-07 as the band was already used for fixed service and not broadcasting in Egypt. However, in WRC-12, the situation was different as the change tackled one third of the GE-06 plan.

With respect to the flexibility in changing the plan, the broadcaster explained that the GE-06 plan enables modification and addition, and that there is no difficulty in changing the plan except when it comes to the borders. Interviewees from NTRA highlighted that according to the RR, any country has the right to use the spectrum allocations within their lands in any way that suits its interests under the condition of not causing interference to services in neighbouring countries. Another issue that was raised by NTRA is that the ITU-R is helping in re-planning the GE-06 plan in countries which wanted to introduce IMT in the 700 MHz band.

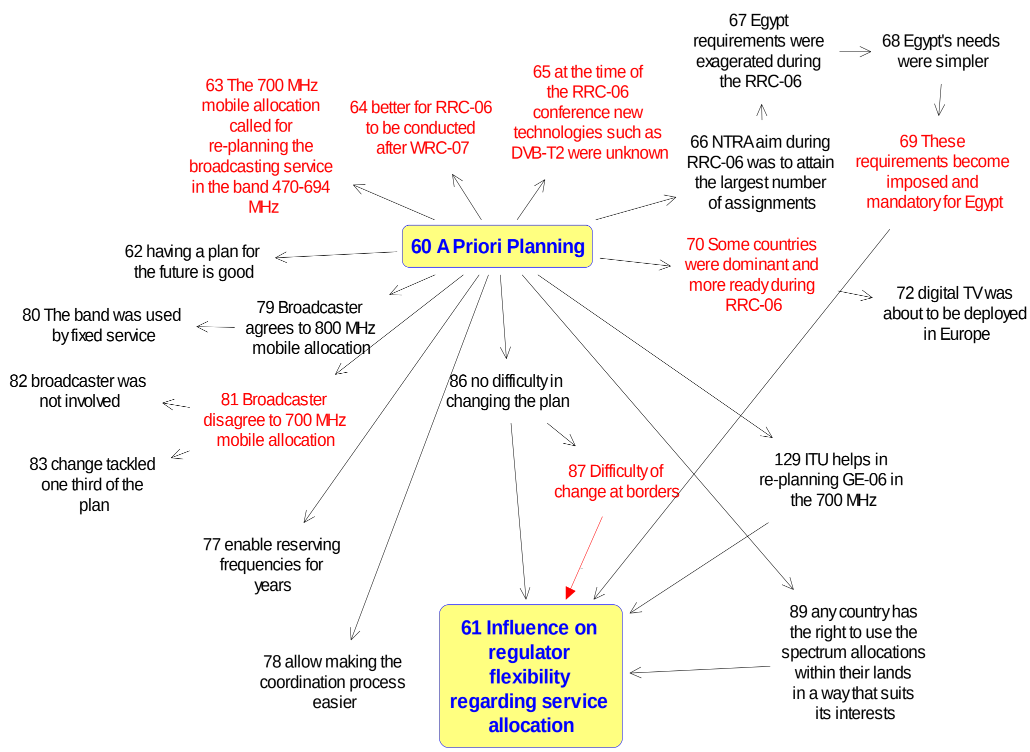

Figure 6-4: Influence of A Priori Planning on Regulator’s Flexibility regarding Service Allocation in Egypt

The causal map in Figure 6-4 highlights some of the deficiencies in the a priori planning process for the broadcasting service from the perspectives of the Egyptian interviewees. Firstly, the timing of the latest broadcasting planning conference (RRC-06) was criticised for not taking into account the development on the mobile allocation in the 800 MHz band that was agreed in WRC-07 (concept 64) and also the 700 MHz allocation agreed in WRC-12 (concept 63). The conference did not consider advancement in technologies that may make planning more efficient (concept 65). Some deficiencies were related to the purpose of the concept. More specifically, several issues showed that Egypt was not aiming in planning its broadcasting service in a way that was forced on them (concepts 66, 67, 68, 69) from the European countries who were more interested in the conference (concept 72) and were more ready than others (concept 70). On the other hand, the concept behind a priori planning is appreciated by NTRA (concepts 62, 77).

Regarding the influence on NTRA flexibility with respect to service allocation, the map shows that in general there is no restriction according to the general principles of allocations at the ITU-R (concept 89). In addition, the broadcasting plan itself could be changed (concept 86) considering difficulties at the borders (concept 87). However, the broadcasting requirements agreed by the RRC-06 conference for NTRA could be considered as a constraint because some of them were not needed (concept 69). The ITU-R BR is helping in re-planning the GE-06 plan in response to these mobile allocations (concept 129). **These observations imply that a priori planning concept for broadcasting does not restrict NTRA flexibility except at borders.**

6.5.2 UAE

Regarding whether the GE-06 plan met the UAE requirements, interviewees from the UAE TRA explained that at the time of the RRC-06 conference, their needs were met but nowadays there is a need to modify the plan. More specifically, it was pointed out that UAE was against having mobile in the 790-862 MHz in WRC-07. However, in 2012, the trend was completely different as UAE wanted to have mobile service in the 700 MHz band and because the broadcasting service has less than 1% view rate in UAE. This is in addition to the further enhancement in the digital broadcasting technologies (e.g. DVB-T2). The band below 694 MHz is sufficient for UAE to accommodate all the requirements of their TV broadcasting operators.

Regarding the RRC-06 conference, it was expressed by the regulator that such conferences are important for countries small in size like the UAE in terms of using the spectrum without interference, having protection against interference and having the procedures to resolve it. It was pointed out that broadcasting is a unique service by its nature due to the high power transmission and the need to long time investments, and this is the reason why the GE-06 plan lasts for a longer time. One interviewee from the regulator argued that a priori planning conferences should be the last solution to guarantee the minimum rights for all countries. It is worth mentioning that one of the international interviewees noted that although GE-06 was originally intended to cover region 1 countries only, Iran, a country in Region 3, requested to join the plan due to the interference concerns from the Gulf countries, including the UAE.

Other concerns with the RRC-06 expressed by the broadcaster interviewees were that the process for registering broadcasting assignments in the MIFR is too long. It was argued that the RRC-06 plan should be changed because of the software and the calculation needs to be changed according to new broadcasting technologies. In addition, an interviewee from the broadcasting group criticised the software used for planning at the RRC-06.

Regarding whether the RRC-06 meets the UAE requirements, there were also diverse views from the broadcasters. While one interviewee argued that it met the requirements by a large extent, other interviewee pointed out that it is less comparing to the analogue TV requirements due to contradictions with neighbouring countries and also due to issues with the software of RRC-06. In addition, time was quite tight and in countries that do not have qualifications, they could not achieve their requirements.

The interviews with the UAE broadcasters revealed diverse views regarding the 700 MHz allocation. On the one hand, part of the broadcaster group in UAE did not show objection to the 700 MHz mobile allocation provided that there would be a financial compensation for them. This is due to the fact that terrestrial broadcasting is not heavily used and is used mainly for political reasons in case of any instability. On the other hand, there was a view from the broadcasting group that is against the 800 MHz and 700 MHz allocation to mobile.

Regarding the influence on flexibility, it was mentioned that the GE-06 plan does not restrict service flexibility as it has guidance for sharing with other services. Besides, it was also mentioned that the GE-06 plan is flexible in particular for the broadcasting service as it allows improving planning while technology evolves. On the other hand, TRA is in favour of less exclusive allocation for broadcasting to provide more flexibility.

This is due to the fact that the GE-06 plan can provide sufficient protection for broadcasting and mobile if there is a co-primary allocation. It was also expressed that the GE-06 plan is difficult to be changed especially for adding new assignments and that there must be an approval from the other countries. In addition, it is needed to hold such conferences in order to modify assignments agreed at previous conferences, which might not be practical in the coming year

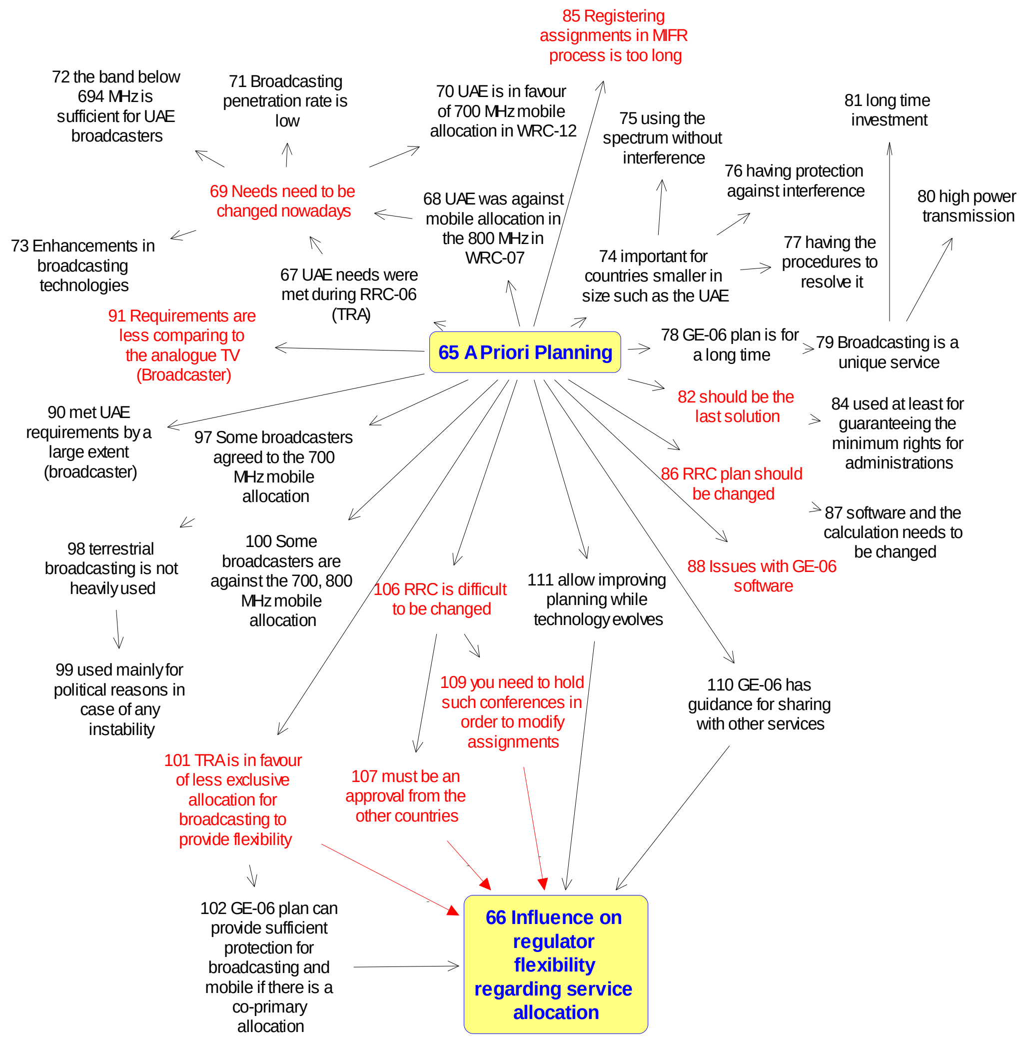

Figure 6-5: Influence of A Priori Planning on Regulator's Flexibility regarding Service Allocation in UAE

The causal map in Figure 6-5 shows that the UAE TRA shares the views with Egypt NTRA that there is a need to revise the GE-06 requirements due to the emerging need for additional mobile allocations (concept 70), enhancements in broadcasting technologies (concept 73) and low broadcasting views (concepts 71, 72). In addition, it seems that such type of planning has a special importance for a small country such as UAE due to several factors (concepts 74, 75, 76, 77), and also is needed for the specific case of broadcasting service (concepts 78, 79, 80, 81) considering that is a priori planning is not an optimum type of spectrum management (concepts 82, 84).

Regarding the influence on the regulator's flexibility with respect to service allocation, the map reveals several elements of restriction and flexibility as well. On the one hand, the GE-06 plan is argued to cope with advancement in broadcasting technologies (concept 111). On the other hand, modifying the GE-06 plan is considered to be difficult and conditioned by getting approval from neighbouring countries (concept 107) or conducting another a priori planning conference (concept 109). Moreover, TRA is in favour of less exclusive broadcasting allocation in general to provide more flexibility (concept 101) considering that the GE-06 plan can provide sufficient protection for broadcasting and mobile if there is a co-primary allocation (concepts 102, 110).

These findings highlight that the concept of a priori planning for broadcasting has elements of restriction in terms of modifying the plan and getting approval from neighbouring countries and flexibility in terms of coping with technology advancement and accommodating other radiocommunication services considering that TRA is in favour of co-primary allocation for other services other than broadcasting in the UHF band to provide more flexibility.

6.5.3 International Interviewees

In general, there were two diverse views regarding the influence of a priori planning on service allocation flexibility shared by twenty six interviewees. On the one hand, eighteen interviewees were in the view that it does not restrict regulator's flexibility. In particular, it was clarified that GE-06 plan already includes the flexibility because it did not include the very detailed frequency planning and did not set up a specific situation with geographically fixed data but just used an umbrella of coordination triggers. It was also argued that it has partial flexibility upon agreeing with neighbouring countries. The envelope concept was also highlighted by a senior interviewee from CEPT who mentioned that the concept was pushed by the European countries to provide flexibility and it was in line with the WAPECS concept in Europe.

In particular, the envelope concept allows using the 8 MHz TV channel for any other use than broadcasting as long as you do not violate the upper limits of this mask. Therefore, the broadcasting allocation could be used for other use such a downlink of LTE technology providing that there is a mobile allocation. It was also pointed out that flexibility could be achieved by having many frequency bands allocated to more than one radiocommunication service. The RRC-06 has not prevented allocating additional spectrum to mobile and identifying additional spectrum for IMT. It was noted that flexibility could be provided through footnotes.

One senior interviewee from the ITU-R pointed out that the RRC-06 conference was not concerned with service allocation. Instead, it is planning a given allocation. Another interviewee explained that the flexibility depends on your country geographical positions and how diverse use your neighbours are utilising. Therefore, RRC-06 could give flexibility to introduce mobile if this is the common approach of your neighbours. More specifically, mobile systems such as IMT require harmonisation among large number of countries. Therefore, the GE-06 plan allows reassigning or modifying the broadcasting assignments depending on the agreement with the neighbouring countries. For instance, the African countries in Sub-Sahara region are currently re-planning the spectrum below 694 MHz following the WRC-12 without cooperating with the European countries.

On the other hand, eight interviewees were of the view that a priori planning could affect countries' flexibility. Firstly, while such conferences plan efficient use for the technology that it is planned for, it is also restricted in terms of being fixed to that technology and that kind of radiocommunication service. One other interviewee clarified that while planning conferences can be as flexible as possible it is still not under the service flexible concept as in such case it would not be possible to conduct any planning regionally. Besides, the RRC-06 could be a restriction because it is a regional conference, which means that only a regional conference can make any modifications to the agreement. As expressed by one of the interviewees "*There is no WRC, there is nothing,* *no other meeting can make anything about it. And that's really the difficult part*".

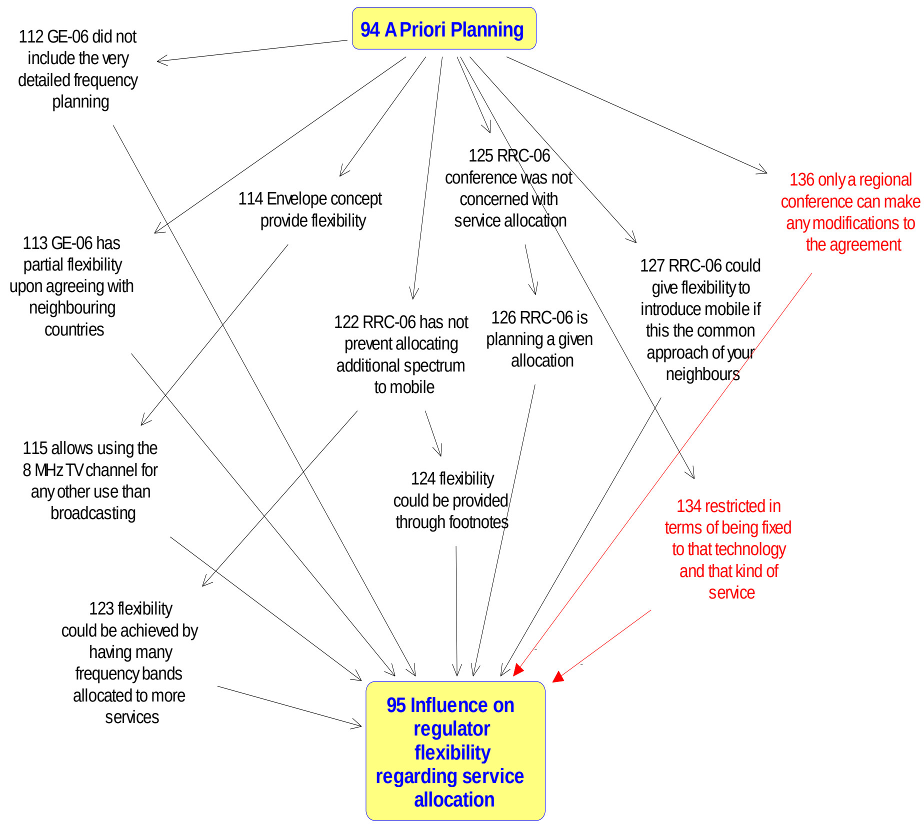

Figure 6-6: Influence of A Priori Planning on Regulator's Flexibility regarding Service Allocation from Perspectives of International Interviewees

The causal map in Figure 6-6 illustrates that the concept of a priori planning accommodates many elements of flexibility. Firstly, the envelope concept inherited in the GE-06 plan allows using the plan for other radiocommunication services (concepts 114, 115). In addition, while only anther planning conference is able to modify the GE-06 plan (concept 136), the plan can be modified regionally if this is the common approach of some neighbouring countries (concept 113). Another element of flexibility could be achieved via additional allocation in the UHF band (concepts 122, 123, 124). Elements of restriction include the difficulty to modify the plan unless there is an approval from neighbouring countries (concepts 113, 136). The concept of a priori planning is concerned with only one radiocommunication service, and therefore, it is considered against service flexibility in theory. **This leads to a general conclusion that the concept of a priori planning mostly does not restrict regulators' flexibility regarding service allocation. However, there could be restriction in case there is a need to get the approval of neighbouring countries or to have another planning conference to modify the plan.**

6.6 *Decision Making Procedures*

It was important to investigate the influence of service allocation decision-making procedures within the ITU-R on regulators' flexibility. As explained in Chapter 3, WRCs deal with allocation of frequency band to various radiocommunication services to be added to the RR.

6.6.1 Egypt

In general, there were two views regarding the decision-making procedures. On the one hand, it was argued that the cycle period between the conferences is good due to the adequate studying period and that the conference decision is a compromise. One the other hand, it was expressed that having an agenda item approved requires 8 years which is a problem considering the advance of technology. Instead, some issues could be finished every year instead of waiting four years. In addition, most of the countries do not attend the study groups. It was also argued that the process is influenced by large countries

Regarding the influence on flexibility, it was explained that Egypt was never in advance of the ITU but it may happen in the future similar to the case of UAE, which decided to deploy mobile in the 700 MHz without waiting for the ITU. In addition, it was pointed out that decision-making procedures are not something that should not stop you as long as you do not cause interference to your neighbours. The mobile group complained about the slowness of the system in terms of the cycle between the conferences. On the other hand, it was argued that Egypt is not a technology leader. Moreover, it was expressed that operators does not participate in the discussion. The broadcasting group was satisfied with the period between the conferences, as there are a lot of required studies. It was also mentioned that the ITU considers the interests of specific countries like the US and EU which have leverage in the ITU.

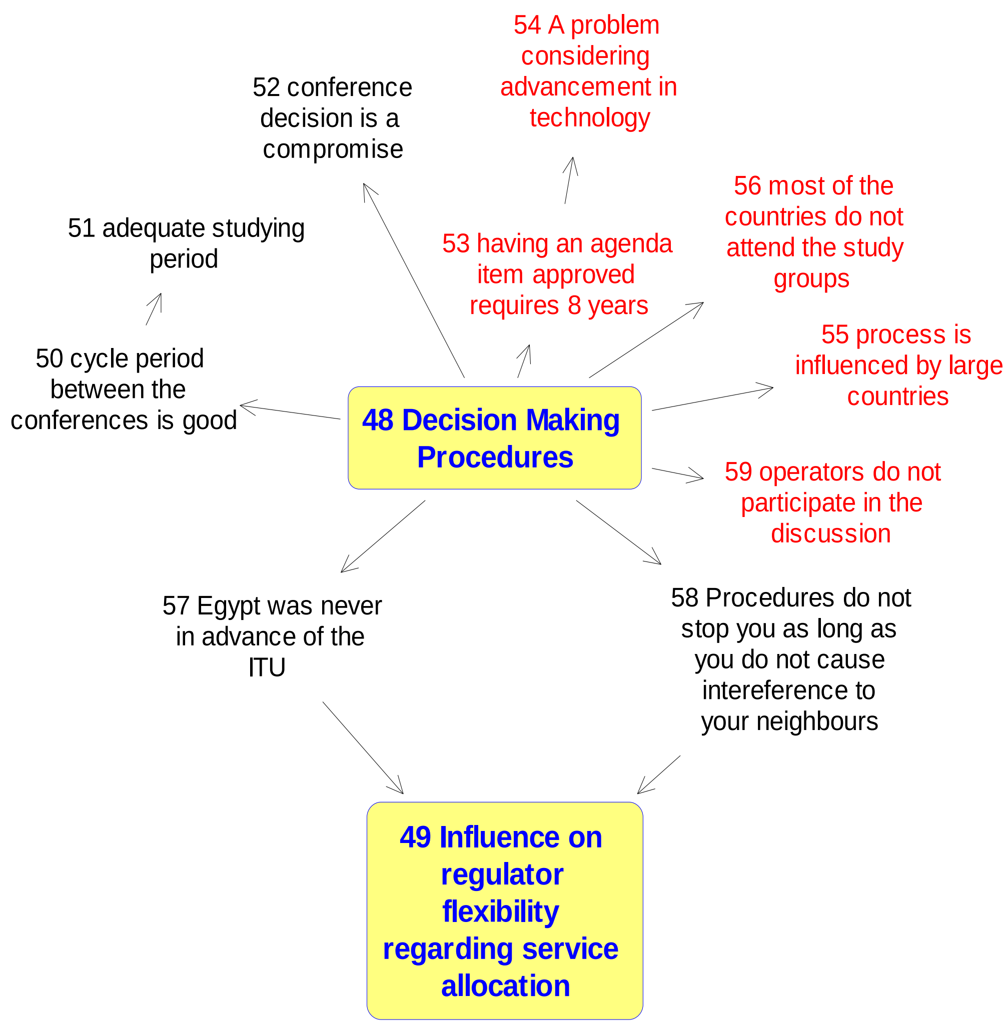

Figure 6-7: Influence of Decision Making Procedures on Regulator's Flexibility regarding Service Allocation in Egypt

As shown in Figure 6-7, there are different perceptions on the efficiency of the decision-making procedures in terms of its length (concepts 53, 50). In addition, concerns are expressed regarding the equity of all participants in the procedures (concepts 56, 55, 59). Regarding the influence of the decision making procedures on regulator's flexibility with respect to service allocation, the data analysis illustrates that they are not considered to be a constraint due to the flexibility of the main allocation principles in the RR (concept 58) and also due to the relatively slowness of Egypt advancement in deploying new technologies (concept 57). **These findings highlight that the decision-making procedures do not restrict NTRA flexibility regarding service allocation.**

6.6.2 UAE

In general, interviewees from TRA highlighted advantages and disadvantages of the decision-making procedures. Firstly, the procedures address mutual interest of all parties including the private and public sector. Regarding the slowness of the process, one interviewee from the UAE regulator explained that it is normal because you are trying to have one standard for all the participant countries. In addition, one of the main ITU-R advantages is that voting is the last solution and that most of the decisions are approved on a compromise basis. Therefore, no one can enforce a decision in ITU-R because it is a consensus based organisation and developed and developing countries are equal. Moreover, it was mentioned that the present system is tailored towards the developing and under-developed countries because it is a very slow system which is good for these countries which need more time, or have more equipment life for their networks.

In addition, the decision-making procedures are country driven, and therefore, it is all dependent on countries' participation. One other advantage that was pointed out regarding the decision-making system is that it is a steady regular system where there is a conference every three or four year. There was an argument against the procedures that there is a period between the conference and the following conference of 4 years where new technologies could emerge. This was the case for the 700 MHz issue. In general, interviewees from the mobile operators criticised the slowness of taking decisions and it was explained that one of the aim of operators in UAE is to bring the latest technology to the country.

Regarding the flexibility of the decision-making procedures, interviewees from

TRA explained that this depends on the flexibility of the people who attend the conference so that each conference has its own flexibility. It was argued also that the conference agenda item should be regarded as the least that can be achieved, not the most that can be achieved. As expressed by one interviewee from TRA "*The maximum is really based on the conference, and we gave the whole world a message in the last conference, that this is the minimum and we actually added the maximum during the same conference*".

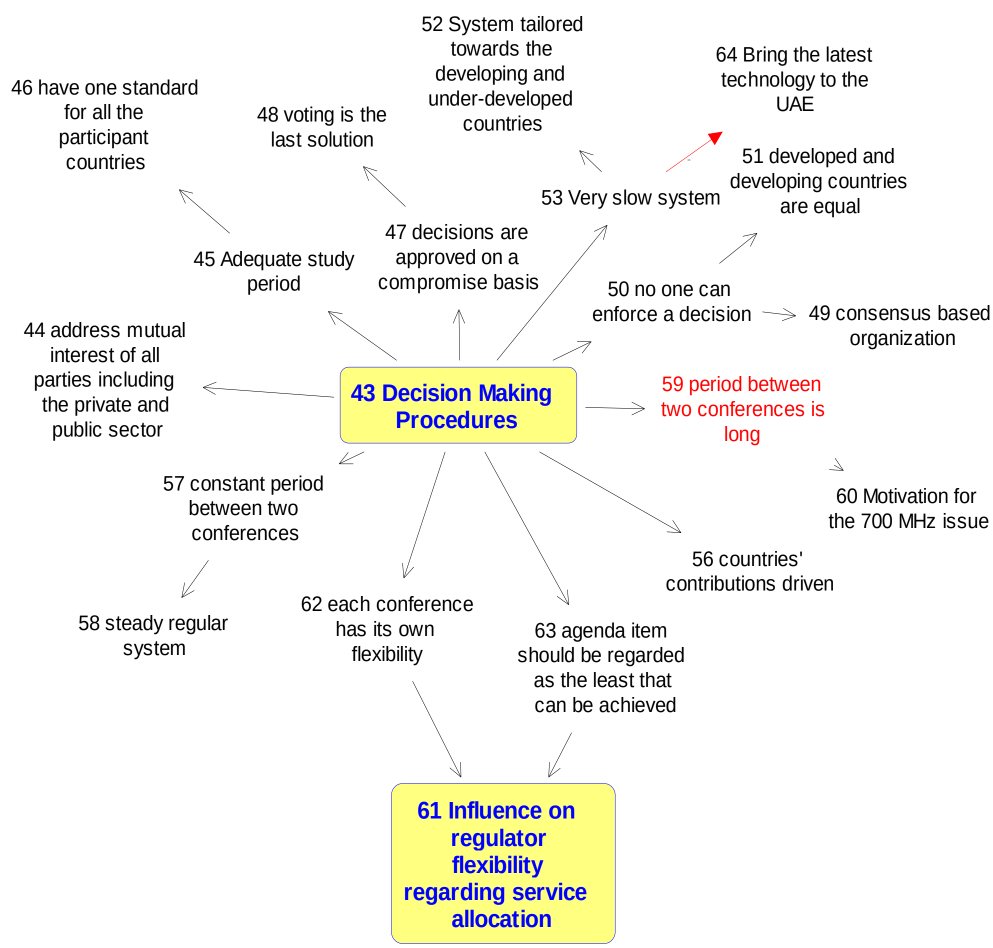

Figure 6-8: Influence of Decision Making Procedures on Regulator's Flexibility regarding Service Allocation in UAE

Figure 6-8 shows that similar to the case of Egypt, there are two contrasting perceptions in UAE on the efficiency of the service allocation decision-making procedures in terms of its length (concept 45, 53, 59, 57, 58). Unlike perceptions of NTRA, it was perceived that the system accommodates equality between the countries depending on countries' participation (concepts 50, 51, 49, 56). Regarding the influence of the procedures on TRA flexibility with respect to service allocation, the procedures are perceived to be flexible enough considering that the agenda of the conference could be adjusted according to the requirements of the participant countries (concepts 62, 63). **This leads to a general conclusion that the decision-making procedures do not restrict TRA flexibility regarding service allocation.**

6.6.3 International Interviewees

There were views shared by eighteen interviewees out of twenty nine that the decision-making procedures of the ITU-R are not restrictive. Firstly, there was a view that the decision making process reveals where it is possible for potential agreement and considering that a compromise is needed, it increases the flexibility because otherwise no one will be able to reach agreement on anything. Regarding discussing only issues that are on the agenda of the WRC, it was argued that it is not restricting because every WRC is sovereign. As explained by one of the interviewees "*Agenda items give guidance and it happened before with the Teledesic in WRC-95 or WRC-97 regarding little Leo satellite*". In particular, modification of the WRC agenda can be agreed at the plenary of the conference but the agenda enables countries to know what is at stake for the next conference.

It was also argued that the procedures do not restrict flexibility as industry stakeholders are present to participate in the discussion. A senior interviewee from the ITU-R argued that the procedures were able to accommodate any type of technology developments for many years and the procedures themselves have evolved from time to time. As expressed by this quote "*The ITU has no real role in the timing of development of the technology apart from the fact that it's true that the international coordination and harmonisation takes time...That does not preclude preliminary implementation or preliminary developments*". It was also pointed out that the ITU-R working methods are set by the countries themselves.

It was mentioned that although WRC is a treaty making conference, countries may legally deviate from it. More specifically, while the final act is signed by the member states, they can at the time of signature record their reservations towards particular propositions, which have a conflict with their national interest legislations. Countries and their respective operators or operating agencies are then free to manage and operate systems under the envelope of the allocation, respecting the terms and conditions of allocation while not causing harmful interference. As explained by one of the interviewees ”*any country can do anything it wants but it does not get any protection for it. It does not restrict anybody from doing anything but it does restrict your ability to do it in interference or a protected way*”.

On the other hand, there were views shared by eleven interviewees out of twenty nine that the current ITU process may limit administrations capabilities to introduce some flexibility to their service allocations. In particular, one interviewee mentioned that studies under resolution 951 (WRC-12 A.I. 1.2) showed that ITU response to the changing dynamics of the market is not sufficient. One other view is that there is a restriction but only from a time point of view. In particular, countries cannot make decisions until the time of a WRC. However, it was mentioned that there are exceptions such as the 700 MHz mobile allocation in WRC-12. In addition, companies may use the ITU-R decision-making procedures to restrict other competitors’ technologies, and even countries can block the others even if their technologies are possible due to political conflicts.

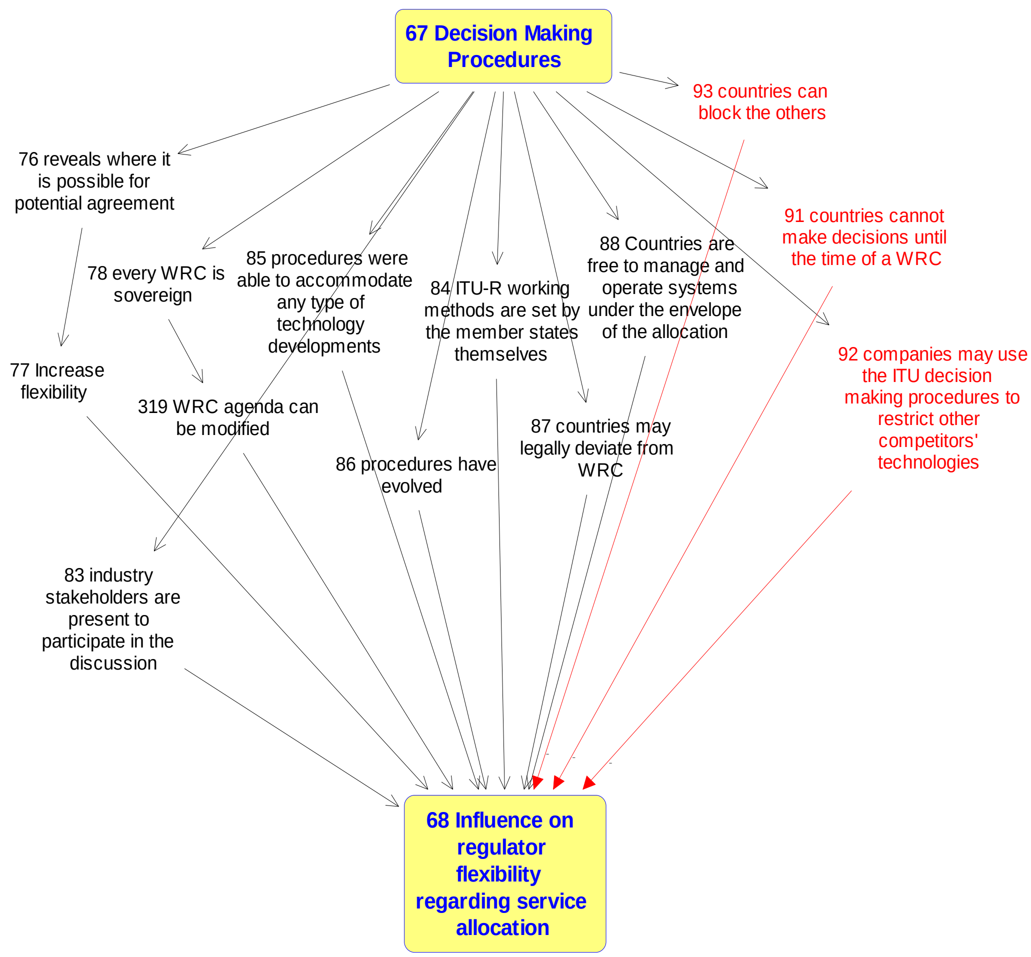

Figure 6-9: Influence of Decision Making Procedures on Regulator's Flexibility regarding Service Allocation from Perspectives of International Interviewees

The views of the international interviewees illustrated in Figure 6-9 show that there are different elements of flexibility in the process. Most importantly, every WRC is sovereign in terms of modifying its agenda (concepts 78, 319) and the procedures are determined and agreed by the participant countries themselves (concepts 84). This is in addition to the flexibility already provided under the RR allocation principles (concept 88). On the other hand, the procedures could be used by countries or companies to block the others (concepts 93, 92). The procedures could be considered as a restriction in terms of timing of new allocation introduction (concept 91). **These observations imply that**

the service allocation decision-making procedures accommodate several elements of flexibility but they could be used by some of the participants to restrict others and they could be restrictive in terms of timing.

6.7 *Footnotes*

This section focused on footnotes' use related to radiocommunication service allocation. In general, it was clarified during the interviews that there are several types of footnotes. The first one indicates that in this country there will be an alternative or additional allocation to the allocation indicated in the RR. The second is where there are restrictions such as maximum power level in certain services. The third is to refer to some detailed studies in certain ITU-R recommendations. The fourth is to clarify the priority of different services in the same spectrum band. In addition, a permanent agenda item in every WRC is to ask countries to revisit their footnotes.

6.7.1 Egypt

In general, regarding the use of footnotes, it was also indicated that Egypt may face difficulty in having or modifying footnotes if neighbouring countries oppose. Moreover, there were few cases where NTRA wanted to deviate from the RR, and therefore NTRA does not use footnote regularly. It was also pointed out that too much footnotes restrict global harmonisation. Also, adding footnotes is subject to approval from affected administrations while removing footnotes does not require such approval. However, there were no cases where Egypt had failed in adding a footnote. The broadcaster's interviewees clarified that they are not authorised to add the footnotes. Instead, it is the regulator who can do that.

Regarding influence of footnotes on applying service allocation flexibility, it was argued that footnotes have three influences. The first if a country applies service flexibility and it has footnotes which exclude specific services in particular bands, in such case it is restricting. The second is that neighbouring countries' footnotes may restrict countries flexibility in case that national interest is not matched with neighbouring countries. The third is that footnotes provide NTRA with more flexibility as footnotes could be considered as the exception of the RR. It was also explained that having footnotes for additional allocation is easier than having alternative allocation, as there is a need to coordinate with larger number of countries.

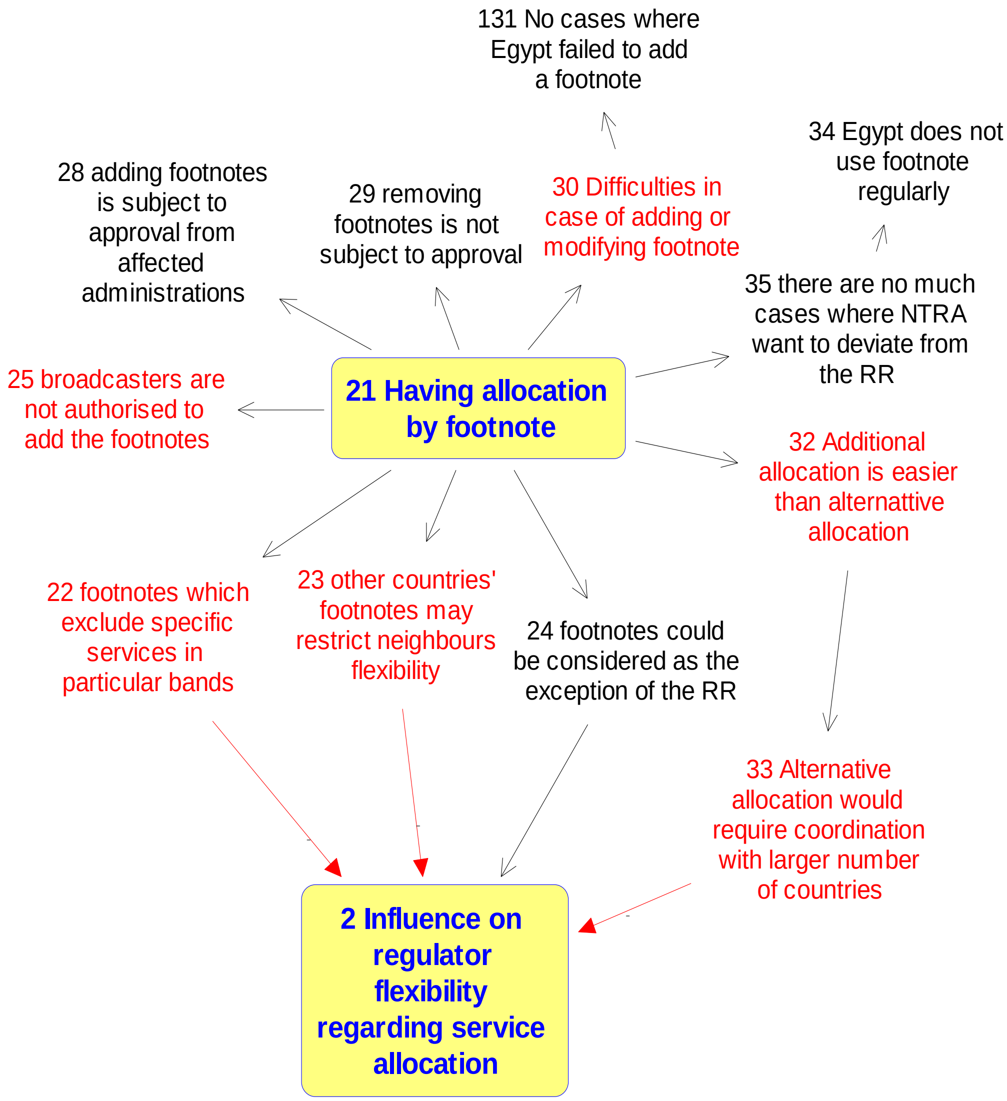

Figure 6-10: Influence of Footnotes on Regulator's Flexibility regarding Service Allocation in Egypt

The map in Figure 6-10 reveals that NTRA usage of footnotes in not much in general (concepts 35, 34), and that while there is a difficulty in adding or modifying a footnote (concept 30), in practice, NTRA never failed to add a footnote (concept 131).

Regarding the influence of footnotes on NTRA flexibility with respect to service allocation, footnotes are perceived as a tool for introducing flexibility to the RR (concept 24) considering the difficulty to add footnotes due to the coordination with neighbouring countries (concepts 30, 32, 33). In addition, while other's countries footnotes provide flexibility to them, it could restrict NTRA flexibility (concept 23). **These findings show that footnotes provide flexibility to NTRA considering the difficulty to introduce footnotes and constraints from other countries' footnotes.**

6.7.2 UAE

Regarding the use of footnotes, it was clarified that footnotes may be used in case the countries want to reserve their positions against specific allocation and take a decision in the next conference or for countries that do not have authority at the stage of the conference to agree on a specific allocation. It was also mentioned that the large number of footnotes violates the idea of harmonisation. Regarding the difficulty to add footnotes, it was explained that there is no such difficulty but sometimes footnotes by UAE were refused in WRC-03 and WRC-07. It was also explained that even if a footnote could not be introduced, TRA would still be able to run the service. In addition, countries refusing the footnotes have to prove that it will have an effect on them.

Regarding the influence on service allocation, it was argued that footnotes enable flexibility in service allocation in case you cannot get the agreement from all the countries to allow the usage of a certain service in a particular band that is different than the allocation in region 1. It was also considered that footnotes are the transitional point for full flexibility advocated by technologies such SDR or a transitional stage for having global harmonisation until the rest of the word join the footnote.

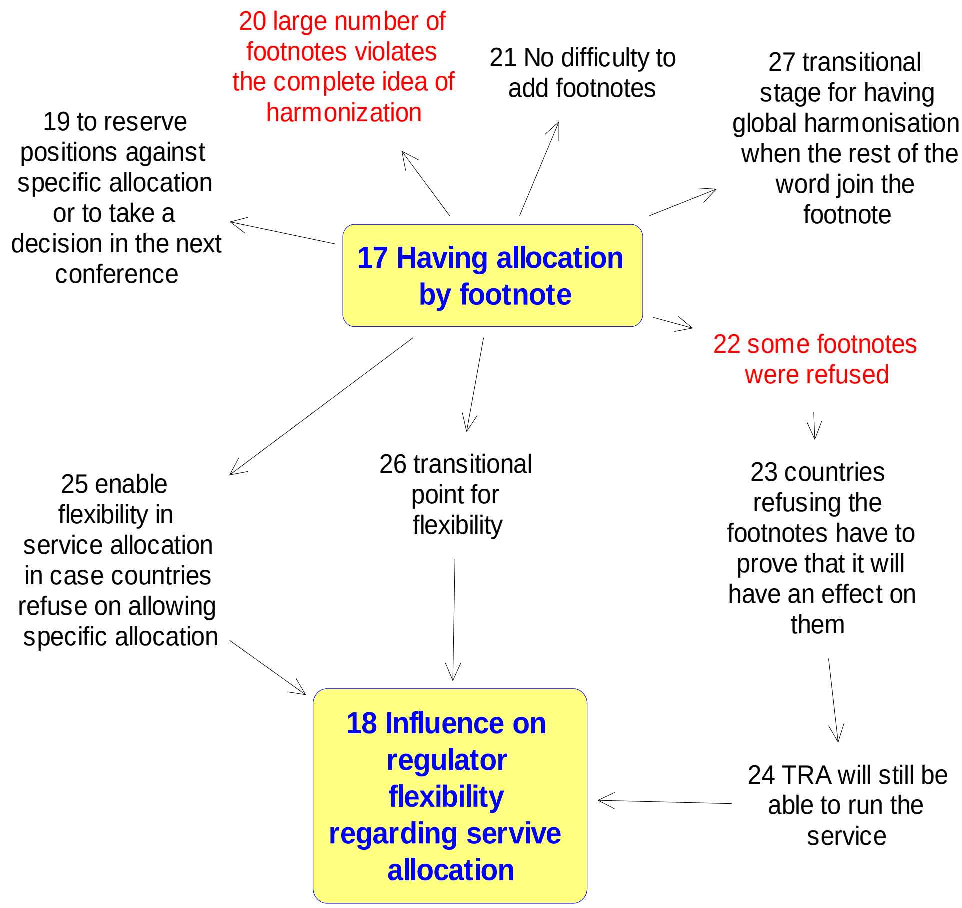

Figure 6-11: Influence of Footnotes on Regulator's Flexibility regarding Service Allocation in UAE

Figure 6-11 clarifies that TRA felt it has no difficulty in adding footnotes to the RR (concept 21) and that footnotes could be used as a step to enable harmonisation (concept 27) or could be misused to restrict harmonisation (concept 20). Regarding the influence of footnotes on TRA flexibility with respect to service allocation, the data analysis shows that footnotes are considered as a tool for flexibility and harmonisation in the same time (concepts 25, 26, 27) and that while TRA may not succeed in adding particular footnote (concept 22), this does not stop TRA from deploying that specific service allocation (concept 24). **This leads to a general conclusion that footnotes**

provide flexibility to TRA in terms of service allocation considering that the failure to add a footnote does not restrict TRA from introducing a service.

6.7.3 International Interviewees

In general, twenty eight interviewees had different perceptions on the influence of footnotes on flexibility. On the one hand, eighteen interviewees argued that footnotes enable elements of flexibility. In particular, when a new allocation is made at the conference, in some countries you need some time to re-farm some services from a band and such redeployment takes time. Footnotes provide also flexibility as it could be used to add an additional service or alternative service or to be exempted from a service (e.g. the C-Band, developing countries want to use it for IMT while in island countries, fixed satellite service is more attractive). Footnotes may be used by countries that have some special interest (e.g. a conference decided to allocate this band for maritime mobile service but some countries may not have access to the sea, so there is no need for them to have this allocation).

Interviewees from the mobile group argued that footnotes could provide flexibility when it is hard to reach a compromise and it could be considered also as a good starting point for normal allocation in the RR and harmonisation. As clarified by one interviewee from the mobile industry "*It gives the opportunity to build confidence and then expand that out".* One example of footnotes is the mobile footnote at the 3.4 GHz, which was argued to be useful for the mobile community as it has more than 100 countries. On the other hand, there was a view that the footnote in the 3.4 GHz does not provide full harmonisation to drive the market, as it has not achieved the sort of critical mass to drive the eco system.

Ten interviewees were of the view that footnotes could be restrictive. In particular, the more footnotes that you have in the RR, the more restriction you may have for others. For instance, they could be used to provide priority to the incumbent service. Besides, the flexibility provided to some administration may reduce the flexibility to a neighbouring country (e.g. footnote in the UHF band for radio navigation services provide flexibility to Eastern European countries but it puts constraints on other administration). In addition, footnotes could be used to reduce flexibility in case they take an allocation out of the RR. Additionally, unlike assignments registered in MIFR, footnotes can only be changed during WRCs.

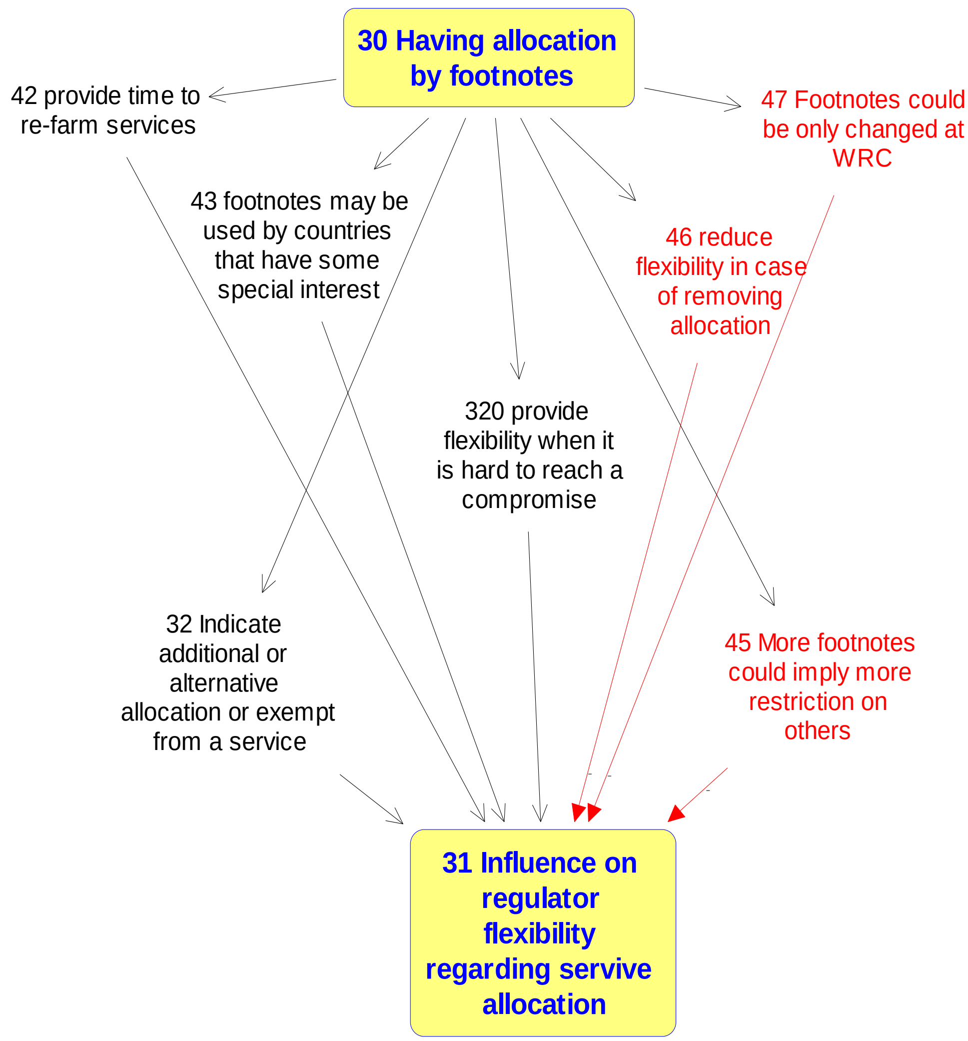

Figure 6-12: Influence of Footnotes on Regulator's Flexibility regarding Service Allocation from Perspectives of International Interviewees

The international interviewees' perspectives on the influence of footnotes as shown in Figure 6-12 illustrate how footnotes could provide flexibility in different ways (concepts 32, 42, 320) and also when it difficult to have a regional agreement on an allocation in WRCs (concept 43). On the other hand, these elements of flexibility could be considered as elements of restriction for others (concept 45) or for the country itself in case an allocation is excluded (concept 46). One element of restriction in footnotes is that it could be only introduced or modified at the time of WRC (concept 47). **These observations imply that footnotes could provide flexibility in different ways while may restrict other countries' flexibility considering that footnotes could only be introduced or modified at WRCs.**

6.8 *MIFR*

Investigating the influence of MIFR on service allocation flexibility was important as registering assignments in the MIFR requires information on the service allocation of these assignments. It should be noted that while MIFR could be used for different types of radiocommunication services, the focus of this research was on three services: fixed, mobile, and broadcasting.

6.8.1 Egypt

Interviewees from NTRA explained that MIFR are important to give priority and to seek the help of the ITU in case of interference. It was mentioned that it is a common process that NTRA does every year. However, it was noted that it is a lengthy process and that some assignments may be refused in bands shared between satellite and terrestrial services. Another interviewee from NTRA argued that there is no problem with MIFR and that is an easy process.

One other interviewee from NTRA mentioned that Egypt registered frequencies for political reasons and for technical reasons; technical to protect important assignments from interference and political to use them for negotiation with Egypt's neighbours. An interviewee from the fixed incumbent (TE) explained that they do not register frequencies in the MIFR. Instead, it is the regulator who is responsible of that.

Interviewees from the broadcasting group explained that they register their assignments for international protection and that it is an easy process. It was also acknowledged that in case of adding or modifying assignments, you need to coordinate with countries that oppose such modification to get their approvals but there is no difficulty in such modification. Changing the place or the specifications needs to be approved. One issue that was raised by the broadcaster is that sometimes the coordination distance is 500 km with radiocommunication services such as aviation and sometimes countries oppose although they are not actually using the band for aviation.

Regarding the influence on flexibility, it was mentioned that MIFR may hinder service flexibility because registered stations are based on a particular service and not service neutral. Countries that have registered assignments in the MIFR may influence countries applying service neutrality. One other interviewee explained that in reality MIFR does not have much effect on Egypt.

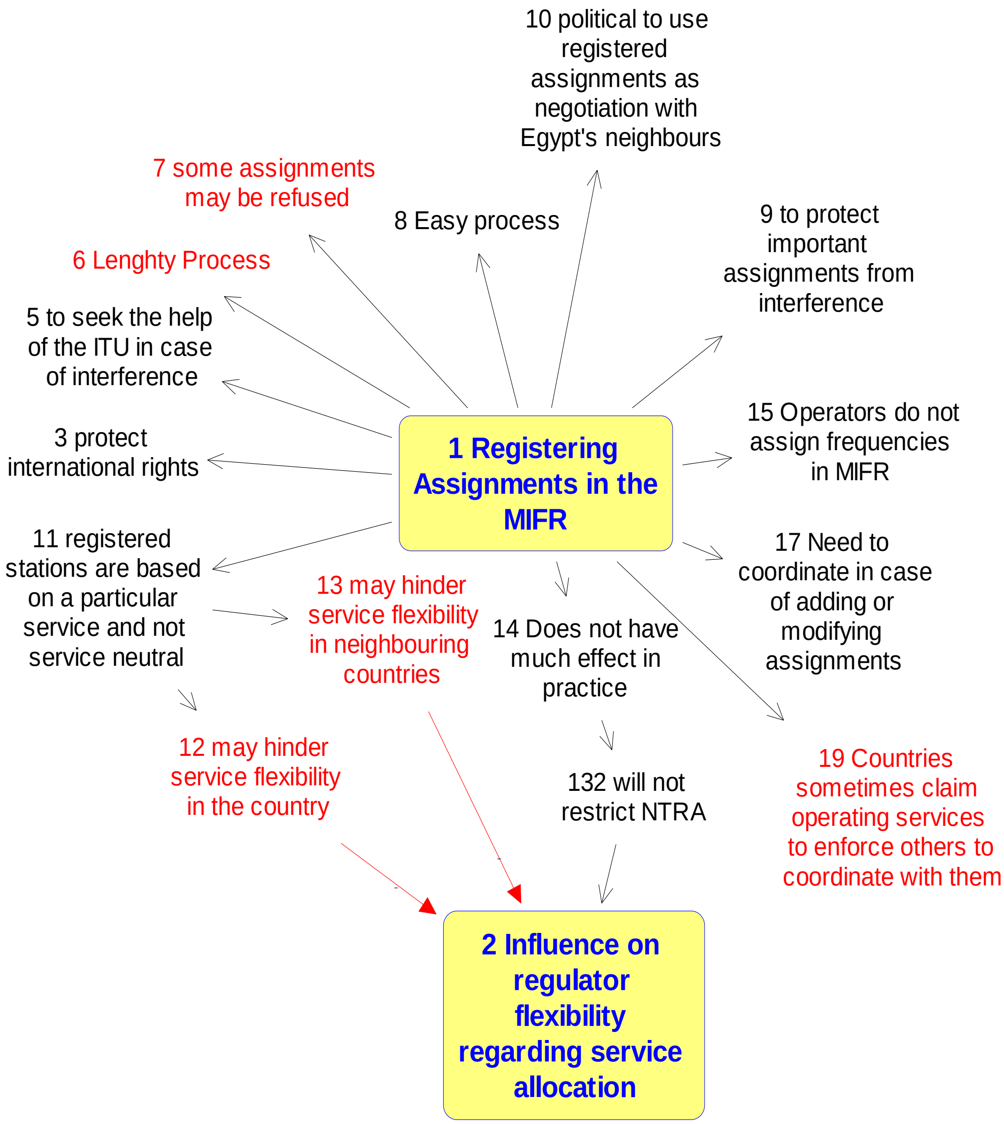

Figure 6-13: Influence of MIFR on Regulator's Flexibility regarding Service Allocation in Egypt

The causal map in Figure 6-13 illustrates how registering assignments in MIFR is important for NTRA in different aspects related to interference (concepts 3, 5, 10).

These registered assignments could be used as part of the negotiation with Egypt's neighbours (concept 10). In other words, MIFR use is not purely technical but could be used to trade positions on other issues (concept 19). Regarding the influence on service allocation flexibility, it seems that the use of MIFR could restrict NTRA flexibility (concept 12) and could restrict Egypt's neighbouring countries as well (concept 13). Meanwhile, restriction accommodated in MIFR does not have an effect on NTRA in practice. **These findings highlight that while the use of MIFR accommodates element of restriction, it does not confine NTRA in practice.**

6.8.2 UAE

It was clarified by interviewees from TRA of UAE that when the focus of MIFR was on the HF band, registration was important but when VHF and UHF bands were used, there is no much registration unless they are either part of aeronautical service or frequencies which require international registration and recognition. In higher bands, no registration is conducted because links are geographically constrained. It was also explained that there is a difficulty of registration coordination with 7 or 8 neighbouring countries.

Two interviewees from the TRA and the mobile operators argued that MIFR could be considered as a double-edged weapon. On the one hand, it is a channel of advertising for the administrations to declare the use of spectrum for specific services. On the other hand, there are many countries that misuse MIFR. More specifically, within the MIFR, the superiority is given for who comes first even if their uses are not real. As expressed by this quote "*It is restricting those administrations who are trying to notify their existing user against something that has been notified which never exist*".

One other interviewee from TRA explores the issue of how political conflicts may have an influence on the use of MIFR "*a country managed to notify lots of base stations, and the way which accepted in the ITU that they do not check whether these stations are in use or not in use*". Regarding the influence of the MIFR on regulator service allocation flexibility, it was explained that as TRA is not in favour of flexibility in service allocation, the MIFR is not a problem for UAE.

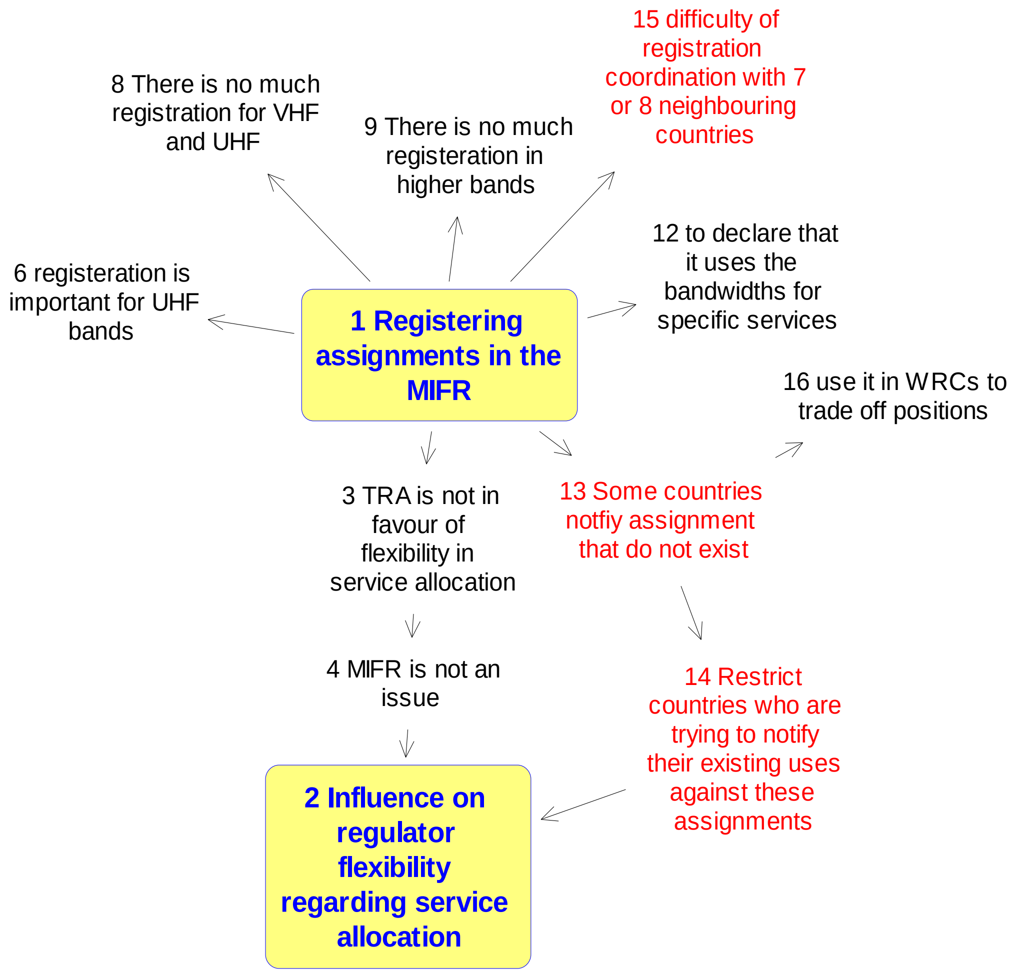

Figure 6-14: Influence of MIFR on Regulator's Flexibility regarding Service Allocation in UAE

The causal map of UAE in Figure 6-14 reveals that TRA is restricted by other countries' registration in the MIFR especially those countries that do not have actual deployment. On the other hand, as there is no interest in applying service neutrality in UAE, using MIFR by TRA would not be considered as restriction. **This leads to a general conclusion that while the use of MIFR by TRA is not considered as restriction, the misuse of MIFR by UAE neighbouring countries may restrict TRA flexibility.**

6.8.3 International Interviewees

Regarding the influence of MIFR on flexibility, eleven interviewees out of sixteen indicated that the MIFR does not restrict countries' flexibility regarding service allocation because it is usually used for satellite services only to get protection and not for fixed and mobile services. Furthermore, it was argued that although MIFR may impose a restriction because all the data related to the assignment have to be sent (e.g. service allocation) but practically a lot of administrations do not notify their assignments. For countries that rely on agreements with its neighbours, MIFR is not much used. It was indicated that changing the registered assignments in the MIFR could be conducted at any time, unlike the case of footnotes where countries have to wait for WRC to edit it.

On the other hand, five interviewees argued that registering assignments may restrict neighbouring countries' flexibility. In particular, one country's registered assignments in the MIFR may restrict neighbouring countries flexibility in case they want to register their own assignments in the future. There is a trade between flexibility and protection where flexibility is needed, international protection provided by the MIFR is lost. More specifically, if assignments are flexible enough, they will not be registered in the MIFR, which has specific rules in terms of registering the assignment under one allocation. One issue that was mentioned by several interviewees is that some countries register assignments and even after the system become obsolete; they do not withdraw the assignments. There is no good mechanism to delete these entries and therefore it could be a restriction on other countries' assignments as the ITU does not have any means of determining real deployment and in case countries claim some deployment, the ITU have to accept that as actual use.

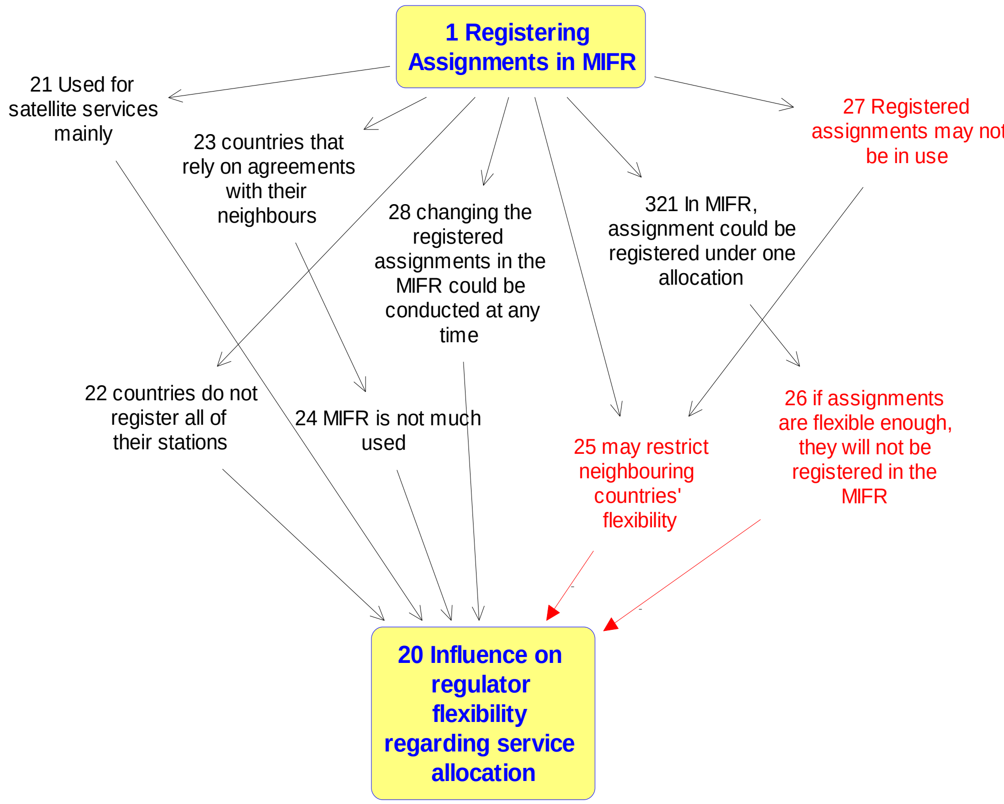

Figure 6-15: Influence of MIFR on Regulator's Flexibility regarding Service Allocation from Perspectives of International Interviewees

The international interviewees perspectives displayed in Figure 6-15 illustrates that there is no much use for MIFR in practice (concepts 21, 22, 23, 34), and therefore, MIFR does not consider as a restrain. Another element of flexibility in contrast with footnotes is that registered assignments in the MIFR could be changed at any time without waiting for a WRC (concept 28). On the other hand, in order to register an assignment, there should be a specific declared radiocommunication service, which is in conflict with flexibility (concepts 321, 26). Moreover, registering assignments in the MIFR could restrict other countries' flexibility (concept 25) considering that some assignments may not exist in practice (concept 27). **These findings show that while**

MIFR is not in line with radiocommunication service flexibility in principle as there should be a specific declared radiocommunication service; MIFR is not used much in practice. On the other hand, other countries assignments in MIFR could restrict country's flexibility considering that some of these assignments may not exist in practice.

6.9 *Three Region Systems*

The three regions system is an important element of service allocation that is worth examining considering that Egypt and UAE lie in ITU-R region 1.This is due to the fact that each region has its own radiocommunication service allocation.

6.9.1 Egypt

In general, the NTRA interviewees expressed their interest in having only one global region for the attainment of harmonisation considering that there is no technical reason to have three regions. It was also expressed that the differences among the 3 regions are not that large to create difficulty in unifying the allocation over the three regions. With regard to the division of region 1, it was argued that even within region 1, there is a need to coordinate between coastal countries in Europe and Africa. It was also expressed that region 1 is already divided in terms of development and not allocation. More specifically, it was mentioned that region 3 is more harmonised than region 1 politically and economically where region 1 has variance between Africa and Europe.

Additionally, the Egyptian broadcasting group pointed out that there is no influence on them from the 3 regions system as it is a must for them to coordinate with Europe, Arab and African countries. Interviewees from the operators group expressed that there is no problem with the current system as there is a need to coordinate with countries in region 1 only. Regarding the influence of the three regions on service allocation flexibility, it was argued by interviewees from NTRA that the division of the regions has the advantage of relatively easing the process of reaching agreement. It was also mentioned that region 2 has more freedom regarding its allocations decisions due to the geographical separation from the other regions. On the other hand, region 1 and region 3 issues are discussed as one package.

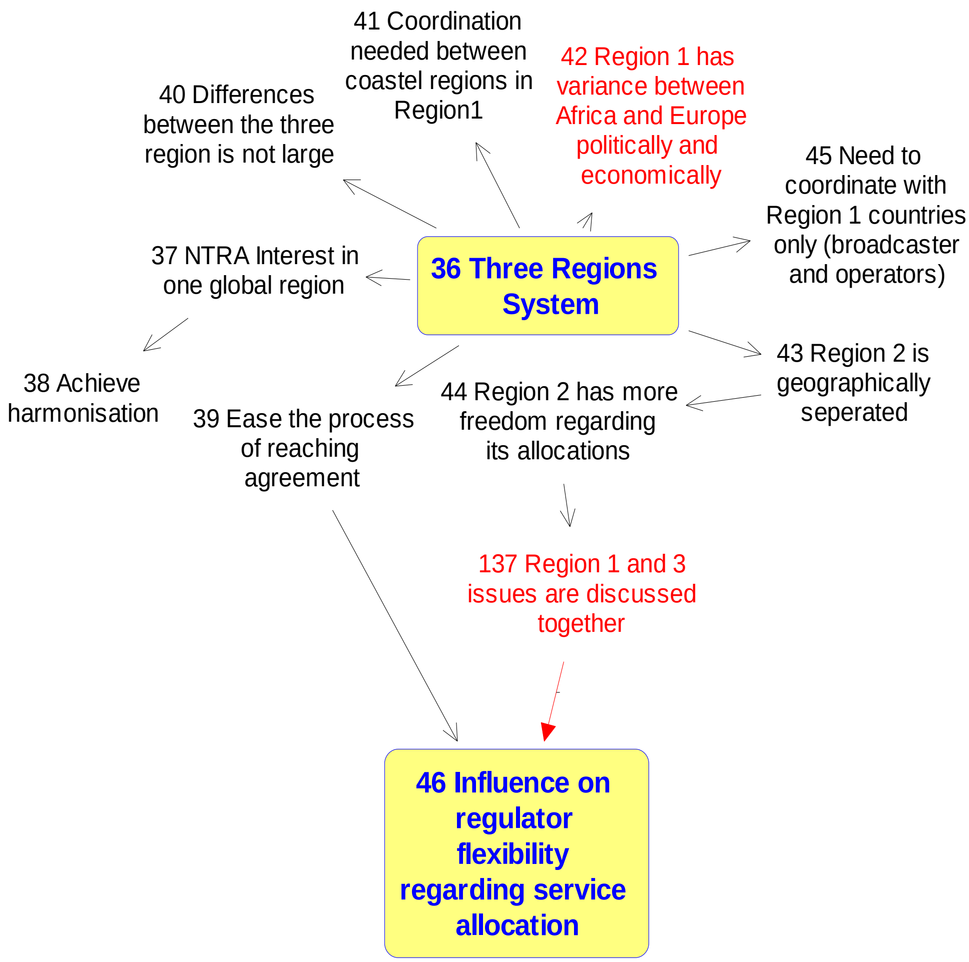

Figure 6-16: Influence of The Three Regions System on Regulator's Flexibility regarding Service Allocation in Egypt

The perceptions on the three regions system in Egypt in Figure 6-16 show that NTRA is interested in having one region instead of three (concept 37) for the purpose of global harmonisation (concept 38). Regarding the influence on flexibility, being close by region 3 is restricting region 1 decision where Egypt lies. On the other hand, having regions facilitates reaching agreement on service allocation within each region. **These observations imply that NTRA is constrained in general by the proximity of region 3 to region 1 while having the advantage of reaching decisions easily within region 1 regarding service allocation.**

6.9.2 UAE

In general, interviewees from TRA envisioned the three regions system as a political division rather than technical one that is related to competition issues between the regions and that is hard to be changed. This is the reason why higher bands have global harmonisation. In addition, the three regions system was perceived as a restriction against global harmonisation. Another difficulty in region 1 is the large number of regional organisations (ASMG, ATU, CEPT, and RCC) and sub-regional groups such as Gulf Cooperation Council (GCC) and West Africa. It was also perceived that the steps to eliminate regions are to support harmonisation between regions as much as possible similar to the case of the 700 MHz.

The broadcaster group in the UAE explained that UAE must coordinate with its neighbouring countries from other regions as their borders are close to the UAE. It was also mentioned that the broadcaster prefers to be in separate region with the Gulf and Arab countries. Additionally, while one of the mobile operators did not have specific position towards the three region system explaining that it does not have international operations, the other mobile operator called for harmonisation and for one global region if possible. A concern was raised by one interviewee from the mobile operator regarding the regions system, which is the difficulty to apply the same rules to the whole region. Another issue that was raised against the division between region 1 and 3 is regarding the GE-06 plan, which focused on region 1, but then Iran wanted to join.

Regarding the influence on regulator flexibility with respect to service allocation, an issue was raised which is that UAE have neighbours from other regions, which cause problems if the allocation is different. An example of that is the restriction on the 700 MHz deployment for mobile in UAE because of the use of high power transmission broadcasting service in the 700 MHz in UAE's neighbouring countries.

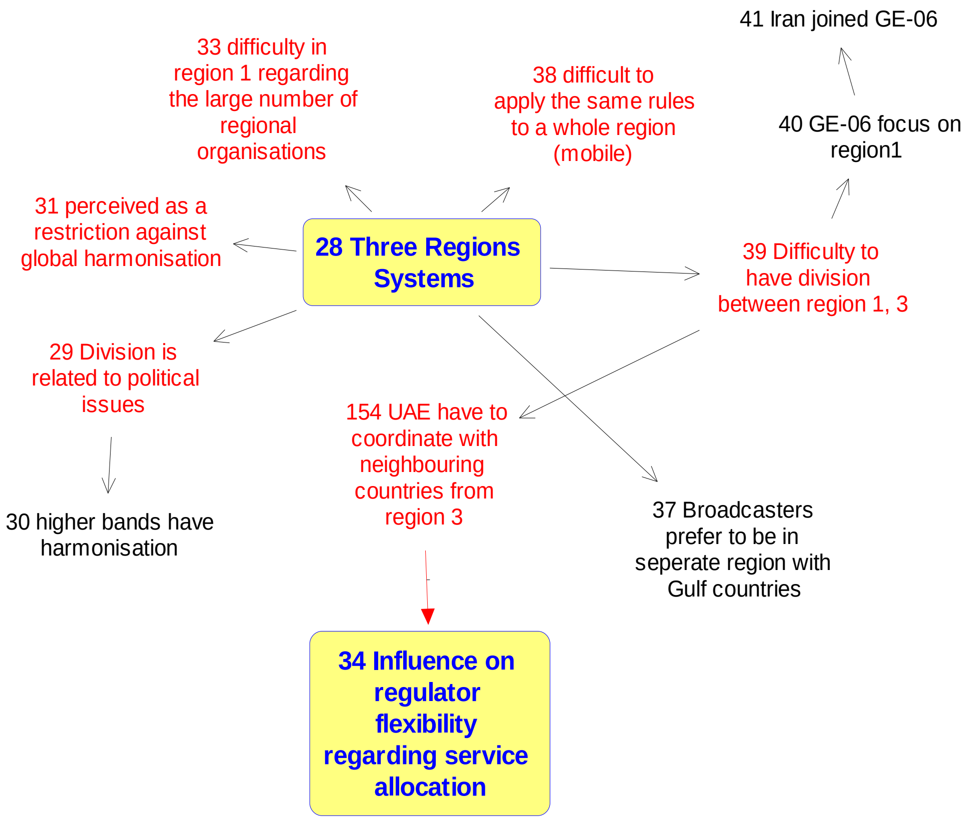

Figure 6-17: Influence of The Three Regions System on Regulator's Flexibility regarding Service Allocation in UAE

As shown in Figure 6-17, TRA of UAE shares the same view with NTRA of Egypt that the three regions system is against global harmonisation (concept 31). However, it seems that TRA is more vulnerable to the restriction imposed from the proximity between regions 1 and 3 due that UAE is close to region 3. In particular, Iran is near to UAE and this is one of the reasons why Iran joined the GE-06 plan although it was concerned with Region 1. **Therefore, the three regions system has an element of restriction on TRA due to proximity of UAE to region 3.**

6.9.3 International Interviewees

There were two distinct views regarding the influence of the three regions system on countries' flexibility. On the one hand, four interviewees out of seventeen shared the views that there is no restriction at all. More specifically, by having three regions, it is easier to decide on a flexible allocation. This is due to the fact that the division of the three regions is less problematic to decision-making process. In other words, the division makes it possible to get an agreement in one region instead of three. It was also felt that the division is unavoidable due to the differences of countries' interests and requirements, which may be related to geographical situation (e.g. Tropical countries need C band because of propagation conditions). Therefore, such division could provide flexibility to these countries.

Thirteen interviewees consider that the three regions system accommodates element of restriction. More specifically, it was argued that the three regions are in practice six regions (CEPT, ATU, ASMG, RCC, CITEL, APT) and that for region two and three, flexibility is much better than region one where you have four smaller regional groups that all have to agree (CEPT, ATU, ASMG, RCC). In addition, countries that are on the borders have restriction on their flexibility (e.g. Iran, and Saudi Arabia). Also, one interviewee argued that individual countries are constrained by the region they lie in in terms of where to buy their equipment.

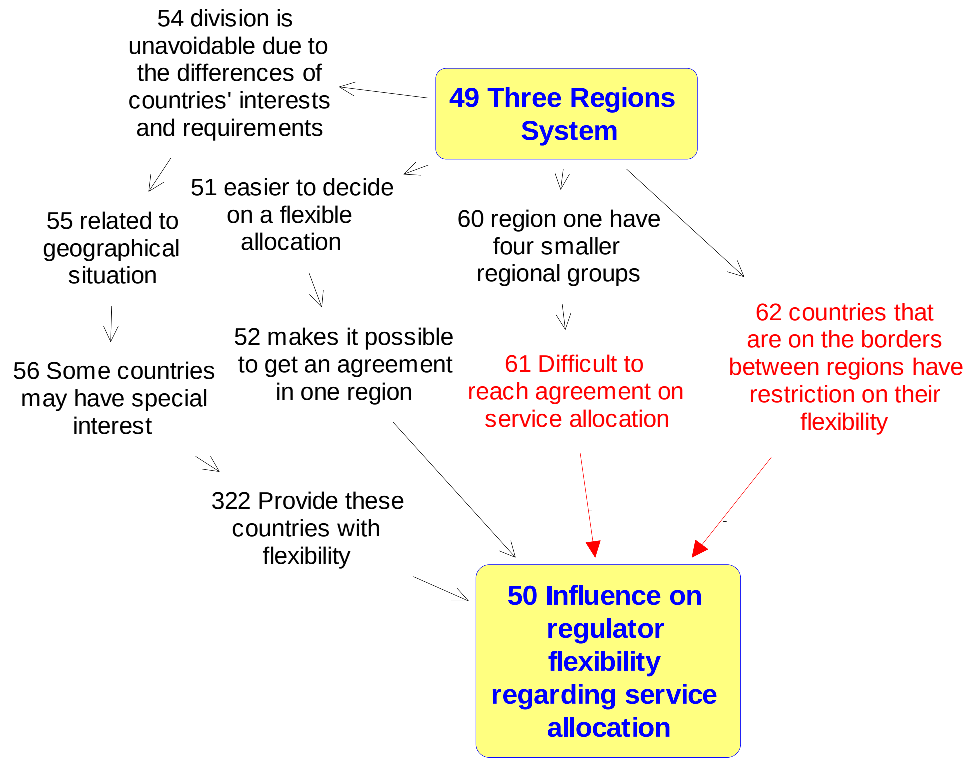

Figure 6-18: Influence of The Three Regions System on Regulator's Flexibility regarding Service Allocation from Perspectives of International Interviewees

The causal map for the international interviewees in Figure 6-18 shows similar concepts to Egypt and UAE including the relatively easiness to reach agreement on service allocation in one region (concept 52). However, there is a difficulty in region one due to the high number of regional groups (concept 61). Mostly common with UAE and Egypt is the observation that flexibility with respect to service allocation is more difficult for countries on borders between regions (concept 62). The division provides flexibility to countries with special interest (concepts 54, 55, 56, 332).

This leads to a general conclusion that while the three regions system provides more flexibility within each region to decide on service allocation and to countries that have special interests in terms of service allocation, there is more difficulty for region 1 countries due to the high number of regional groups in the

region. In addition, flexibility for these countries that lie on the borders between regions is negatively influenced.

6.10 *Conclusions*

The examination of the perceptions of the Egyptian interviews showed that NTRA is mostly against the concept to keep control over the market and to have protection against interference while recognising the merits of the concept in term of facilitation of allocation process and retrieving spectrum from the broadcasters. The TRA of UAE interviewees shared similar views with NTRA of Egypt. Concerns associated with service flexibility include global harmonisation and cross-border interference considering the small size of the UAE and the propagation characteristics in the Gulf area.

Regarding the applicability of service flexibility, it seems that there are practical restrictions against introducing the concept in Egypt including the legal framework and status of existing operators. Mobile and fixed operators' licenses are not radiocommunication service neutral. The broadcasters have exclusive access to the broadcasting spectrum. Licenses in UAE are technology neutral but not radiocommunication service neutral and there are many restrictions that prevent applying the concept in UAE. Broadcasting services are provided via the broadcasters only.

The analysis of the case study of Egypt with regard to service allocation flexibility has shown that NTRA has tendency to follow the RR due to the advantages of the service harmonisation in the RR, deficiencies of the ITU-R in interference resolving, and not being leader in terms of technology development. Moreover, the RR are important for Egypt which has several neighbours in order to have protection against interference considering the lack of effective interference resolution procedures from the ITU-R.

Regarding the interaction with the RR with respect to NTRA flexibility on service allocation, there are different accommodating and restrictive elements regarding the interaction with the RR with respect to NTRA flexibility on service allocation. On the one hand, following the RR is perceived to be voluntary while not causing interference. Additionally, the concept of having the spectrum allocated to more than one service accommodates the concept of service flexibility. On the other hand, the RR are not in conformity with the concept of service flexibility in principle as the RR determine services allocation in each band and separate between services.

The a priori planning concept for broadcasting does not restrict NTRA flexibility except at borders. Nevertheless, there are deficiencies in the a priori planning process for the broadcasting service from the perspectives of the Egyptian interviewees in terms of not taking into account mobile allocations in the 700 MHz and 800 MHz bands, and advancement in broadcasting technologies. The broadcasting requirements agreed by the RRC-06 conference for NTRA could be considered as a constraint because some of them were not needed.

Decision making procedures do restrict NTRA flexibility regarding service allocation. In particular, they are not considered to be restriction due to the flexibility of the main allocation principles in the RR and also due to the relatively slowness of Egypt advancement in deploying new technologies. With respect to footnotes, they provide flexibility to NTRA considering the difficulty to introduce footnotes due to the need of coordination with neighbouring countries. Furthermore, while other's countries footnotes provide flexibility to them, they could restrict NTRA flexibility.

The use of MIFR could restrict NTRA flexibility and Egypt's neighbouring countries as well. However, restriction accommodated in MIFR does not have an effect on NTRA in practice, as these registered assignments by other countries would not stop Egypt from deploying a service. Additionally, Egypt is constrained in general by the proximity of region 3 to region 1 while having the advantage of reaching decisions easily within region 1 regarding service allocation. Nevertheless, having regions facilitates reaching agreement on service allocation within region 1.

Regarding the case study of UAE, TRA has tendency to follow the RR for several reasons including avoiding interference, introducing new services, creating harmonisation, and protecting TRA services. Moreover, there are different flexible and restrictive elements regarding the interaction with the RR with respect to TRA flexibility on service allocation. Firstly, there is flexibility in the RR by deviating from it as long as not causing interference and by having multiple allocations in the same spectrum. Nonetheless, the RR could be restrictive in case there is urgent need to introduce specific service allocation in the UAE while it is not allocated in the RR so that TRA has to wait for next WRC.

With respect to the a priori planning concept, TRA has the view that there is a need to revise the GE-06 requirements due to the emerging need for additional mobile allocations, enhancements in broadcasting technologies, and low broadcasting views. Furthermore, the concept of a priori planning is of a great important especially for a small country such as UAE. TRA is also in favour of co-primary allocation for other services other than broadcasting in the UHF band to provide more flexibility considering that the GE-06 plan can provide sufficient protection for broadcasting and mobile if there is a co-primary allocation.

The decision-making procedures do not restrict TRA flexibility regarding service allocation considering that the agenda of the conference is flexible. Besides, footnotes are considered as a tool for flexibility and harmonisation in the same time for UAE. While TRA may not succeed in adding particular footnote, this does not stop TRA from deploying that specific service allocation. Moreover, using MIFR by TRA would not be considered as restriction considering that there is no interest in applying service neutrality in UAE. However, TRA is restricted by other countries' registration in the MIFR especially those countries that do not have actual deployment. Moreover, TRA is more vulnerable to the restriction imposed from the proximity between regions 1 and 3 due to the fact that UAE is close to region 3.

The international interviewees perspectives reveal that the RR restrict national regulators' flexibility regarding service allocation only towards neighbouring countries unless a country reaches an agreement with these countries, and also in bands where special radiocommunication services operate. An element of restriction is that new radiocommunication service allocation should be introduced through WRC because such new allocation may cause interference if implemented to neighbouring countries. In addition, flexibility could be provided via having multiple services allocations in the same band or through having another allocation on secondary basis, via footnotes, or according to article 4.4.

The concept of a priori planning mostly does not restrict regulators' flexibility regarding service allocation. However, there could be restriction in case there is a need to get the approval of neighbouring countries or to have another planning conference to modify the plan. More specifically, the envelope concept inherited in the GE-06 plan allows using the plan for other radiocommunication services. Additional flexibility could be achieved via additional allocation in the UHF band.

The decision-making procedures accommodate several elements of flexibility. In particular, every WRC is sovereign in terms of modifying its agenda, and the procedures are determined and agreed by the participant countries themselves. On the contrary, procedures could be used by countries or companies to block the others, and could be considered as a restriction in terms of timing of new allocation introduction.

Footnotes could provide flexibility in different ways but may restrict other countries' flexibility considering that footnotes could only be introduced or modified at WRCs. Also, while MIFR is not in line with radiocommunication service flexibility in principle as there should be a specific declared radiocommunication service, MIFR is not used much in practice. However, other countries assignments in MIFR could restrict country's flexibility considering that some of these assignments may not exist in practice. Besides, registered assignments in the MIFR could be changed at any time without waiting for a WRC.

The three regions system provides more flexibility to each region countries to decide on service allocation and to countries that have special interests in terms of service allocation. More specifically, it is relatively easier to reach agreement on service allocation in one region. However, there is more difficulty for region 1 countries due to the high number of regional groups in the region. Flexibility with respect to service allocation is more difficult for countries on borders between regions. Table 6-1 below presents a summary of the research findings of this chapter.

Case Study	**Main Conclusions**
Egypt	• Interviewees from Egypt are mostly against the concept of service allocation flexibility due to concerns related to interference, global harmonisation, and increasing spectrum fees while acknowledging the merits of the concept in terms of reducing spectrum scarcity. • There are several restrictions against introducing the concept in Egypt. Mobile and fixed operators' licenses are not radiocommunication service neutral. Broadcasters have

	exclusive access to the broadcasting spectrum. • NTRA has tendency to follow the RR. • There are different flexible and restrictive elements regarding the interaction with the RR with respect to NTRA flexibility on service allocation. • The a priori planning concept for broadcasting does not restrict NTRA flexibility except at borders. • The decision-making procedures do not restrict NTRA flexibility regarding service allocation. • Footnotes provide flexibility to NTRA considering the difficulty to introduce footnotes and constraints from other countries' footnotes. • The use of MIFR accommodates element of restriction, however, it does not confine NTRA in practice. • Egypt is constrained in general by the proximity region 3 to region 1 while having the advantage of reaching decisions easily within region 1 regarding service allocation.
UAE	• Interviewees from UAE are mostly against the concept of service allocation flexibility due to concerns related to interference, global harmonisation, and increasing spectrum fees considering the small size of the UAE and the propagation characteristics in the Gulf area. • There are several restrictions that prevent applying the concept in UAE. Licenses in UAE are not radiocommunication service neutral. Broadcasting services are provided via the broadcasters only. • TRA has tendency to follow the RR. • There are different flexible and restrictive elements regarding the interaction with the RR with respect to TRA flexibility on service allocation. • The concept of a priori planning for broadcasting has elements

	of restriction and flexibility. TRA is in favour of less exclusive broadcasting allocation in general to provide more flexibility. • The decision-making procedures do not restrict TRA flexibility regarding service allocation. • Footnotes provide flexibility to TRA in terms of service allocation considering that the failure to add a footnote does not restrict TRA from introducing a service. • While the use of MIFR by TRA is not considered as restriction, the misuse of MIFR by UAE neighbouring countries may restrict TRA flexibility. • The three regions system has an element of restriction on TRA due to proximity of UAE to region 3.
International Interviewees	• The RR restrict national regulators' flexibility regarding service allocation only towards neighbouring countries unless a country reaches an agreement with these countries, and also in bands where special radiocommunication services operate. On the other hand, flexibility is already provided by the RR through different measures. • The concept of a priori planning mostly does not restrict regulators' flexibility regarding service allocation. However, there could be restriction in case there is a need to get the approval of neighbouring countries or to have another planning conference to modify the plan. • Decision-making procedures accommodate several elements of flexibility but they could be used by some of the countries to restrict others and they could be restrictive in terms of timing. • Footnotes could provide flexibility in different ways while may restrict other countries' flexibility considering that footnotes could only be introduced or modified at WRCs. • While MIFR is not in line with radiocommunication service flexibility in principle as there should be a specific declared

	radiocommunication service, MIFR is not used much in practice. On the other hand, other countries assignments in MIFR could restrict country's flexibility considering that some of these assignments may not exist in practice. • While the three regions system provides more flexibility to each region countries to decide on service allocation and to countries that have special interests in terms of service allocation, there is more difficulty for region 1 countries due to the high number of regional groups in the region. Moreover, flexibility on these countries that lie on the borders between regions is negatively influenced.

Table 6-1: Summary of Research Findings for the Concept of Service Allocation Flexibility

7 Technology Neutrality

7.1 *Introduction*

This chapter handles the second research question concerned with the technology neutrality concept. Section 7.2 and Section 7.3 start with exploring the perceptions of the interviewees from Egypt and UAE on the concept and discusses its applicability as well in these two countries. Section 7.4 then explores the interaction between the IMT standardisation process and national spectrum management policies with regard to decisions related to technology neutrality and technology selection from the perspectives of the Egyptians, UAE, and international interviewees. Following that, Section 7.5 and Section 7.6 address the influence of IMT standardisation and IMT spectrum identification on technology generations' definitions and on regulator's decision regarding technology selection respectively. Section 7.7 ends with key findings.

7.2 *Perception on the Concept of Technology Neutrality*

While the research focuses on the interaction between the international regime and national policies regarding the concept of technology neutrality, it is useful to examine the perceptions of Egypt and UAE interviewees on the concept per se in order to find out factors that may influence the adoption of the concept other than those related to the international regime.

7.2.1 Egypt

Advantages of the concept from NTRA interviewees' perspective include providing flexibility for operators to select any technology that can provide the service and also enabling NTRA not to be biased towards specific technology. On the other hand, it was mentioned that neutrality may lead to the introduction of a proprietary technology so that particular manufacture could monopolise the market. Moreover, it was explained that if NTRA allows specific proprietary technology and then NTRA introduces another license for another technology, this may lead to fragmentation of the market and decrease competition. Other concerns include the potential influence on national security, and that neutrality needs a legal framework and rules for it not to cause problems afterwards.

The operators' perspective on technology neutrality was also clarified during the interviews. On the one hand, technology neutrality has the advantage of not being in favour of a specific technology or vendor. Operators have the flexibility to choose any technology. Besides, limiting technologies may restrict innovation in technology development. On the other hand, it was expressed that having nearby operators deploying different technology could be not feasible technically. Operators may end up with a technology that is not widely used around the world, and neutrality may negatively influence roaming.

On the issue of having flexible duplex mode, NTRA interviewees' perception was that it would lead to inefficient utilisation of the spectrum. For instance, if one operator is assigned TDD block and the other block was not assigned to anyone, it would be left unused. In addition, it may complicate the management of the spectrum for the regulator. From the operators' perspective, one view is that having flexible bands would lead to increase in the number of the bands to be supported by the handset, which would lead to more complexity and higher prices.

7.2.2 UAE

Interviewees from TRA of UAE explained that there is no issue with technology neutrality for the same service on the condition that no interference is caused to neighbouring countries or adjacent operators. When discussing the issue of having interference from neighbouring countries using incompatible technologies, it was explained that this may be the case with neighbouring countries, which adopt technologies such as IDEN. However, it was also clarified that due to the geographical nature of scattered vacant areas, interference probability is low. In addition, UAE has agreement with neighbouring countries on overspill between the different technologies (e.g. UMTS and GSM in the 900 MHz).

The operators' perception on the concept of technology neutrality was that it is important to provide the latest technologies. As expressed by one interviewee "*The nature of people is that they like racing. They want to have what others do not have*". In addition, neutrality provides flexibility to operators in terms of dividing the traffic between the used technologies according to the customer requirements without returning to the regulator. On the other hand, there were concerns expressed by the operators that neutrality may have the disadvantages of higher risk and interference and it put additional responsibility on the operators. Another limitation is related to the licence fees, which are different in cases where the operator wants to replace a technology like WiMAX in the 3.5 GHz with LTE.

The UAE TRA views on the concept of flexible duplex mode are that it may lead to interference and may also negatively influence competition as some operators may manage to get FDD blocks while other use TDD blocks. Therefore, it was argued that it is better to choose the optimum arrangements from the beginning. Mobile operators' perceptions were that as long as there is protection and harmonisation, the concept is accepted, as it will provide more flexibility.

7.3 *Applicability of the Concept of Technology Neutrality*

Another related aspect of the concept of technology neutrality is whether Egypt and UAE regulators have introduced and applied the concept in practice and to what extent. This is also needed in order to highlight other influential factors that may not be related to ITU-R IMT.

7.3.1 Egypt

Six interviewees from NTRA explained that the regulator is not applying technology neutrality in fully and that operators are limited to the technologies specified in their licenses. In particular, licenses accommodate specific services, technologies, and frequencies. However, operators can use any specified technology in their license in the assigned frequency band for them upon obtaining approval from the regulator. It was also indicated that NTRA is restricted by international agreement set by the World Trade Organisation (WTO) Agreement on Basic Telecommunications Services (BTA), which does not allow countries to select specific technology. Therefore, NTRA tends to compromise between the two trends of being technology neutral and technology specific.

More specifically, it was also clarified that while NTRA tends to be technology neutral as much as possible, however, it is important to be in conformity with international organisations such as the ITU and IEEE. This is the reason why mobile operators licenses Request for Proposal (RFP) refer to some of these organisations. As clarified by one of the interviewees from NTRA "*As long as the technology is approved by certain organisation or it adopts a certain standard it's OK for us to deploy it in Egypt*". In addition, standardisation importance was related to issues such as compatibility, roaming, availability and price of handsets.

From the operators' perspective, it was confirmed that their licenses are restricted to specific technologies. However, it was also clarified that NTRA was more restrictive before the 3G licenses and spectrum re-farming was not allowed but after that, NTRA provided flexibility where any operator can provide any technology specified in the license in whatever spectrum mentioned in the license upon acquiring approval from NTRA.

Some of the interviewees focused on the case of TE, which does not have a mobile license while having several frequency bands that are currently used for fixed wireless services although they could be used for mobile service. In particular, TE has frequencies in the 800 MHz that are used for fixed service by any release of CDMA technology, and has also frequencies in the 1800 MHz that are used for DECT technology for WLL service. Senior interviewee from TE explained that adopting the US-based standard CDMA was based on the availability of the spectrum.

It is worth mentioning that during the interviews, some specific circumstances related to the Egyptian market that may influence the need for technology neutrality were revealed. Firstly, it was expressed by interviewees from mobile operators that operators face shortage in spectrum due to the special nature of Egypt where there is high density in small areas. Secondly, the 2G traffic is high which reduces the need for re-farming the spectrum bands used for 2G services in the 900 and 1800 MHz spectrum bands. This is also related to the handsets and network equipment, which do not operate in all bands (e.g. There is no equipment to provide 2G services on the 2 GHz band).

7.3.2 UAE

The interviews showed that TRA is neutral in terms of mobile technology and that there have been already several cases of re-farming (e.g. UMTS in the GSM bands) on the condition that there is no interference on operator in adjacent band. Such re-farming should not influence the channel arrangement. However, operators are required to inform TRA before changing the technology. This is due that some technologies changes may have negative effects on existing technologies in adjacent bands. For instance, deploying LTE in bands previously used by GSM (e.g. 900 MHz) may require guard bands or protection criteria with the other operators operating GSM in the adjacent bands.

It was also clarified that WiMAX is used in the UAE but as a fixed temporary solution for areas not covered by the fibre network. Operators cannot use WiMAX , as a mobile technology as the fees for fixed service is lower than the fees for mobile service. One point that was explained by one interviewee from TRA is that one of the motivations to apply technology neutrality is to overcome the monopoly of Etisalat. In particular, Etisalat was the monopolist operator before the establishment of TRA and they have the power to provide any service. Therefore, TRA applied technology neutrality to handle such issue.

From the operators' perspective, one interviewee argued that TRA normally considers standardised technologies. Otherwise, the technology needs to be studied. In addition, it was confirmed that there is technology neutrality based on negotiation with TRA due to need for measures such as guard bands between the different technologies. Moreover, operators' licenses do not mention particular technologies, and fees are the same for the same spectrum bands regardless of the used technology. However, fees are different according to the spectrum bands and whether it achieves large coverage areas (e.g. higher bands have less fees).

Interviewees from Etisalat clarified that the company was established before TRA and at that time Etisalat was the regulator and there was no license for Etisalat. Upon the establishment of TRA, Etisalat was awarded one license that provides a general framework to provide all telecom services in the UAE (fixed, mobile, and broadband). However, such license does not accommodate conditions associated with the spectrum use. Instead, these conditions are stated in the TRA's spectrum policy.

7.4 *Influence of IMT Standardisation on Technology Selection and Technology Neutrality*

This section is the first to examine the second research question in general. In particular, it investigates the influence of IMT standardisation on technology selection and neutrality on the national level.

7.4.1 Egypt

One issue that was discussed with the Egyptian regulator is how important for a mobile technology to be one of the IMT standards in order to be adopted in Egypt. It was evident during the interviews that being part of the IMT family gives a great support to the technology and is an essential factor in selecting a technology. However, it was also indicated that it is possible for non-IMT technology to be introduced in the Egyptian market if it has a strong business case. In other words, it is not a strict condition for a mobile technology to be from the IMT family in order to be accepted by NTRA. Further reflections on IMT were mentioned during the interviews with the regulator such as that NTRA is neutral towards the different IMT technologies and is not in favour of a particular technology. However, the mobile operators' licenses contain a list of specific technologies.

It was also explained by interviewees from NTRA that being one of the IMT standards is necessary but not sufficient. In other words, worldwide deployment, cheap handsets, compatibility with existing technology, and global roaming are also important factors in addition to being approved by the ITU-R. Other issues are considered while taking a decision on a particular technology such as national security. On the influence of IMT standardisation on NTRA approach to technology neutrality, one interviewee from the regulator argued that it could support the regulator decision to apply technology neutrality. Moreover, one senior interviewee from TE argued that it enables the regulator to walk away from being technology specific by inviting them to use the generic term of IMT.

During the interviews with the operators, it became clear that most of the interviewees are not aware of the activities related to IMT in the ITU-R. This is due to the fact that the operators' decision on technology is dependent on the vendors who are involved in such activities. Meanwhile, the operators are more concerned with the discussion related to the spectrum bands over which mobile could operate. Moreover, it was mentioned that worldwide commercial adoption is important and ITU process is going in parallel if vendors are pushing for something. Figure 7-1 below represents a causal map of the different views.

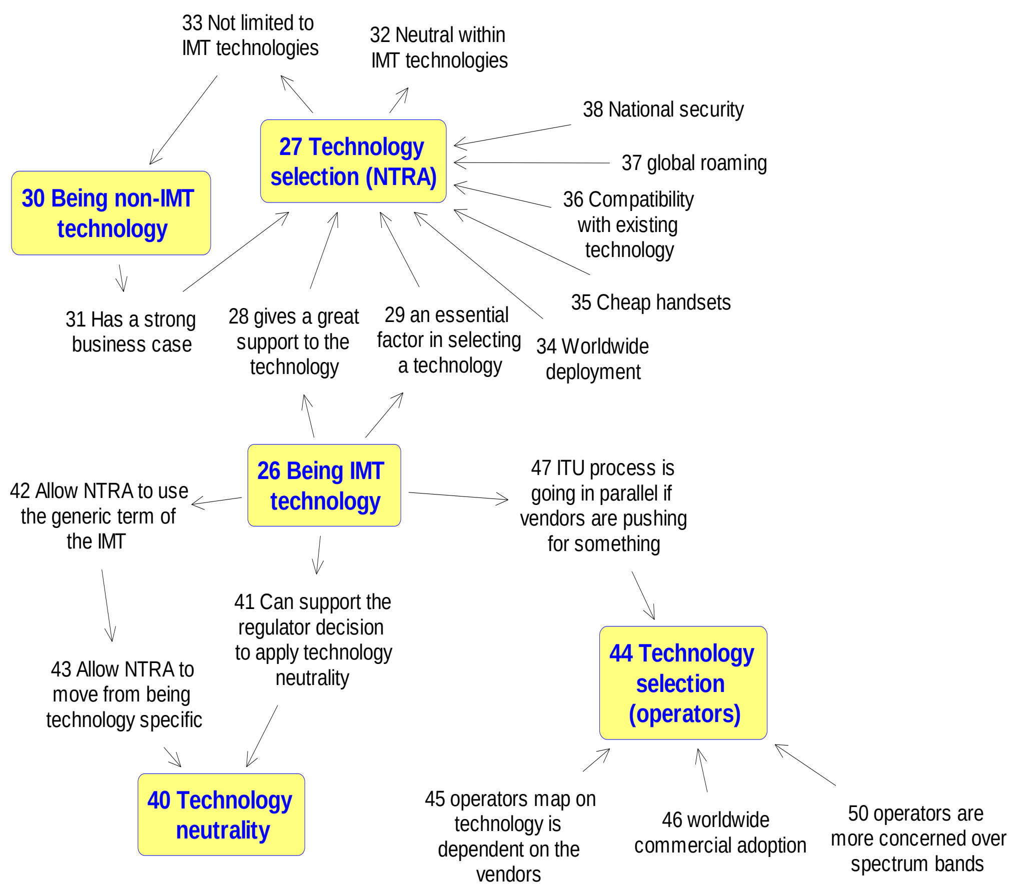

Figure 7-1: Influence of IMT Standardisation on Regulator and Operator Decision on Technology Selection and Technology Neutrality in Egypt

The causal map in Figure 7-1 reveals interesting observation regarding the influence of IMT standardisation on regulator's decision with respect to technology selection. More specifically, while being part of the IMT family is an important factor in decision on applicant technologies (concepts 28, 29), there are other factors that are important in order to accept a technology by NTRA (concepts 34, 35, 36, 37, 38). This was evident in concept 33 which reveals that NTRA decision on technologies is not limited to IMT technologies a and that a non-IMT technology could be accepted if it has a strong business case (concept 31). NTRA is neutral within the IMT family of standards (concept 32).

For operators, being IMT technology is not a big plus as it is perceived to be a complementary issue if a technology already has the support from the industry (concept 47). On the other hand, there are other factors that are considered to have influence on operators' decision on technology selection (concepts 45, 46, 50). On the influence of IMT standardisation on regulator's decision on applying technology neutrality, this was perceived to have positive influence in terms of supporting NTRA decision to apply technology neutrality and to allow NTRA to move from being technology specific (concepts 41, 42, 43).

These observations imply that for NTRA, being part of the IMT family of standards provides support to the applicant technologies. However, this is not mandatory or sufficient to accept a technology by NTRA. For national operators, being IMT technology does not have a significant influence on their decision regarding adopting a particular technology. Furthermore, IMT standardisation has a positive influence on NTRA of Egypt regarding technology neutrality.

Appendix XI provides examples of the application of technology selection in Egypt.

7.4.2 **UAE**

On the influence of IMT on regulator decision regarding technology selection, interviewees from TRA explained that the technology decision comes from market rather than the ITU nor the regulator. Moreover, it was pointed out that mobile standardisation activities are not limited to IMT. This is in addition that TRA applies technology neutrality. On whether it is mandatory for a technology to be from the IMT family to be introduced in UAE, it was explained by interviewees from TRA that it is not necessary. In particular, TRA is technology neutral and a mobile technology does not to have to be one of the IMT standards.

Regarding the possibility to introduce non IMT technologies such as IBurst, it was explained that TRA prefer to go for the recognised and standardised technologies under the umbrella of the ITU and that this is the main preference before going to other technologies which are not identified as the IMT. More specifically, having a technology from the IMT family ensures the compatibility and coexistence in the market. On whether having IMT standards encourage TRA to apply technology neutrality, one interviewee from TRA highlighted the issue that being technology neutral is against having defined air interfaces such as IMT. On the other hand, one other interviewee from TRA argued that the IMT technologies give a variety for those who are willing to utilise any technology.

From the operators' perspective, it was found that both operators, Etisalat and DU, follow the activities of ITU-R WP 5D. On the influence of IMT on technology selection, it was indicated that neutrality implies selecting technologies even if outside of IMT as operators would ultimately adopt the most feasible technology from economic and technical point of view. In addition, it was explained that the operators' licenses provide them with flexibility, and therefore, referencing the license to a specific standard would restrict the operators. Standards from organisations such as 3GPP and ITU-R are taken into consideration. Operators' strategy is mainly influenced by the availability of solutions from the vendors.

On whether IMT standards should be mandatory, it was explained that this is not necessary. As expressed by one interviewee from the mobile operators "*I do not restrict myself with the ITU, because it serves me. The ITU is the one who serves*". Furthermore, one interviewee from one of the mobile operators explained that there may be indirect influence from ITU standards on operators as the operators' licenses refer to the regulatory framework of UAE, which refers to the ITU standards.

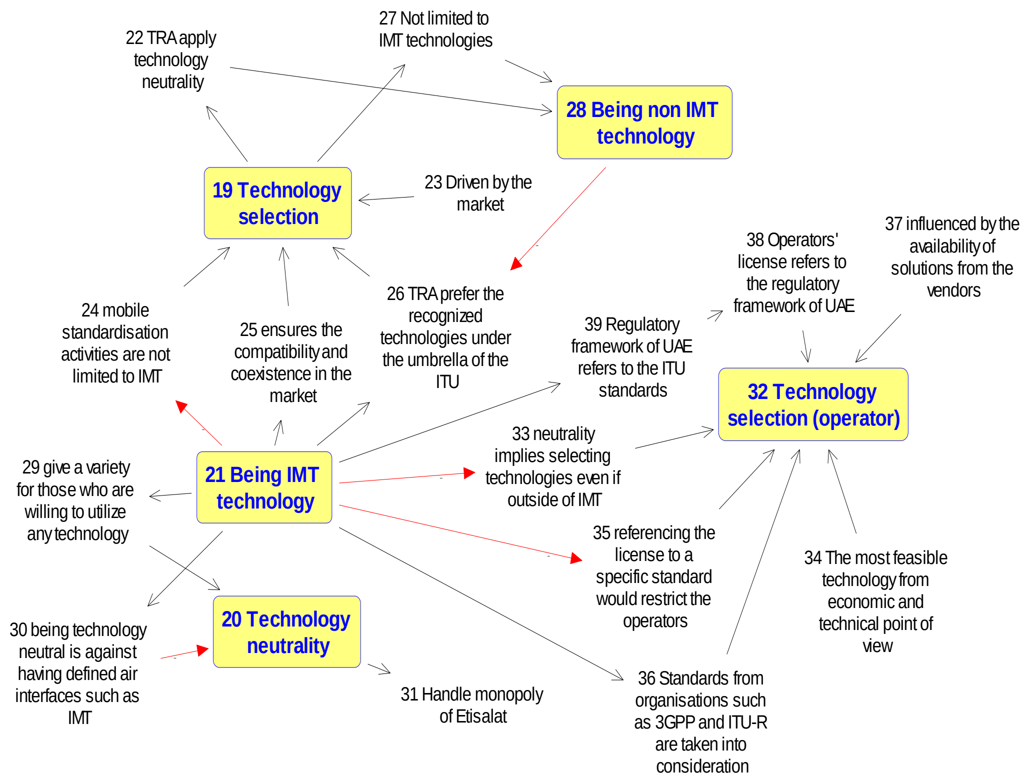

Figure 7-2: Influence of IMT Standardisation on Regulator and Operator Decision on Technology Selection and Technology Neutrality in UAE

The causal map in Figure 7-2 revealed that while TRA is technology neutral (concept 22) and not limited to IMT technologies (concept 27), TRA preferences are towards recognised technologies by the ITU (concept 26). This is due that being IMT technology ensures compatibility and coexistence (concept 25). From the operators' perspective, being limited to IMT technologies is restrictive to them. However, their licenses refer indirectly to the IMT standards (concepts 38, 39). Regarding the influence of IMT standardisation on regulator decision on technology neutrality, there are different influences. On the one hand, the IMT family of standards gives a variety of technologies to select from (concept 29). On the other hand, being limited to IMT standards is not considered to be fully neutral (concept 30).

This leads to a general conclusion that for TRA of UAE, being part of the IMT family is not mandatory but preferable. For national operators, being limited to IMT technologies is restrictive but there is indirect influence from the IMT standardisation on them. Furthermore, IMT standardisation has positive and negative elements in terms of influence on TRA of UAE regarding technology neutrality.

Appendix XII provides an example of the application of technology selection in UAE.

7.4.3 International Interviewees

Thirty three interviewees commented on the IMT standardisation influence on technology selection. On the one hand, a view shared by twenty one interviewees is that being part of the IMT family has a positive influence on the regulators' decision regarding technology selection to be from the IMT standards. This is due to several reasons. Firstly, IMT could be considered as an encouragement for administrations to adopt internationally accepted standards. It was also argued that it is in the interest of a country to comply with IMT in order not to lose the benefits of economies of scales and roaming. Moreover, IMT technologies are recommended by the ITU-R in its recommendations.

Besides, being IMT is necessary to define sharing conditions with neighbouring services and indicates that the used equipment will be consistent with frequency bands and will offer backward compatibility in terms of the previous generations of equipment. One additional point is that the developing countries, which lack technical resource to judge technologies, rely heavily on the ITU-R recommendations. In these countries, it is important for manufactures to get their technologies listed in the IMT family to argue at the developing countries that it is one of the technologies that are used by the majority of the world.

One the other hand, there was a view shared by twelve interviewees that being one of the IMT technologies is not related to regulators' decision regarding technology selection for several reasons. One view is that what matters regarding the technology is to be worldwide technology with low cost handsets more than being standardised by the

ITU. For instance, one senior interviewee from the mobile industry in Africa mentioned that regulators in Africa did not know if CDMA-2000 is one of the IMT-2000 family or not but it was the vacant spectrum that attracted the vendors to deploy the technology in Africa. In addition, having a technology out of the IMT family (e.g. IBurst) depends on whether the technology is capable of solving a problem in a particular country. One senior interviewee from CEPT argued that the influence from CEPT and EC is more important than the influence of IMT in Europe.

Regarding the influence of IMT standardisation process on regulators regarding technology neutrality, twenty five interviewees commented on the issue. On the one hand, there were views shared by eleven interviewees that the IMT process has influenced positively regulators' approach towards neutrality for several reasons. Firstly, the standardisation process in ITU-R has helped the regulator to move forward to more technology neutral approach. In particular, IMT encourages regulators to have licenses that allow any IMT technology. For instance, it has encouraged the European countries to be more neutral especially at the time when they were limited to ETSI technologies and companies such as Qualcomm wanted to bring CDMA 2000 with the 3G auctions.

Furthermore, it was argued that IMT encourages regulators to have licenses that allow any technology that complies with the emission mask of IMT. In addition, the IMT concept gives regulator the possibility to a greater extent to introduce more technology neutrality regulation because there is a family of technologies which you can use. Also, although there are certain requirements and conditions for a technology to be part of the IMT family, this is not considered as a constraint. This is due that access of a technology into IMT standards is open provided those technical conditions can be met. Moreover, all technologies applied for IMT-Advanced were approved and if there is another technology comes along, they could be included on the condition they meet the requirements of IMT. As expressed by one of the interviewees "*let's not speak of IMT technologies; it's wrong. IMT is like a system objective. Any technologies which met the minimum objectives are welcomed*".

One other interviewee highlighted that while it is not mandatory to be IMT technology to be adopted, almost all technologies are part of the IMT family. Therefore, even if a regulator is neutral, most probably the winning technology would be IMT. One senior interviewee from the ITU-R argued also that the intention of the ITU-R is not to make any IMT mandatory. As explained by him "*It is because the ITU does not want to impose too many things on its membership… ITU standards are actually a catalogue of possible solutions but none of them is imposed*". In particular, countries are sovereign and there is nothing that mandates them to adopt IMT. Therefore, it is up to national regulators to reference or just acknowledge IMT standards.

One other interviewee explained that the IMT process was an open and transparent one and involved independent assessment groups. Therefore, there was no a priori judgement against any specific technology. This was supported by another interviewee who argued that the IMT process is technology neutral itself because the process has defined what the specifications of quality and performance are. Accordingly, the different technologies which can meet these objectives of performance are called IMT. In addition, even within technology neutrality, technical conditions are designed with some assumptions on the technology, which uses frequency band, which could be IMT. Regarding non-IMT technologies such as IBurst, it was pointed out that the ITU has not stopped the IBurst from operating because there was a different model for IBurst that is based on operating in particular guard bands. Instead, IBurst was not successful due to the advancement of LTE and lack of handsets rather than not being one of the IMT family of standards.

On the other hand, there was a view shared by seven interviewees that specifying technologies to be only IMT is restrictive and not neutral as it looks. As expressed in this quote "*you realize you are doing subsection of technology neutrality*". Firstly, having a defined family of standards such as IMT discourages regulators from being neutral as it would be easier to limit the access to the spectrum to the IMT family. This is one of the reasons why WiMAX fought to be one of the IMT standards. Secondly, it limits operators' ability to move to a more efficient technology when it becomes available. Thirdly, it was perceived that in cases where countries issue license for IMT, at the end of the day this prescribe that operators will use LTE.

Moreover, one interviewee argued the IMT is used to keep out the competitive technologies off that list. One other view was that introducing new radio interface into the IMT family is quite difficult and requires a lot of time and money. Although neutrality and IMT standards may be independent, the concept of IMT harmonisation is more or less against technology neutrality. IMT process may restrict innovation in new technologies. In particular, companies supporting the 4G technologies want to postpone the discussion on 5G. As expressed in this quote "*From a bipolar world of '90 you move to unipolar world, and the unipolar world is IMT and because of that the innovation has taking a little back seat…governments in the world is focused on how do we make use of this technology, how do we make it more useful to us, rather than thinking what's next*".

One third view that was shared by seven interviewees that both issues of IMT standardisation and applying technology neutrality are independent and that the influence of IMT is more on the manufactures rather than the regulators. In particular, some countries adopt technology neutrality before the beginning of the IMT standardisation activities. Instead, it is the technology development that drives the neutrality issue due to the need to deploy other advanced technologies in the same spectrum band without getting a new license every time. In support of this, one interviewee from the ITU-R commented on that "*Technology neutrality is really something which is for the regulator. This is not something that the ITU cannot mandate or orient it in any way*".

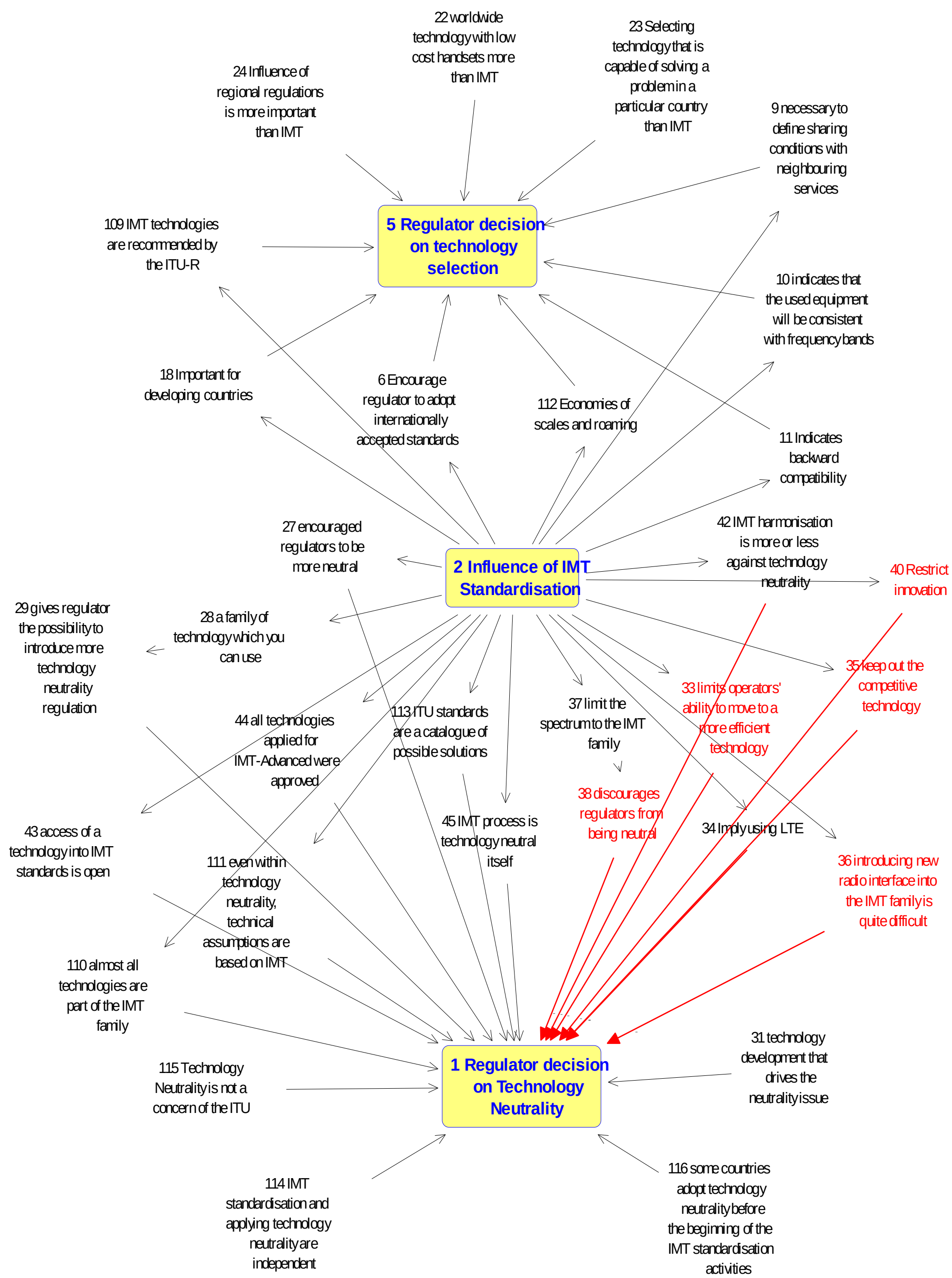

Figure 7-3: Influence of IMT Standardisation on Regulator Decision on Technology Selection and Technology Neutrality from Perspective of International Interviewees

The display of data in Figure 7-3 reveals two different views on the importance of being one of the IMT technologies on regulator decision on technology selection. While one view is that such influence is significant due to different reasons (concepts 18, 6, 112, 10, 9, 11, 109). On the other hand, there was a view that being IMT technology is a second priority to other factors that has a greater influence on regulator decision on technology (concepts 24, 22, 23).

Regarding the influence of IMT standardisation on technology neutrality, the map shows the complexity of the issue. In particular, there are elements that encourage more neutrality approach in technology selection (concepts 28.29.27), and elements that support the argument that the IMT family of standards is considered to be in conformity with technology neutrality (concepts 43, 110, 44, 111, 113, 45).

The map also highlights the contrast view that the IMT standardisation is against the concept of technology neutrality and may discourage regulators form being neutral for several reasons (concepts 37, 38, 34, 42). The map shows that the IMT standardisation process may have negative influence on operators (concept 33) and technology developers (concepts 35, 40, 36). Moreover, there is an argument that IMT standardisation does not have influence on adoption of technology neutrality (concepts 31, 114, 115, 116).

These findings highlight that being part of the IMT family of standards provides support to the applicant technologies. However, there are other elements that may have stronger influence on decisions regarding adopting a particular technology rather than being IMT technology. Moreover, IMT standardisation has positive (supportive), negative (opposing), and neutral elements in terms of the influence on regulators regarding technology neutrality according to the perception on technology neutrality and on the IMT standardisation process per se.

7.5 *Influence of IMT Standardisation on Perspectives regarding Mobile Technology Generations Definition*

One important area that the research focused on is the influence of the IMT standardisation process on the perception of mobile technology generations definition.

More specifically, it is important to examine whether the ITU-R definitions of IMT-2000 and IMT-advanced technologies have an influence on the perception and differentiation between 3G and 4G services.

7.5.1 Egypt

From the regulator perspective, it was mentioned that the definitions on 3G speeds are set according to the ITU-R definitions on IMT and according to the ITU-R recommendation. More specifically, 3G was defined to be of a speed 384 Kbps. Moreover, it was clarified that 3G and 4G are commercial brands that are not used in the ITU. One other issue related to the third license RFP is the 3G speeds perceived by NTRA at the time of the bidding. These speeds were determined to be a greater or equal to 384 kilobit per second and higher.

In general, the operators were not aware of the IMT-2000 and IMT-advanced definitions and therefore, there was no clear influence of the IMT on their perceptions on mobile technology generations. Instead, some of them are more connected to standardisation agencies such as 3GPP. On their perception on 3G technologies, it was expressed that all releases of 3G technologies are considered from the 3G family even if it achieves high speeds as long as core and access components are the same (e.g. HSDPA, HSPA, HSPA+). The same applies for 2G technologies where GSM, GPRS, and EDGE are considered as 2G technologies. On 3G speeds, one view was that it is 3.6 Mbps.

One issue that was raised during the interviews with the regulator is regarding which technology is considered to be 4G. It was explained by interviewees from NTRA that until now the NTRA do not have a clear definition for 4G. However, LTE is considered to be a 4G technology because of the data rates it provides and because of the ITU ranking. It was also mentioned that 4G speeds are set according to the ITU definitions on IMT and according to the ITU-R recommendation. There were also different views from the operators. One view by one interviewee from an operator is that 4G is where technology would accommodate artificial intelligent and where triple play (voice, data, and video) services are offered. One other view shared by 5 interviewees is that LTE is a 4G technology because it is considered as a different family rather than 3G.

More specifically, being one of the 4G technologies is not about the speed but more about being a new technology in terms of having new core and access components. This is due that the LTE technology can provide the same speeds as the ones provided by the 3G technologies in case LTE operates in a 10 MHz band. The third view by one interviewee is that LTE-advanced is a 4G technology while LTE is one of the 3G technologies. In particular, LTE-advanced is where there carrier aggregation and speeds over 300 Mbps. The fourth view, which was shared by one interviewee, is the 4G technologies usually work on specific bands (e.g. 2.6 GHz). Hence, it was perceived that operators can use their current spectrum to provide high-speed services via 3G technologies as long as they do not require new frequencies.

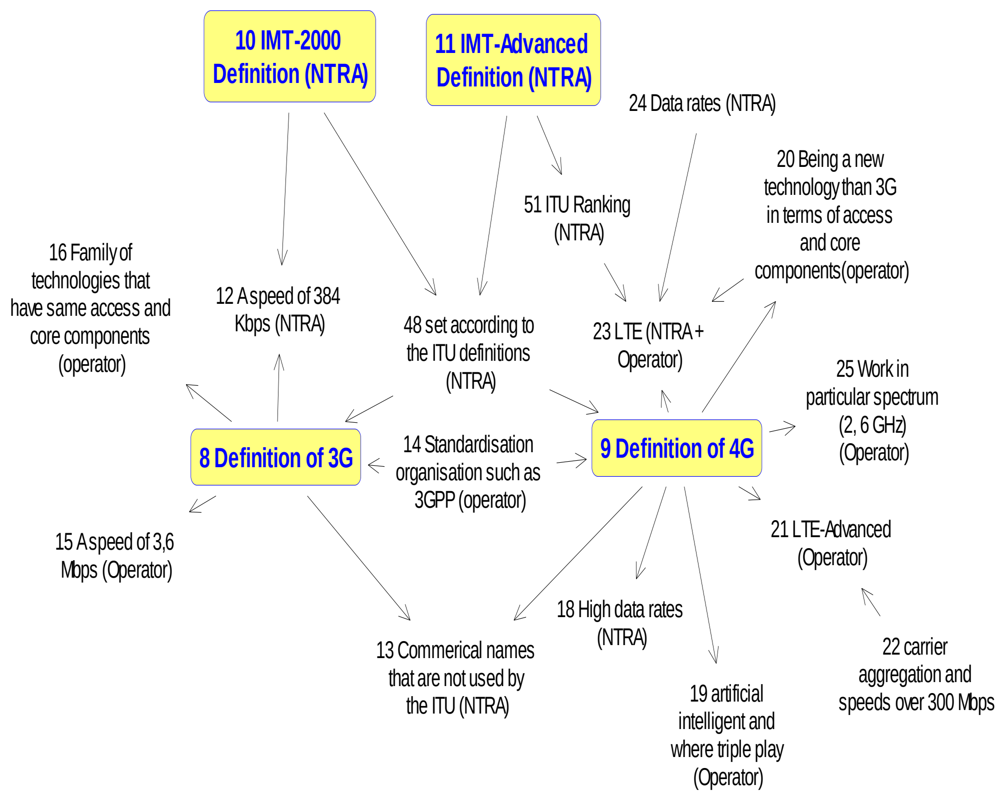

Figure 7-4: Influence of IMT Standardisation on Perspectives regarding Mobile Technology Generations Definition in Egypt

The causal map in Figure 7-4 reveals that NTRA perception on 3G and 4G definitions is influenced by the ITU definitions (concept 48). In particular, the NTRA definition of 3G is extracted from the IMT-2000 definition. Regarding the 4G definition, NTRA perceives LTE to be a 4G technology (concept 23) according to the ITU ranking (concept 51) although it is LTE-advanced that is categorised as IMT-Advanced according to the ITU-R. From the operators' perspective, there is no influence from the ITU. Instead, it is standardisation organisations such as 3GPP that have greater influence (concept 14). In addition, LTE has been perceived by NTRA and some of the operators as a 4G technology (concept 23) while LTE-Advanced has been considered by some of the operators as a 4G technology (concept 21).

Other interesting observations from the operators' views are that 4G technologies are those that are different in terms of access and core components (concept 20). That is why LTE is considered as 4G technology even if it has similar data rated to those provided by 3G technologies. **These findings show that the while NTRA perceptions on mobile technology generations definitions are largely influenced by IMT standards, there is no influence on national operators' perception.**

Appendix XIII provides examples of the Influence of IMT standardisation on perspectives regarding mobile technology generations definition in Egypt.

7.5.2 UAE

Regarding the influence of the IMT definitions on the perception on technology generations' definition, interviewees from the TRA explained that the licenses refer to the standards in general and not to the IMT as TRA tend to be more flexible. TRA does not use the terms 3G and 4G as they are used mainly for commercial purposes. Regarding the influence of the IMT on definition of 3G and 4G, interviewees from TRA stated that there is no influence. In particular, according to the ITU, 3G and 4G are not mentioned and there is no differentiation between IMT-2000 and IMT-Advanced according to the decision of RA-07. With respect to 4G, a technology could be called a 4G when there is a big step from the previous technology. One other view is that data throughput is what determines the generation. It was also explained that LTE is not an IMT advanced but starting from LTE release 10.

It was also important to get the views of the operators on the issue. Regarding the influence of IMT on generation definition, the data analysis showed no relationship between the two of them, and that operators aim to provide the latest technology and speed. Regarding the 4G technologies, one view is that 4G means LTE. One other view is that LTE-Advanced is the true 4G. Regarding the influence of IMT on 3G, 4G definition, it was perceived that it has an influence from the harmonisation rather than definition viewpoint. In particular, spectrum is identified to IMT, whether it is IMT-2000 or IMT-advanced. One interviewee from the mobile operators argued that while the ITU-R defines targets for IMT standards, the market implementation is something different and is driven by people needs even if it has nothing to do with the standard. The causal map in Figure 7-5 below represents the different views of TRA and the operators.

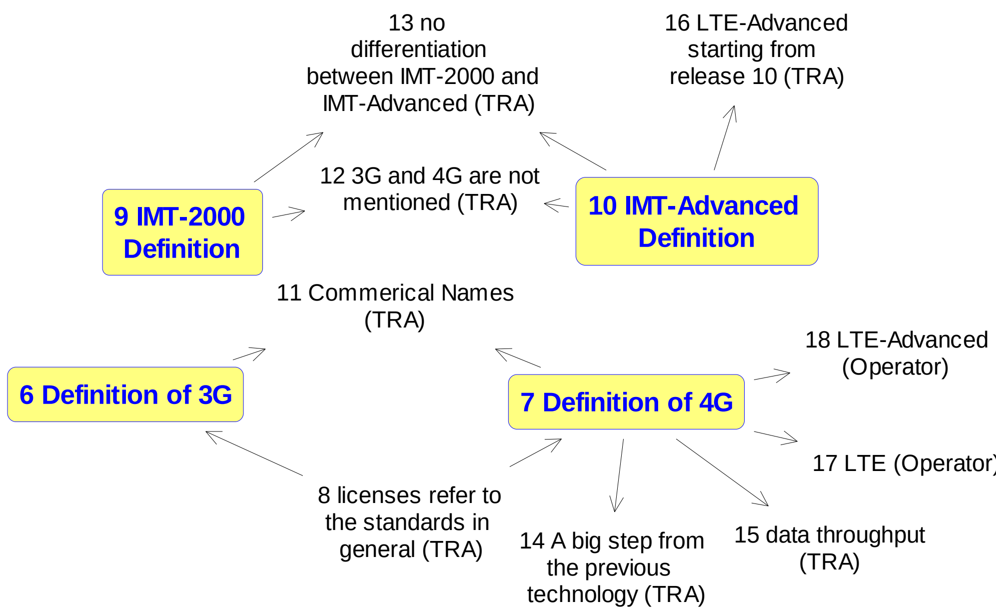

Figure 7-5: Influence of IMT Standardisation on Perspectives regarding Mobile Technology Generations Definition in UAE

Figure 7-5 shows that there is no influence from the IMT definitions on the 3G and 4G definitions from the perspectives of TRA and operators. From the viewpoint of TRA, 3G and 4G are commercial names (concept 11) that are not used by the ITU (concept 12). Furthermore, it seems that there is no agreement on what is considered to be 4G.one remarkable influence from the ITU is with regard to the absence of differentiation between IMT-2000 and IMT-Advanced technologies (concept 13). **These observations imply that TRA and operators' perceptions on mobile technology definitions are not influenced by IMT standards definitions.**

Appendix XIV provides examples of the Influence of IMT standardisation on perspectives regarding mobile technology generations definition in UAE.

7.5.3 International Interviewees

The next two sections address the influence of the IMT standardisation on the perception on 3G and 4G technologies in terms of generation definition, and the influence of IMT standardisation on the discrimination between mobile technology generations on the national level. The issue of discrimination is quite important in order to assess the influence of the IMT in the case of EDGE in Egypt.

7.5.3.1 Influence of IMT Standardisation on Technology Generation Definitions

In general, there were two distinct views on the influence of IMT on mobile technology generation definitions (3G, 4G) by twenty seven interviewees. On the one hand, twenty two interviewees were of the view that there is no influence for the following reasons. Firstly, it was explained that 3G and 4G are marketing terms that have nothing to do with the ITU. In particular, the ITU has been reluctant to use these marketing terms (e.g. 3G, 4G) because the marketing way of the state of technology is an evolutionary change (e.g. 3.75, 3.9) rather than revolutionary change (IMT-2000, IMT-Advanced). One interviewee from the ITU-R mentioned that there was a decision in the WP 5D not to use the terms of 3G and 4G. As expressed in this quote "*The ITU would not be called caught in a situation of giving a false expression impression*".

Moreover, it was expressed that the IMT umbrella provides a high level of definition and that the ITU-R sets vision without much detail. One interviewee from the

WP 5D argued that the influence of the IMT was much less in the case of 4G than the 3G, as certain regulators were not concerned with the term IMT-Advanced. Moreover, the industry parties did not care much about what the ITU-R was doing in the case of IMT-Advanced. This interviewee's remark supports this: "*There were those in the marketplace who felt that their position in the marketplaces as operators or others was enhanced by waving a flag saying, We are 4G, therefore we do not care to have 4G defined, because if it is defined, it's probably not going to be what we are doing*".

On the other hand, five interviewees argued that the influence exists between IMT standardisation and technology generation definitions. In particular, it was argued that the commercial and IMT definitions go hand in hand and that the ITU-R definitions were strongly influenced by the industry representatives at the WP5D meetings. In particular, it was argued that there was influence in the case of 3G because it was an emerging green field market as the ITU-R recommendation M.1457 stated clearly that these are the 3G technologies, which made a clear distinction between 2G and 3G. One interesting remark was mentioned during the interviews regarding the influence of technology developers on the IMT definitions. More specifically, it was explained that originally CDMA 1X was not a 3G technology according to the ITU-R definitions, which was a problem for Qualcomm, which asked to slightly change the definitions from only 2 Mbps to accommodate 144 Kbps for mobile use, which was exactly what CDMA 1X provided.

One issue that was raised during the interviews is the influence of IMT standardisation on the definition of 4G. More specifically, there was one view that LTE is and its evolution form are branded as IMT-2000 according to the ITU-R recommendation ITU-R M.1457, and LTE-Advanced is categorised as IMT-Advanced according to the recommendation ITU-R M.2012. Therefore, only LTE-Advanced is considered as 4G. The other view is that for regulators, LTE is 4G even if the ITU-R does not categorise it as IMT-Advanced. As clarified by one of the interviewees "*If 4G is IMT-Advanced, nobody has it*". One other interviewee from the WP 5D argued that there is no real good hard definition for 4G. He highlighted an example in the US where T-Mobile came out and stated that "*We do not have any LTE, we do not have any IMT-*

Advanced, we do not have any of this and that. But what we've got is 4G, because it's fast".

Moreover, one interviewee from SG 5 argued that the influence on commercial definition varies from country to another. For instance, in Japan, LTE is understood to be 3G. One interesting story was mentioned by one of the interviewee regarding the interaction between the industry and the ITU-R on generation definition. More specifically, when the RA-12 approved the IMT-Advanced technologies, the press release from the ITU mentioned that these are the true 4G. Meanwhile, the US operator, Sprint, was already marketing fourth generation on the basis of the evolution of their IMT -2000 deployments. As a result, Sprint complained that the ITU is doing damage to the market.

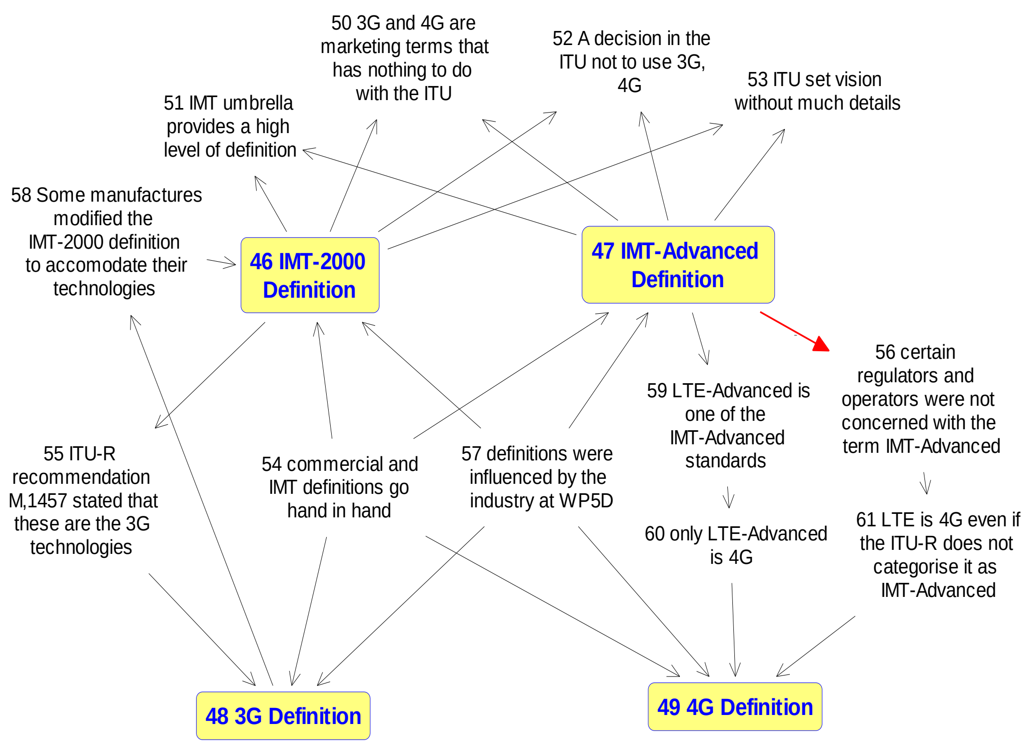

Figure 7-6: Influence of IMT Standardisation on Perspectives regarding Mobile Technology Generations Definition from Perspectives of International Interviewees

The causal map shown in Figure 7-6 reveals several observations on the interaction between the IMT standards on the one hand and the 3G and 4G definitions on the other hand. Firstly, several actions were taken in the ITU-R to diminish any influence from the IMT standards on the technology generations terms used in the market (concepts 51, 50, 52, 53). On the other hand, there is a view that both IMT and commercial definitions are developed in parallel (concept 54) and that both definitions are influenced by the industry (concept 57). Regarding the influence from the industry on the IMT definitions, there is a view that there was an influence specifically from the market on the IMT-2000 (concept 58). Similarly, there was an influence from the IMT-2000 definitions on categorising what is 3G.

Regarding the 4G, there are two views. The first is that only LTE-Advanced is considered to be 4G because only LTE-Advanced is included in the IMT-Advanced standards and not LTE. The second view is that this is not the case as LTE is still considered by many as 4G technology although LTE is not one of the IMT-Advanced technologies. **These observations imply that while one view is that there is mutual influence between the IMT definitions and definitions of 3G and 4G, the other view is that there is no influence because the ITU-R has taken several actions not to influence the market terms.**

7.5.3.2 Influence of IMT Standardisation on Discrimination between Technology Generations

One point that the research focused on is the influence of the IMT standardisation on the discrimination between mobile technology generations where twenty six interviewees commented on the issue. One view that was shared by eighteen interviewees is that there is no influence on the discrimination between generations. In particular, it was argued that the issue of having IMT-2000 and IMT-Advanced under one label named IMT has provided more flexibility in the spectrum use. Accordingly, most regulators have started to use IMT as a single name so that operators can move from technologies such as WCDMA to LTE directly. This was also confirmed by one senior interviewee from the ITU-R who argued that the ITU-R does not mention IMT-2000 or IMT-Advanced anymore. Instead, the use of the term IMT shows that neutrality of system in spectrum bands is already under consideration by ITU-R. However, he further explained that this may not be the case for some regulators because they have the licenses with specific conditions.

An interviewee from the WP 5D clarified the origin of the decision of having IMT-2000 and IMT-Advanced under one label. In particular, it was mentioned that the ITU-R actually banned the 3G and 4G terms and started removing it from all the ITU-R documents. The original intention was that IMT-2000 was 3G and IMT advanced was 4G. However, there were technology upgrades within IMT-2000 and those upgrades have been called 4G, which was confusing. Accordingly, the reason for having one label, IMT, was to ensure that the footnotes in the RR identified spectrum for IMT could be used for all of the technologies instead of having spectrum identified separately for IMT-2000 and IMT-Advanced. Another reason for having only the IMT label was that IMT-2000 was expected to be deployed around the year 2000 and to be linked to the 2000 MHz band, which was not the case. More specifically, IMT-2000 was not limited to the 2000 MHz band and was not necessarily deployed in the year 2000. Therefore, it was decided just to call it IMT.

One point that was raised is that although LTE is included in the M.1457 and LTE-Advanced in M.2012, release 10 will also be included in M.1457. As expressed by one of the interviewees "*They're going to keep updating on it, so they were going to have it in both places*". Therefore, there would be an overlap between the two recommendations so that there would be no discrimination between IMT-2000 and IMT-Advanced. In addition, one senior interviewee from the ITU-R clarified that one of the requirement for IMT-Advanced was to be backwardly compatible with the IMT-2000 to ensure that there is an evolution between the two of them. A senior interviewee from the mobile industry argued that the differentiation is due to historical reasons as most of the 3G licenses were awarded by beauty contest. As stated by him "*all the history of what we done in the past probably drives the resistance to making it completely technology neutral*".

More specifically, the huge license fees paid in the 3G licenses made it difficult for regulators to allow operators who have spectrum used for 2G technologies to use it for 3G. Moreover, it was argued that the license matters are really a national consideration that the ITU-R does not get involve in. It was also mentioned that regulators differentiate between generators not only for getting higher license fees but also in terms of prestige. As expressed by one of the interviewees "*I had noticed in countries in Latin America is that is a matter of prestige, when the government says ah we have the latest technology this is 4G and that's spectrum they make a big fast of update*". In addition, regulators usually refer to the common practise rather than the ITU-R.

On the other hand, there was a view shared by eight interviewees that having IMT-2000 and IMT-Advanced labels could be used as an excuse for regulators to differentiate between technologies. As expressed by one of the interviewees from WP 5D "*It has an influence. But everything has an influence. It could be used that way".* It was also mentioned that this is not the intention of the ITU-R. One senior interviewee from the mobile industry highlighted the issue of EDGE being considered as 3G due that it was included in the IMT-2000 family although EDGE was obviously a 2G standard. He further raised the point that the LTE technology may face similar situation because it is mentioned in IMT-2000 and IMT-Advanced ITU-R recommendations.

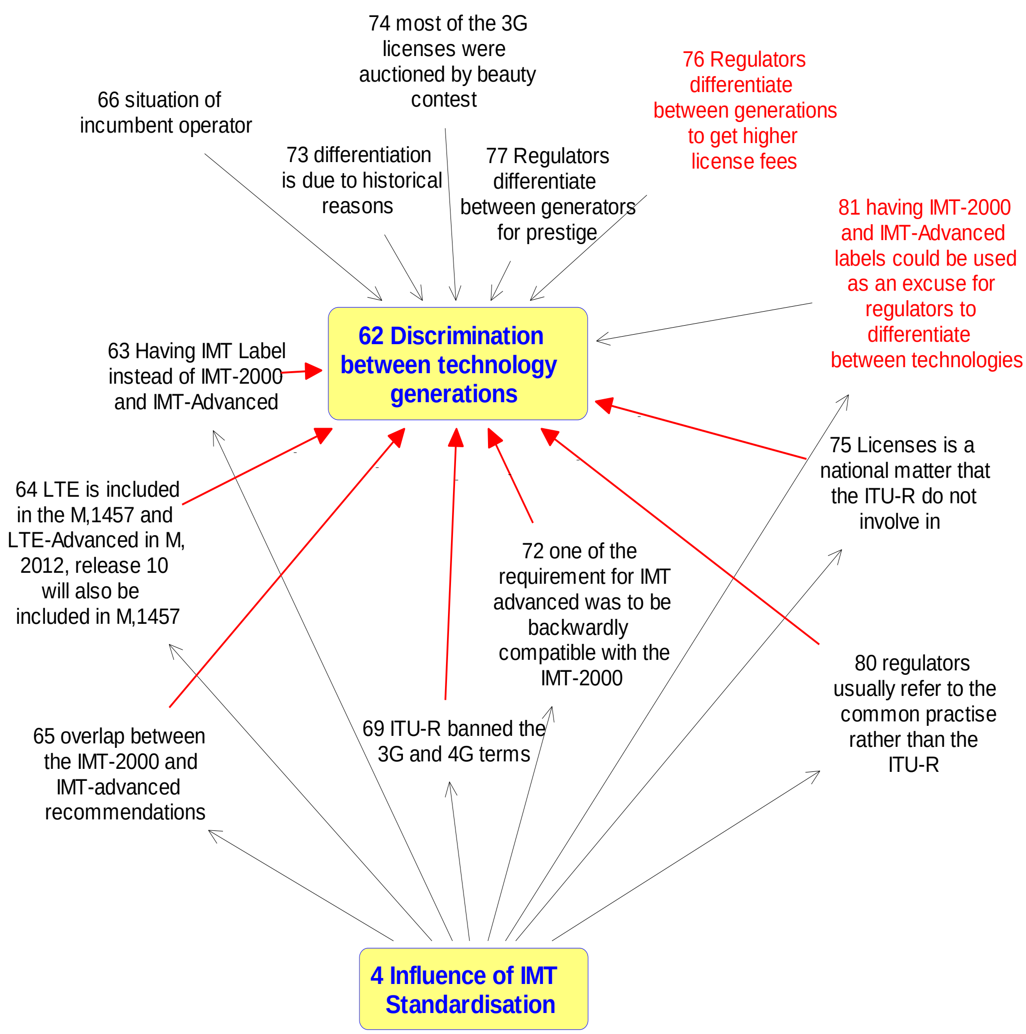

Figure 7-7: Influence of IMT Standardisation on Discrimination between Mobile Technology Generations

The causal map in Figure 7-7 shows that there are several reasons why regulators differentiate between technology generations due to issues related to the telecommunication market circumstances on the national level (concepts 66, 73, 74, 77). In addition, regulators may discriminate between the different technology generations in order to acquire higher license fees (concept 76). Regarding the influence of the IMT standardisation process of such discrimination, the map shows that the ITU-R by different actions has reduce the variation between IMT-2000 and IMT-Advanced (concepts 64, 65,72) and by not being involved in the discussion related to the differentiation between 3G and 4G (concept 69). The ITU-R does not involve in national matters (concept 75) and national regulators usually refer to the common practise rather than the ITU-R (concept 80). However, there was view that national regulators could use the IMT-2000 and IMT-Advanced labels to justify such discrimination (concept 81). **Therefore, these findings show that the IMT standardisation has mostly no influence on the discrimination between technology generations on the national level.**

7.6 *Influence of IMT Spectrum Identification on Technology Selection and Technology Neutrality*

One area that needs further focus is the IMT spectrum identification in the RR. This is due to the fact that it is not usual in the RR to have spectrum identified specifically for a particular family of technologies. Instead, spectrum is allocated to radiocommunication services (e.g. fixed, mobile).

7.6.1 Egypt

One interviewee from NTRA linked his interest in selecting technologies from the IMT family to the availability of frequency bands that match with these technologies. In other words, the selection of the IMT technologies is linked also to the available frequencies, which are identified to IMT. For instance, the 2 GHz band, which is identified for IMT, was decided to be for the third operator for the 3G services. It was also mentioned by an interviewee from NTRA that IMT spectrum identification enables NTRA to use any generation of IMT technologies without returning back to the ITU. In addition, such identification has the advantage of global harmonisation.

The importance of IMT identification is exemplified in the third mobile license RFP where it was mentioned that the licensee shall adhere to the ITU's frequency plan in region 1. Additionally, one of the interviewee from NTRA explained that one of the reasons of mentioning explicitly the ITU beside the international standard organisations in the third license RFP is that the issue is related to the radio spectrum.

Another issue that highlights the importance of IMT spectrum identification is that when a non-IMT technology was considered by NTRA, one of the main points was whether it would operate in IMT identified spectrum bands. In such case, it would have been refused because it is not IMT technology. The importance of IMT identification to the NTRA is evident in the 700 MHz discussion in the WRC-12, which was related to mobile service allocation as well as IMT identification. In particular, interviewees from NTRA of Egypt highlighted the importance of having the 700 MHz identified to IMT in order to align with region 2 and region 3.

From the operators' perceptive, one view was that spectrum identification is important in order to enable economies of scale. In particular, while some bands may achieve high coverage area, without identification, finding suitable equipment would be difficult. One senior interviewee from the operators commented on the issue of IMT identification by arguing that the ITU was irrelevant to NTRA up to the 2000s, and then there was a change when the ITU started to address spectrum allocation. One example of this is the 800 MHz digital dividend where the mobile lobby managed to have the allocation and, therefore, Egypt was able to capture the spectrum and utilise it for mobile.

As expressed in his own words "*The ITU gave the regulator a legal framework to start negotiations with the different agencies in Egypt where major holders of the spectrum that is not being used. So when the ITU-R says that this spectrum is, will be primarily used for mobile after 2000 and XX, that gives the regulator the platform to stand on and say, look this is what everybody in the world is doing, we should be on par with everyone else in the world, and it is the burden on the other agency to defend. And with the promise of the premiums then it becomes a very easy discussion*".

One point that is worth highlighting is that two interviewees from NTRA mentioned that the 2.5 GHz will be mostly used for 4G (LTE). However, nothing related to IMT spectrum identification was mentioned with this regard. This was in line with another interviewee from the mobile operators who pointed out that LTE would be used in new frequencies in the 2.5 GHz and therefore, operators would require a new license. In his own words "*We expect auction for 2.6 GHz for LTE…NTRA links between spectrum and service*". In addition, it was revealed during the interviews that one view from the operators that they can use their current spectrum to provide high-speed services via 3G technologies as long as they do not require new frequencies. This is due to the fact that 4G technologies would require new frequencies (e.g. 2.5 GHz).

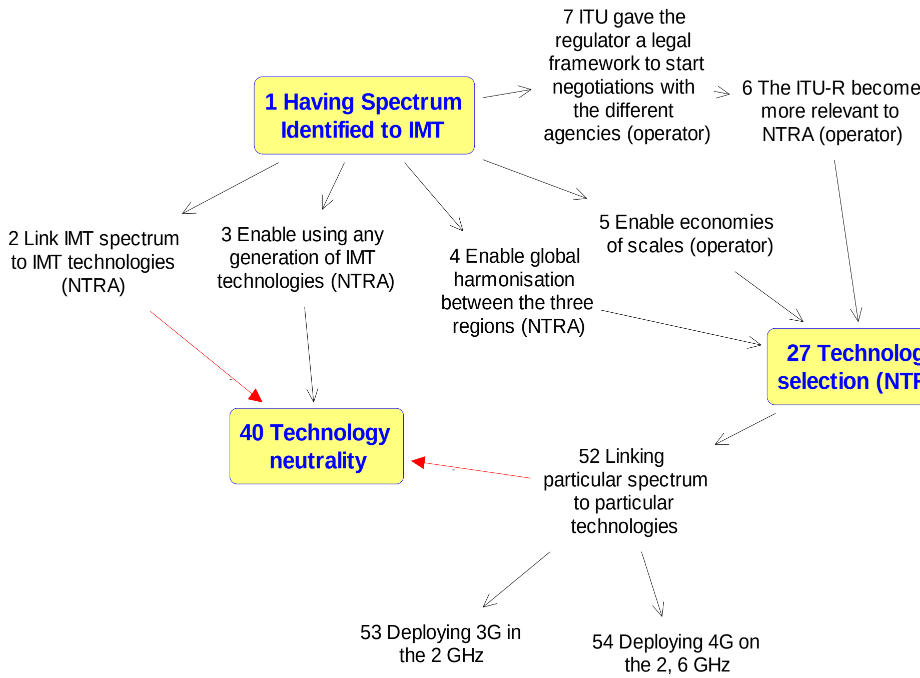

Figure 7-8: Influence of IMT Spectrum Identification on Regulator Decision on Technology Selection and Technology Neutrality in Egypt

The display of the data in Figure 7-8 shows that having spectrum identified to IMT has positive impact on NTRA and operator decision on technology selection from IMT (concepts 4, 5). Furthermore, one interesting observation is regarding concept 7. In particular, it seems that having particular spectrum band identified to IMT supports NTRA efforts on the national level to re-farm the spectrum from its current use to IMT. Regarding the influence of IMT spectrum identification on regulator's decision on applying technology neutrality, there are two different influences. On the one hand, it provides flexibility to NTRA to use any technology generation within the IMT (concept 3), which is considered as partial neutrality. On the other hand, such spectrum identification restricts technologies selection to IMT technologies on exclusive basis (concept 2), which is considered against the concept of full technology neutrality.

One element of regulator decision on technology selection that has a negative influence on technology neutrality is the linkage between particular spectrum bands and specific technologies (concepts 52, 53, 54). However, there was no evidence that this related to the IMT standardisation or spectrum identification. **These findings show that IMT spectrum identification supports NTRA and operators' decision on selecting technologies from IMT standards to operate in these IMT identified spectrum bands. Moreover, while IMT spectrum identification provides flexibility to NTRA in technology selection, however, linking IMT identified spectrum to IMT standards is against being fully neutral.**

7.6.2 UAE

TRA perception on the IMT spectrum identification is that it is useful in terms of enabling global harmonisation, economies of scales, and roaming. On the other hand, it may restrict country's flexibility in terms of being limited to IMT only. The operator's perception was similar regarding the advantages of IMT identification. In particular, it was expressed that harmonisation is important for spectrum as well as for technologies. It is worth mentioning that one interviewee from the UAE regulator explained that while UAE has a lot of bands for mobile service, 700 MHz issue was different because of global harmonisation between the three regions.

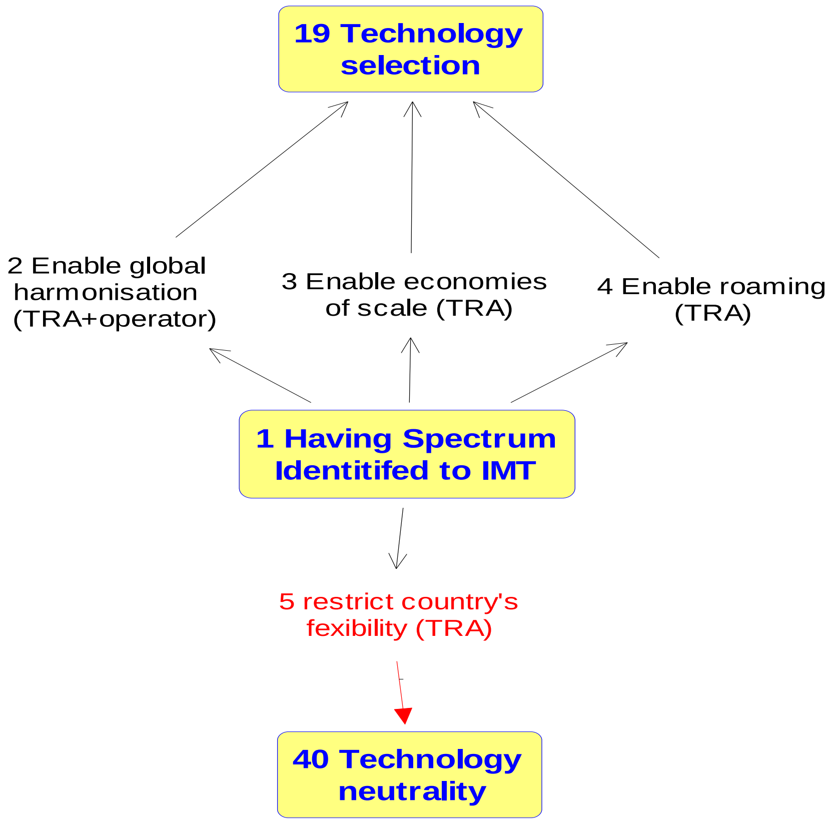

Figure 7-9: Influence of IMT Spectrum Identification on Regulator Decision on Technology Selection and Technology Neutrality in UAE

The causal map in Figure 7-9 shows that having spectrum identified for IMT has different elements of support towards selecting technologies from IMT standards (concepts 2, 3, 4). On the other hand, the IMT spectrum identification has the disadvantage of restricting TRA flexibility regarding technology selection to be limited to IMT technologies only (concept 5). This has a negative influence on regulator's decision towards technology neutrality (concept 40). **These observations imply that IMT spectrum identification supports TRA and operators' decision on selecting technologies from IMT standards to operate in these IMT identified spectrum bands. In addition, IMT spectrum identification restricts TRA flexibility regarding technology selection, which negatively influences technology neutrality in UAE.**

Appendix XV provides an example of the influence of IMT spectrum identification on technology selection and technology neutrality in UAE.

7.6.3 International Interviewees

In general, ten interviewees commented on the influence of spectrum identification on regulator's decision on technology selection. Firstly, it was perceived that the ITU is one of the most authorised entities in telecommunication world, and therefore, many vendors and operators like to have authorisation of the ITU for the used frequency bands. Therefore, the identification sends strong signals to the manufacturers of the equipment that these are the bands that they should focus and concentrate on in developing mobile technology in order to achieve harmonisation, roaming, and economies of scales. This is due to the fact that there are technological limitations so that it is only possible to have a handset that supports specific bands. The alternative would be to consider all the spectrum bands allocated to mobile service.

This was also supported by a senior interviewee in a large worldwide mobile manufacture who stated "*we do not want to go down the road and develop something if it is not going to see the light at the end of the day*". The identification sends also signals to the regulators to make sure that they had these identified spectrum band that could be used for IMT at an appropriate time when they decided to introduce it into their countries. In addition, designation or identification was argued by several interviewees to make spectrum more valuable. As expressed by one interviewee "*physics did not change, but the fact that you now designated IMT suddenly you raking in millions*".

One senior interviewee from the ITU-R argued that such identification could raise the value of spectrum and increase the license fees that operators are willing to pay. This was confirmed by a senior interviewee from CEPT who explained that IMT identifications through WRCs have been always followed by spectrum awarding activities. Moreover, one interviewee argued that IMT spectrum identification is important for regulators, which are not as advanced as large regulators (e.g. FCC) in terms of making their own decision. For these regulators, it is difficult to conduct studies to decide on which bands would be used for IMT technologies. Instead, they rely on the ITU to take such decision.

Another advantage that was mentioned is that when you auction spectrum bands identified for IMT technologies, there is a guarantee that you will have operating devices in these bands. Besides, a senior interviewee from the ITU-R explained that the identification is an indication that most of the countries using this service in the particular band will follow the IMT standards. In addition, one interesting point that was raised by one of the interviewees is that having a particular spectrum band identified for IMT gives support to the regulator to re-farm the spectrum from its existing use.

An example for that is the 700 MHz identification where several regulators were considering deploying mobile service in the 700 MHz. In his own words "*They did not want to even mention it because they knew that the broadcasters in their country, TV broadcasters, will be very upset, will make a lot of fuss and it will be very difficult. But once the ITU has said this band is going to be used for mobile, it made it much easier for regulators to say, well this is not my idea but look the rest of the world think this band should be 700 MHz*".

The interviewees mentioned several case studies that show how the influence of IMT spectrum identification is different from country to another. For instance, one senior interviewee from region 2 highlighted the case of WRC-07 where the issue of IMT identification in the C-band was discussed. At the time of the conference, the band was already allocated to mobile service but not identified to IMT. The European countries wanted to have the band identified to IMT and the opposing countries wanted to put restriction on IMT in order to protect the other services operating in the band. In particular, countries of region 2 did not want to have restriction on the use of the band as it is already allocated to mobile service. Therefore, they decided not to have the band identified for IMT while still using it for IMT due to the existence of mobile allocation.

In addition, one senior interviewee from Japan explained that companies usually adopt IMT technologies in bands identified for IMT. However, there is one exceptional case in Japan where the 2.5 GHz was identified for mobile broadband in general and not only IMT. This was motivated by the request of one company to deploy WiMAX at the time where WiMAX was not yet part of the IMT family. When it was asked whether it is mandatory to deploy only IMT systems in bands identified for IMT, it was clarified that this is not strictly specified but there is no need for operators to adopt a quite different interface for that IMT frequency band.

It is worth mentioning that several interviewees highlight some deficiencies associated with IMT spectrum identification although they may not be related to regulators' decision on technology selection. Firstly, it is difficult and takes a long time to get an agreement on IMT identification through WRCs. The case of IMT identification has encouraged other technology developers to seek identification (e.g. High Altitude Platform Stations (HAPS)). Another difficulty is that while the first IMT identified bands were fully harmonised, it has become more difficult to find harmonised bands throughout the world considering the increasing number of identified bands. In particular, it has become not economical approach to have radio equipment that can support this large number of frequency bands. Identification is also considered as a barrier for emerging technologies, and identification gives less incentive for manufactures to be innovative and produce equipment that works across much more wider range of frequencies.

Moreover, IMT identification is considered as disadvantageous to other radiocommunication services, which do not want the IMT to get their spectrum. As explained by one of the interviewees "*A lot of people think that commercial mobile industry is very arrogant and does not need as much spectrum as they keep asking for, and so there is a backlash against the identification to IMT*". In particular, many parties participate in the ITU-R discussion to restrict IMT access to spectrum (e.g. satellite, broadcasting). Additionally, one interviewee raised an interesting point related to the competition of IMT with other radiocommunication service, which is that IMT identification is not considered by many as identification for particular technologies. Instead, it is like service allocation where you can use IMT technologies.

In his own words "*It is like saying we think that spectrum is identified for the commercial mobile service, or a commercial mobile application, and you can use IMT technologies*". This was confirmed by one senior interviewee from the WP 5D who argued that IMT is not strictly identification for a technology because IMT is not only technology but also services vision. Another noticeable observation by one of the interviewees is that the IMT identification could be perceived as an allocation to a combined service of fixed, mobile, and broadcasting.

Regarding the influence of IMT spectrum identification on regulators regarding technology neutrality, twelve interviewees comment on the issue. On the one hand, four interviewees argued that identification does not negatively influence technology neutrality. In particular, IMT identification does not preclude other use for the spectrum. There is no restriction on re-farming to other technologies because in the same part of the spectrum, the technology will be similar whether the band is identified for IMT or not. Moreover, there was an influence of IMT identification on removing the link between technology and spectrum that used to be. In particular, there used to be a link where GSM operate in the 900 MHz and 3G was linked to 2 GHz band. Regarding the case of having mobile technology in the L-Band as SDL, while the band is not yet identified to IMT and only allocated to mobile services, it is not necessary to wait for WRC-15 to confirm this identification. Instead, work has already started in standardisation organisations such as 3GPP. This may show how mobile development is not limited to IMT spectrum identified bands.

On the other hand, there were several negative comments mentioned by eight interviewees on the influence of IMT spectrum identification. Firstly, one difficulty for IMT identification is that it is considered as disadvantageous for other mobile use in the identified bands rather than IMT (e.g. TETRA - IBurst). More specifically, it becomes only possible for non-IMT technologies to be deployed in non-IMT identified bands. An evidence is that non-IMT technologies were proposed in bands not identified for IMT. For instance, IBurst technology, which was proposed in the duplex gap of the 1800 MHz where there is no IMT equipment. However, IBurst was not able to outperform IMT technologies. Therefore, it was argued that any proprietary technology would not be able to compete in the market with IMT technologies regardless of the regulator decisions. The only exception would be in huge markets driven by government-owned manufactures.

Furthermore, linking spectrum to IMT may restrict re-farming in general. More specifically, it could be considered as a good excuse for regulators not to apply technology neutrality and to limit the use of a particular band to be for IMT exclusively. In addition, it was pointed out that having the band identified for IMT would mean an implicit use for LTE in the future. This was confirmed by a senior interviewee from ATU who argued that although some regulators may be neutral; having the IMT technologies with all its advantages motivate them to pick IMT technologies. Moreover, one senior interviewee from the mobile industry argued that while there is no relationship between applying technology neutral and having IMT spectrum identification, having such identification encourages regulator to identify the band for IMT. In other words, the spectrum identification process focuses the attention on IMT solutions as opposed to alternative technologies even if such identification does not preclude other uses.

Additionally, one senior interviewee in a large global manufacture argued that IMT identification would imply using the band for IMT. For instance, regarding the 700 MHz allocation, there was a suggestion to allocate the band to mobile service without IMT identification so it would not give signals that the spectrum is moving from the broadcasters to mobile operators. This highlights the major influence of IMT identification and the difference from normal mobile service allocation as it largely implies using IMT.

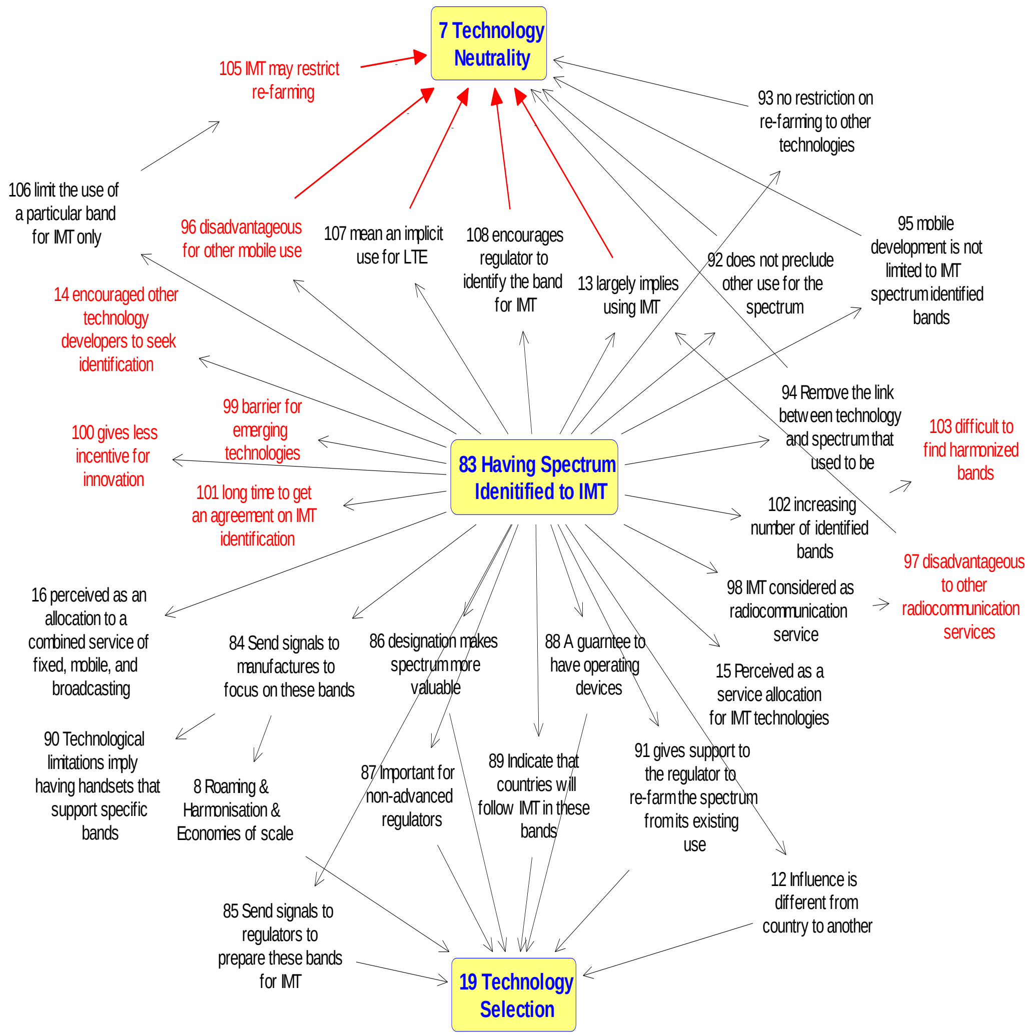

Figure 7-10: Influence of IMT Spectrum Identification on Regulator Decision on Technology Selection and Technology Neutrality from Perspectives of International Interviewees

The causal map in Figure 7-10 shows how the IMT spectrum identification has different positive influences on regulators' decision regarding regulator decision towards selecting technologies from the IMT family (concepts 84, 8, 86, 87, 88, 89, 91). However, it was noted that such impact is dependent on the country (concept 12). Regarding the influence on technology neutrality, there were several perceived positive and negative elements that have an influence on the concept of technology neutrality. On the one hand, having spectrum identified to IMT may largely imply using the spectrum for IMT, which may discourage regulators to apply technology neutrality and to limit the band use to IMT only instead (concepts 106, 105, 96, 107, 108, 13). On the other hand, such identification does not preclude other mobile use (concepts 92, 93) and mobile development has been progressed in bands other than those identified for IMT (concept 95). Moreover, the IMT spectrum identification was argued to contribute positively to the introduction of technology neutrality (concept 94).

In addition, several general observations emerged during the research. Firstly, IMT spectrum identification has a negative influence on new technologies and on innovation (concept 99, 100). Secondly, within the ITU-R, reaching agreement on identification is difficult (concept 101) and other technologies related to other services rather than mobile have started to seek identification as well and not only service allocation (concept 14). The increasing number of identified spectrum for IMT has made harmonisation more difficult (concept 103). One observation that may be related to the first research question on service flexibility is that IMT identification is perceived by some as an allocation to a radiocommunication service rather than just identification for a technology (concept 15). Moreover, such allocation is envisioned as a multiple allocations to fixed, mobile and broadcasting rather than just allocation to mobile service (concept 16). In other words, IMT identification could be argued to enable more flexibility in service allocation as it accommodates elements from three main services (fixed, mobile, and broadcasting).

Furthermore, the issue that IMT spectrum identification is disadvantageous to other radiocommunication services (concept 97) could be perceived also as a support to the argument that IMT identification implies deploying IMT even if the band has other service allocations. One example of that is the IMT identification in the band 790-862 MHz where there are mobile and broadcasting service allocations. **This leads to a general conclusion that IMT spectrum identification has a positive impact on regulator decision towards selecting technologies from the IMT family. However, the extent of such influence is dependent on the country. Moreover, IMT spectrum**

identification has elements of flexibility and restriction on the concept of technology neutrality.

7.7 *Conclusions*

This chapter has addressed the interaction between the international spectrum management regime and national spectrum management policies with a focus on the case of technology neutrality. In general, the Egyptian interviewees from NTRA and the operators acknowledged the merits of technology neutrality in terms of providing flexibility and not being biased towards a particular technology. However concerns were expressed regarding proprietary technologies and difficulty of roaming. On the issue of flexible duplex mode, both of regulator and operators were not in favour of the concept. In addition, interviewees from UAE were in favour of technology neutrality as long as there is no interference within the country and against neighbouring countries. Operators perceive the concept of an importance to the UAE in order to provide the latest technologies. On the other hand, neutrality raises the risk of interference. Moreover, while TRA interviewees were not in favour of the concept of flexible duplex mode while operators support it in case there is no interference.

The examination of the application of the concept in Egypt showed that the regulator is not applying technology neutrality in fully and that operators are strict to the technologies specified in their licenses due to the importance of international standardisation. However, every operator can use any specified technology in their license in the assigned frequency band for them upon obtaining approval from the regulator. The case of the UAE showed that TRA is neutral in terms of mobile technology and that there have been already several cases of re-farming on the condition of informing TRA before changing the technology. Additionally, applying technology neutrality was motivated by the monopoly of Etisalat before the establishment of TRA.

With regard to the influence of IMT, the analysis of the Egyptian case study data has shown the followings. Firstly, for NTRA, being part of the IMT family of standards provides support to the applicant technologies. However, this is not mandatory or sufficient to accept a technology by NTRA. In particular, there are other factors that are important in order to accept a technology by NTRA in addition to being one of the standards of the IMT family. For national operators, being IMT technology does not have a significant influence on operators' decision regarding adopting a particular technology.

Additionally, IMT standardisation has a positive influence on NTRA regarding technology neutrality and it allows NTRA to move from being technology specific. Moreover, while NTRA perceptions on mobile technology generations' definitions are largely influenced by IMT standards definitions, there is no influence on national operators' perception. Besides, IMT spectrum identification supports NTRA and operators' decision on selecting technologies from IMT standards to operate in these IMT identified spectrum bands.

While IMT spectrum identification provides flexibility to NTRA in technology selection, however, it is also against being fully neutral. More specifically, IMT spectrum identification provides flexibility to NTRA to use any technology generation within the IMT, which is considered as partial neutrality. Nonetheless, such identification may restrict technologies selection to IMT technologies on exclusive basis, which is considered against the concept of full technology neutrality.

With regard to the influence of IMT, the analysis of the UAE case study data has shown the followings. Firstly, for TRA, being part of the IMT family is not mandatory but preferable. For national operators, being limited to IMT technologies is restrictive but there is indirect influence from the IMT standardisation on them. In addition, IMT standardisation has positive and negative elements in terms of influence on TRA of UAE regarding technology neutrality. Firstly, the IMT family of standards gives a variety of technologies to select from. However, being limited to IMT standards is not considered to be fully neutral.

The research findings highlight also that TRA and operators' perceptions on mobile technology definitions are not influenced by IMT standards definitions. Moreover, IMT spectrum identification supports TRA and operators' decision on selecting technologies from IMT standards to operate in these IMT identified spectrum bands. IMT spectrum identification restricts TRA flexibility regarding technology selection, which negatively influences technology neutrality in UAE.

With regard to the influence of IMT, the analysis of the international interviewees' data has shown the followings. Firstly, being part of the IMT family of standards provides support to the applicant technologies. On the other hand, there is another view that being one of the IMT technologies is a second priority to other factors that has a greater influence on regulator decision on technology. It was also found that IMT standardisation has positive (supportive), negative (opposing), and neutral elements in terms of the influence on regulators regarding technology neutrality according to the perception on technology neutrality and on the IMT standardisation process per se.

The first view is that there are elements of IMT standardisation that encourage more neutrality approach in technology selection, and the IMT family of standards is considered to be in conformity with technology neutrality. The second view is that the IMT standardisation may discourage regulators form being neutral, and may have negative influence on operators and technology developers, and the third view is that IMT standardisation does not have influence on adoption of technology neutrality.

The data analysis has shown also that while one view is that there is mutual influence between the IMT definitions and definitions of 3G and 4G because both definitions are developed in parallel and both definitions are influenced by the industry, the other view is that there is no influence because the ITU-R has taken several actions to diminish any influence from the IMT standards on the technology generations definitions used in the market. Furthermore, the international interviewees expressed that IMT standardisation has mostly no influence on the discrimination between technology generations on the national level.

With regard to the IMT spectrum identification, it was evident that such identification has a positive impact on regulator decision towards selecting technologies from the IMT family. However, the extent of such influence is dependent on the country. Additionally, it was revealed that IMT spectrum identification has elements of flexibility and restriction on the concept of technology neutrality. Table 7-1 presents a summary of the main findings of this chapter.

Case Study	Main Conclusions
Egypt	• The Egyptian interviewees acknowledged the merits of technology neutrality in terms of providing flexibility and not being biased towards a particular technology while having concerns over proprietary technologies and difficulty of roaming. Moreover, flexible duplex mode is not of interest. • NTRA of Egypt does not apply technology neutrality in fully and operators are strict to the technologies specified in their licenses. • For NTRA, being part of the IMT family of standards provides support to the applicant technologies. However, this is not mandatory or sufficient to accept a technology by NTRA. For national operators, being IMT technology does not have a significant influence on their decision regarding adopting a particular technology. • IMT standardisation has a positive influence on NTRA of Egypt regarding technology neutrality. • There are preferences towards specific IMT technologies that have global adoption and commercial success. • NTRA perceptions on mobile technology generations' definitions are largely influenced by IMT standards while there is no influence on national operators' perception. • IMT spectrum identification supports NTRA and operators' decision on selecting technologies from IMT standards to operate in IMT identified spectrum bands. • While IMT spectrum identification provides flexibility to NTRA in technology selection, however, linking IMT identified spectrum to IMT standards is against being fully neutral.
UAE	• The UAE interviewees are in favour of technology neutrality as long as there is no interference within the country and against neighbouring countries. Moreover, flexible duplex mode is not of interest.

	• TRA of UAE applies technology neutrality motivated by the historical monopoly of Etisalat. • For TRA of UAE, being part of the IMT family is not mandatory but preferable. For national operators, being limited to IMT technologies is restrictive but there is indirect influence from the IMT standardisation on them. • IMT standardisation has positive and negative elements in terms of influence on TRA of UAE regarding technology neutrality. • TRA and operators' perceptions on mobile technology definitions are not influenced by IMT standards definitions. • IMT spectrum identification supports TRA and operators' decision on selecting technologies from IMT standards to operate in these IMT identified spectrum bands. • IMT spectrum identification restricts TRA flexibility regarding technology selection.
International Interviewees	• One view is that being part of the IMT family of standards provides support to the applicant technologies, and the second is that there are other elements that may have stronger influence on decisions regarding adopting a particular technology. • IMT standardisation has positive (supportive), negative (opposing), and neutral elements in terms of the influence on regulators regarding technology neutrality according to the perception on technology neutrality and on the IMT standardisation process per se. • While one view is that there is mutual influence between the IMT definitions and definitions of 3G and 4G, the other view is that there is no influence because the ITU-R has taken several actions not to influence the market terms. • IMT standardisation has mostly no influence on the discrimination between mobile technology generations on the national level. • IMT spectrum identification has a positive impact on regulator

	decision towards selecting technologies from the IMT family. However, the extent of such influence is dependent on the country. • IMT spectrum identification has elements of flexibility and restriction on the concept of technology neutrality.

Table 7-1: Summary of Research Findings for the Concept of Technology Neutrality

8 Opportunistic Access in the TV White Spaces

8.1 *Introduction*

This chapter is the third to examine the interaction between the international spectrum management regime and national spectrum management policies with a focus on the concept of opportunistic access in the TVWS. It starts with the perception of the main stakeholders in Egypt and UAE on the concept per se, and then Section 8.3 examines the applicability of the concept in the two countries. Section 8.4 addresses the third research question in general through analysing the collected data from the two case studies and from the international interviewees. Sections 8.5 and 8.6 explore the interviewees' perceptions on TVWS radiocommunication service allocation status and the influence of the WRC-12 decision on A.I. 1.19 on TVWS adoption respectively. Moreover, Section 8.7 conducts a comparison of international regulations between the two cases of R-LAN in 5 GHz and opportunistic access in the TVWS. Section 8.8 ends the chapter by highlighting the key findings. In each section, the interviewees' data are analysed and then causal maps are developed if needed.

8.2 *Perception of the Concept of Opportunistic Access in the TVWS*

While the research focuses on the interaction between the international regime and national policies regarding introducing the concept of opportunistic access in the TVWS, it is useful to examine the perceptions of Egypt and UAE interviewees on the concept per se in order to find out factors that may influence the adoption of the concept other than those related to the international regime.

8.2.1 Egypt

The NTRA interviewees expressed several concerns over TVWS. Firstly, TVWS devices usually operate on unlicensed basis, and therefore, it is difficult to control them. Furthermore, it is not easy to allocate a band for these devices to be unlicensed and then change its status to be licensed afterwards. As clarified by one of the interviewees from NTRA "*The TVWS systems implementation is a non-reversible process so that it would be difficult to evacuate these systems in case they failed*". There could be interference from these TVWS devices on each other and on existing systems operating in the same bands as they usually operate outdoors. It was also argued that more spectrum resources are needed for applications such as public safety and mobile broadband especially after the reallocation of the 700 MHz band to mobile service. Other concerns include the need for an excellent management system, and security concerns of unauthorised access. It was also expressed that global harmonisation is needed between the different countries which adopt the TVWS concept.

One the other hand, interviewees from NTRA admired the sharing concept per se explaining that several broadcasting frequencies are not used by the broadcaster. The Egyptian broadcasting interviewees explained that new broadcasting services such as HDTV would require more frequencies and that these TVWS devices may restrict the broadcasters' ability to modify their broadcasting spectrum band. There were also concerns over interference from these systems on broadcasting and vice versa. The broadcasters expressed their fear that if part of their spectrum is utilised for these devices, it will not be returned back to the broadcasters. This is due that there could be an indication for NTRA that the broadcaster is not in need for these frequencies.

The mobile operators showed diverse opinions over the concept. On the one hand, they showed an interest in the concept to enhance spectrum utilisation especially in the lower spectrum bands, which provides better coverage and also because it may cost them less compared to dedicated bands. As one interviewee explained, "*If capacity has increased and spectrum is full and shared access is cheaper than licensed spectrum I will definitely go to the shared access*". On the other hand, there were concerns that there would be no continuity for the services provided to the end users. Secondly, TVWS frequencies are scattered which would need more effort in planning the frequencies and avoiding interference. Thirdly, there could be a negative impact of the digital dividend on TVWS. Fourthly, several interviewees from the operators expressed their preference to exclusivity in general in order to avoid interference. A statement made by an interviewee conveys this "*I will prefer to buy the band. People do not understand the concept of having a piece*".

8.2.2 UAE

Interviewees from TRA argued that while the TVWS concept may decrease spectrum congestion, it raises several challenges regarding the management of the database, billing system, licensing, and interference over broadcasting and security concerns from unauthorised access as well. One other note was that there are no successful wide adopted TVWS devices unlike the case of Wi-Fi. Additionally, interviewees from the UAE mobile operators expressed their concerns regarding the quality of service provided over TVWS and the difficulty of sharing with public services. This is the reason why mobile operators in the UAE prefer dedicated spectrum where the revenue come from.

8.3 *Applicability of the Concept of Opportunistic Access in the TVWS*

Another related aspect of the concept of opportunistic access in the TVWS is whether Egypt and UAE regulators could introduce and apply the concept in practice. In other words, it is important to find out if there are regulatory or legislation barriers to TVWS adoption. This is also needed in order to highlight other influential factors that may not be related to international regime.

8.3.1 Egypt

Regarding the applicability of the TVWS concept in Egypt, it was explained by interviewees from NTRA that the band 470-698 MHz is exclusively assigned over Egypt by law for the national broadcaster nationwide. The digital switchover process has not finished yet and the coordination with Egypt's neighbour countries has not finalised yet. It was also clarified that the broadcaster may not approve the TVWS concept even if the spectrum is not fully utilised. Interviewees from NTRA clarified that the regulator is not to decide soon on the TVWS concept. Instead, NTRA is planning to wait for other countries' deployment in order to further assess TVWS.

It is worth highlighting that unlike the case of UAE where there are several bands assigned for the mobile operators, which face no congestion. There were some views from the mobile operators and fixed incumbent (TE) in Egypt that there is shortage in spectrum. This explains why some of the operators in Egypt were in favour of TVWS and sharing in general especially the fixed incumbent (TE), which was a potential fourth operator at the time the interviews were conducted. As expressed by this quote by one of the mobile operators interviewee "*If there are no other options, it's better than having no frequencies at all. And this is a situation that we have sometimes*". However, there were also concerns from the fixed incumbent over whether services would be running undisrupted and that the solution would be practical in Egypt.

8.3.2 UAE

Interviewees from the UAE TRA explained that they have already deployed a similar concept to the TVWS in the vacant frequencies in the TV band that are not in use for services such as programming making and microphones. Devices of these services are used frequently in UAE for events and concerts. The difference between that type of use and the TVWS is that the former is not dynamic and does not have a database for operating devices. Interviewees from TRA further explained that the broadcasters in the UAE did not object to the use of these devices because they broadcast using low power and also because TRA avoid assigning any frequency for these devices which is in use by the broadcasters. Moreover, TVWS is a temporary establishment where on the long run, more frequencies in the UHF bands would be allocated to mobile service and therefore, the broadcasting spectrum would be reduced.

It is worth mentioning that TRA issued an update on their position on the TVWS concept in January 2014 in an ITU-R workshop conducted by WP 1B (Almarzooqi, 2014). Accordingly, an additional interview was conducted to explore such update. It was pointed out that there is a difficulty of deploying TVWS devices because spectrum available for TVWS is getting smaller which was not the case at the beginning. Even these small available frequencies would be used for program making and special uses, and low power devices in UAE. It was also clarified that while TRA support the concept and operation of CRS, CRS in the TVWS seems not workable.

8.4 *Interaction between International Regime and National Policies regarding TVWS*

This section is the first to examine the third research question in general. It is worth mentioning that during the discussion on TVWS, several interviewees tie CRS, opportunistic access, and TVWS together and treat them equally.

8.4.1 Egypt

The analysis of the Egyptian regulator interviews shows different areas of interaction between the ITU-R RR and NTRA decision regarding the concept of opportunistic access in the TVWS. Firstly, it was argued that because the band 470-694 MHz is exclusively allocated to the broadcasting service on a primary basis, this may cause interference from neighbouring countries to these TVWS devices especially in the summer time due to the ducting phenomena. In particular, ducting may cause broadcasting signals to propagate over larger distances than normal and such effect increases in high temperature. Secondly, the allocation of the band 694-790 MHz to mobile service in the WRC-12 would require re-planning of the band 470-694 MHz. Thirdly, it would be difficult for NTRA to assign frequencies for TVWS systems until finalising the DSO process in all of the neighbouring countries. It is worth mentioning that the interviewees from NTRA linked between the service flexibility issue and using CRS, and there was also a perceived relationship between the discussion at WRC-12 on A.I. 1.19 and service flexibility where you can use CRS for any radiocommunication service.

Regarding whether the RR restrict the introduction of TVWS, interviewees from the regulator were of the opinion that the RR do not deal with technologies but with radiocommunication services. Moreover, the RR do not come into conflict with the TVWS concept as the ITU-R table of service allocations contains other allocations than broadcasting in the UHF band which provides some sort of flexibility. However, in case that there is no an alternative allocation in the UHF band other than broadcasting, this may cause a problem. Secondly, the broadcasting interviewees explained that the RR allow each country to do whatever they want as long as it will not influence the neighbouring countries. Thirdly, the mobile operator interviewees argued the ITU-R does not oppose sharing and that the ITU-R will consider the TVWS concept a national issue. The fixed operator interviewees argued that the RR do not restrict the TVWS as they could operate on a secondary basis and that the ITU-R should define the TVWS concept. All the previous views are displayed in the causal map in Figure 8-1.

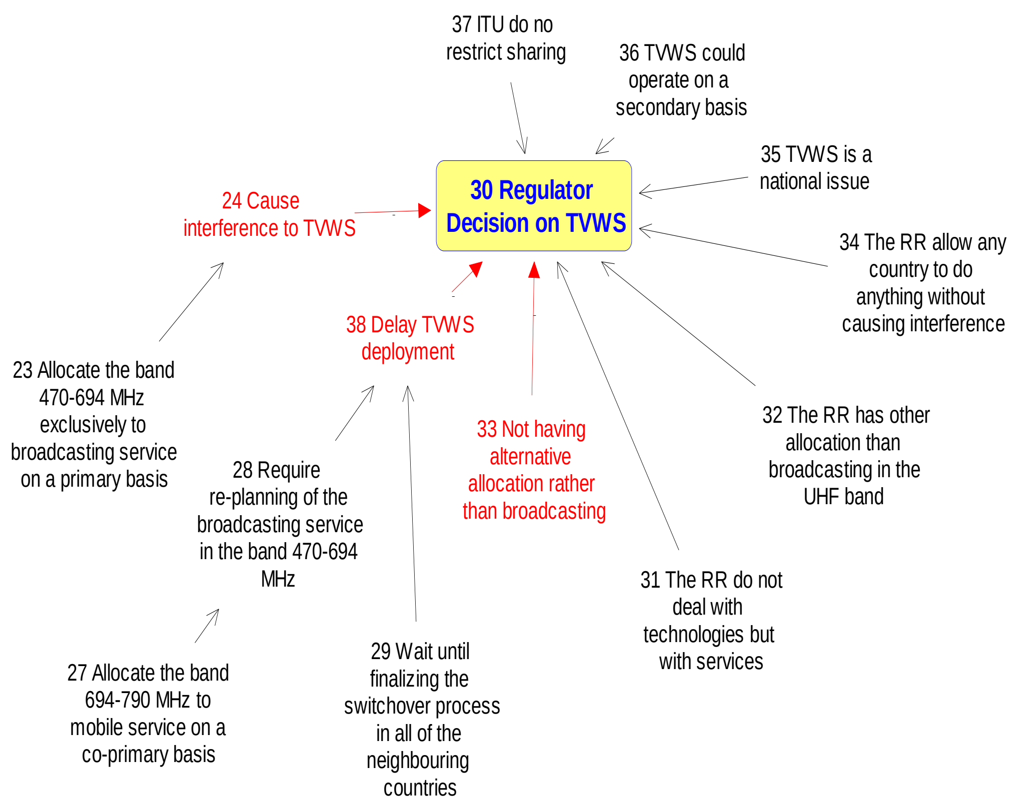

Figure 8-1: Interaction between the International Regime and Egypt Spectrum Policy regarding TVWS

As shown from the causal map of the Egyptian interviewees' perspectives on the issue in Figure 8-1, there are different elements of the international regime that restrict and accommodate NTRA decision on deploying TVWS. The main restrictive element is the a priori planning of the broadcasting service in the UHF band which may delay or cause interference to the deployment of TVWS (concepts 23, 28, and 29). Not having an alternative allocation where TVWS could operate is also a restriction (concept 33). On the other hand, if there was another service allocation in the UHF band, the RR would accommodate TVWS deployment (concept 32). It is worth mentioning that Egypt has a secondary allocation to the land mobile service in the band 470-790 MHz (ITU-R, 2012d).

Elements of flexibility include the possibility of TVWS to operate on secondary basis (concept 36). Concept 34 reveals the perception on the role of the RR in general that Egypt has ultimate flexibility as long as there is no interference to other countries. **These observations imply that the interaction between the international regime and Egypt spectrum policy does not prevent Egypt from deploying TVWS in practice. However, there are concerns related to delay of deployment or interference on TVWS.**

8.4.2 UAE

Interviewees from the UAE TRA explained that the international regime is quite flexible as it allows introducing any service as long as it is not causing interference to others while still protecting what is existent in the RR. They further explained that TRA would not wait for a decision regarding TVWS from the ITU-R, as eventually it is the technology, users, and application, which drive the market. They clarified that there would be no issue if the service is mentioned in the ITU-R table of frequencies. However, if this is not the case, the country needs to get an allocation in the UHF band by footnote as a first step. More specifically, while the band is mainly allocated to broadcasting on a primary basis, there is also allocation for mobile service on secondary basis. Therefore, there is no restriction on TVWS deployment in such case.

Interviewees from the UAE TRA provided the example of PMSE applications where they are not defined as a service by the ITU-R but they could operate under the mobile service. Therefore, the UAE among other countries got an allocation for mobile service on secondary basis in the UHF band by footnote in the RR to deploy these PMSE devices. It was also clarified that the purpose of the footnote for PMSE is not only to add the UAE name to have an allocation but it was also to inform the equipment manufacturers that this band is allocated for these types of applications on a secondary basis. Some interviewees from the UAE TRA perceived a relationship between the service flexibility and the opportunistic access concepts. There was also a perceived relationship between the discussion on the WRC-12 A.I. 1.2 addressing enhancing the international regulatory framework and the discussion on the WRC-12 A.I. 1.19 addressing CRS and SDR.

One interviewee from TRA mentioned that the potential restriction of service allocation in Article 5 of the RR depends on the international obligations of the country. Another point that was raised by interviewees from TRA is the importance of harmonisation of service allocation status for these devices in order to achieve economies of scales and to avoid interference on the countries' borders. In addition, it was explained that the RR is important as a first step in deploying CRS because they give an indication of what are the services that are in use by the different countries so that protection measures could be developed. It was also evident from the interviews that the 800 MHz and 700 MHz mobile allocations and IMT identifications in the WRC-07 and WRC-12 respectively did have an impact on the adoption of the TVWS in UAE. In particular, these allocations squeezed the broadcasting spectrum to the band 470-694 MHz, which is already under the pressure from digital TV.

Other issue that was raised with the UAE TRA is with regard to the influence of registering assignment in the MIFR on introducing TVWS. In particular, it was pointed out that there could be a difficulty in registering assignments for TVWS due to its dynamic nature. The UAE mobile group had the view that the RR indicate that inside the country you have the leverage to do whatever you want as long as you do not affect other countries. The UAE broadcasting interviewees were of the view the ITU-R should conduct studies on opportunistic access and that they could operate primary or secondary according to the nature of the provided applications. The previous issues are displayed in the following causal map in Figure 8-2.

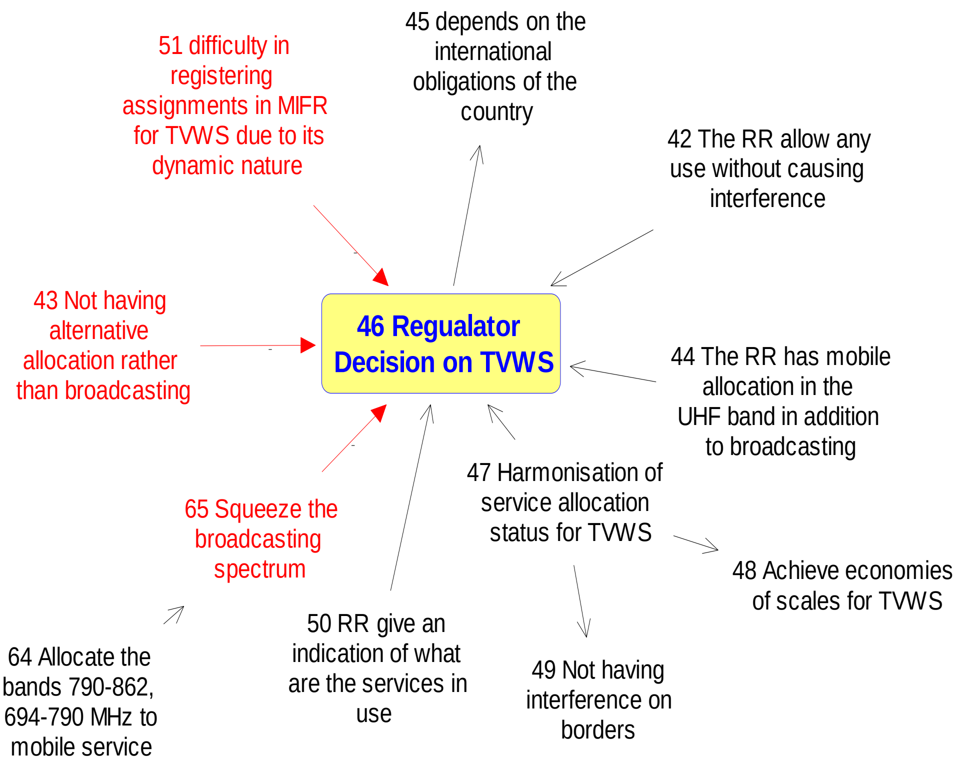

Figure 8-2: Interaction between International Regime and UAE Spectrum Policy regarding TVWS

As shown from the causal map of the UAE interviewees' perspectives on the issue in Figure 8-2 there are different elements of the international regime that accommodate TRA decision on deploying TVWS. In particular, there is flexibility in case there is an allocation in the UHF band in addition to the broadcasting service, which is the case for UAE (concept 44). Harmonisation of service allocation status was perceived beneficial for TVWS deployment (concept 47).

The RR provide the UAE with ultimate flexibility providing no interference is caused to other countries (concept 42). The only restrictive elements are the difficulty to register TVWS assignments in the MIFR (concept 51) and the influence of the mobile allocation in the 694-790 MHz on the broadcasting spectrum in the UHF band (concepts

64, 65). **These findings highlight that the interaction between the international regime and UAE spectrum policy does not prevent UAE from deploying TVWS in practice. However, there are concerns related to the influence of additional mobile allocation in the 694-790 MHz band on the broadcasting spectrum in the UHF band.**

8.4.3 International Interviewees

In general, forty nine interviewees commented on the issue by expressing two different views. The first view, which was shared by thirty five interviewees, is that there is no contradiction between opportunistic access and the ITU-R RR and that the later can accommodate the former without any restriction. In particular, TVWS is a national issue and the RR are flexible as long as you do not cause interference to your neighbours. ITU-R is neutral towards technologies and only concerned with radiocommunication services. The opportunistic access concept per se is not a service and therefore, it could be utilised by the different services.

One interviewee from the SG 6, which is concerned with broadcasting services, argued that there is no need for the RR in the case of the TVWS concept because it is not a cross-border issue. TVWS can operate under the provisions of ITU-R Article 4.4, as the ITU does not recognise unlicensed devices. In his words "*Opportunistic access is exactly the opposite of RR, is 4.4 do whatever you want if you do not create a difference in the country*". One interviewee from the ITU-R clarified that the RR are well established and that many national spectrum regulations are based on them. Therefore, it is not expected that the technology development will dictate real changes of RR. It was also explained that while part of the RR urges the licensing of radio, other parts allow unlicensed use as long as it is not causing interference with licensed operations. Therefore, there is no action needed from the ITU-R to introduce TVWS.

Furthermore, there is a perception that the ITU focuses on primary services of high power-high tower between countries unlike the case of TVWS. One senior interviewee from the ITU-R argued that opportunistic access would imply operating with low power to avoid interference with other services around it. Therefore, TVWS is not related to the RR, which focus on avoiding harmful interference between countries. One other argument is that the paradigm created by the ITU is sharing rather than exclusivity from the early days of the ITU-R where there were three categories of shared access namely, primary and secondary and permitted where permitted is the category of unlicensed use in ITU regulations. As explained in his quote "*from the very beginning there was understanding that spectrum had to be shared*".

On the other hand, fourteen interviewees highlighted the interaction and in some cases restriction from the ITU-R RR on TVWS deployment. Most importantly, it was stressed by some interviewees on the importance of having a service allocation in the RR in which these TVWS devices could operate. In particular, equipment using cognitive radio techniques could operate consistently with the given service that is already allocated in the RR. As expressed by one of the interviewees "*you would use the cognitive capabilities in order to enhance the existing service. If it is a completely different service, then you might run into problems: regulatory in the sense of having an allocation or not*".

Furthermore, having additional mobile allocation in the UHF band in the future will make less room for TVWS. Besides, one of the interviewees from the TVWS group highlighted one of the issues that may delay deployment of TVWS, which is that many countries have not yet finalised the DSO process, as the deadline set by the RRC-06 conference is 2015 for the UHF band for many counties. Therefore, these countries are still waiting to finalise the transition before considering TVWS.

Six interviewees addressed a specific area of the interaction with the international regime, which is the issue of registering TVWS assignments in the MIFR and whether such registration could restrict TVWS by arguing that there is no need for such registration for several reasons. Firstly, TVWS could change too often due to its dynamic nature and therefore, it could not be registered. Secondly, registering assignment is only needed in case that international protection is required which is not the case of TVWS. In particular, one interviewee from the international broadcasting group explained that SDR and similar applications are never registered in the MIFR.

This is due to the fact that they do not have the potential of causing interference across the borders, which justifies this sort of status registration. One interesting point that was raised by one interviewee is that TVWS need to have information on the use of frequencies by other stations, which could be queried through the ITU-R MIFR. In other words, as TVWS devices could use a database to identify vacant frequencies in the UHF and the band usage in general, the MIFR could indicate such information as it accommodates information on the use of the different bands.

One other point that was raised during the interviews is whether the concept of TVWS should be included in the RR. One view was that such inclusion could make it easier to get acceptance for TVWS in some countries, and to achieve global harmonisation. As expressed by this quote: "*if the ITU actually said this band is for broadcasting and for opportunistic access, that might allow some regulators that were having difficulties in talking about white space access to now say, we have to open up that white space access because the ITU has told us*".

One other interviewee argued that the main problem with the TVWS is that the broadcasters are too powerful. On the other hand, the reason why Wi-Fi was successful is that no incumbent was resisting access of others to the ISM bands where the Wi-Fi operates. It was also mentioned that the interaction with the RR depends on the relationship of the country with the ITU-R. This was supported by another senior interviewee from the TVWS group who argued that many developing countries need measures from the ITU-R and whatever the ITU-R says, they just accept it blindly. On the other hand, some countries such as the US do not wait for the ITU.

He further emphasised the issue and argued that developing countries like the idea of international regulations authorising national regulations. These countries adopt the authoritarian tradition [17] where nothing is allowed unless the state specifically authorises it. Therefore, for these countries, TVWS is not allowed, as it is not covered in the RR. On the other hand, in some countries, which follow liberal traditions such as the US, everything is allowed unless the state specifically forbids. It was explained further that regulations radio have been traditionally following the authoritarian law as opposed to liberal law since the early days of radio when liberalism was not an acceptable option in the rivalry between the major powers. Figure 8-3 below is a display of the different issues previously mentioned in the format of causal map.

[17] Authoritarianism is a form of government characterised by absolute, unquestioning or blind obedience to authority, as opposed to a form of government characterised by individual freedom.

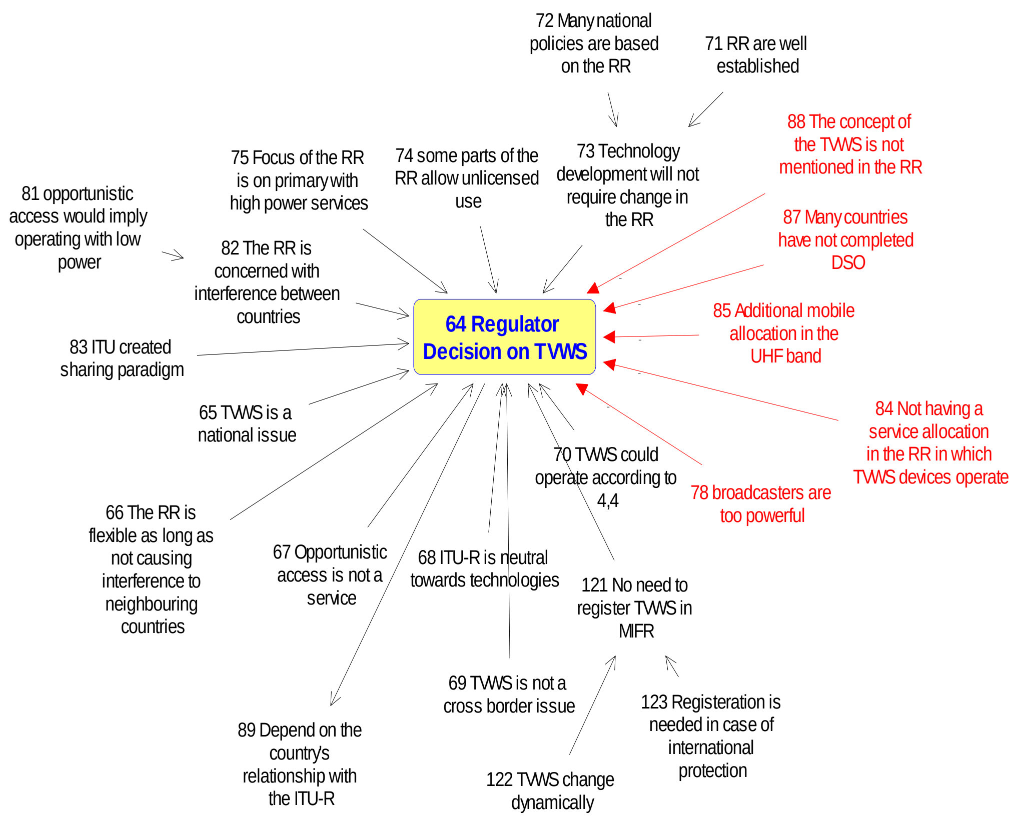

Figure 8-3: International Interviewees' Perception on the Interaction between International Regime and National Policies regarding TVWS

The analysis of the causal map of the international interviewees' on the issue reveals that the interaction between the international regime and national policies combines elements of restriction and flexibility as well. More specifically, elements of restriction include concept 84 which addresses the issue of having service allocation where TVWS devices could operate, and concept 85 which addresses the influence of having additional mobile allocation in the UHF band on TVWS. The map shows that the a priori planning concept could negatively influence TVWS deployment (concepts 87 and 79). Concept 121 shows that MIFR does not restrict TVWS, as there is no need for such registration.

In addition, the ITU-R is neutral towards technologies and therefore, technology development does not require changes in the RR. TVWS can operate on non-interference basis according to the ITU-R article 4.4. Finally, concept 74 tackles the assignment elements of the international regime and it is considered as a flexible element towards TVWS deployment where unlicensed use is allowed by the RR. Other general elements of restriction or flexibility are regarding whether TVWS should be included in the RR (Concepts 88, 82, 65, 66, 69). However, this was perceived to be dependent on the country, its relationship with its neighbours, and its perception on the TVWS concept (concept 89). **These observations imply that the interaction between the international regime and national policies regarding the concept of opportunistic access in the TVWS combines elements of restriction and flexibility. Meanwhile, the interaction is most greatly influenced by countries' perception on the TVWS concept and relationship with the ITU-R.**

8.5 *TVWS Radiocommunication Service Status*

One point that was critical to be examined is the radiocommunication service allocation status of the TVWS devices and whether they would operate on a primary, secondary, or non-interference basis. It should be noted that there was another element of service allocation status of the TVWS devices that was not examined due to the limitation in research time, which is whether these devices should operate as fixed, mobile or broadcasting service.

8.5.1 Egypt

The data analysis of the Egyptian case study showed diverse views regarding the issue under examination. Firstly, the NTRA interviewees did not reach an agreement on the status of these devices. One view was that they should be secondary service because if they are primary, both services of broadcasting and service where TVWS operate will claim protection from interference against each other unless they have different service status priorities. This was also the view of the Egyptian broadcasting interviewees who preferred a secondary status for TVWS while keeping the broadcasting service as a primary.

The second view was that the TVWS service status depends on the viewpoint of the regulators about the technology (primary, secondary, and co-primary) and that this is the reason why there were no regulatory measures needed from the ITU-R. A third view was that TVWS could be implemented on a primary basis in the UHF band because not all the band is used for broadcasting. However, this primary status could be under some restriction to protect the broadcasting service so that it would have a primary status with a secondary priority to broadcasting service. It was further clarified that secondary status for TVWS would not make its application effective. This is a main reason why these applications should be primary to have some priority in their work especially from neighbouring countries.

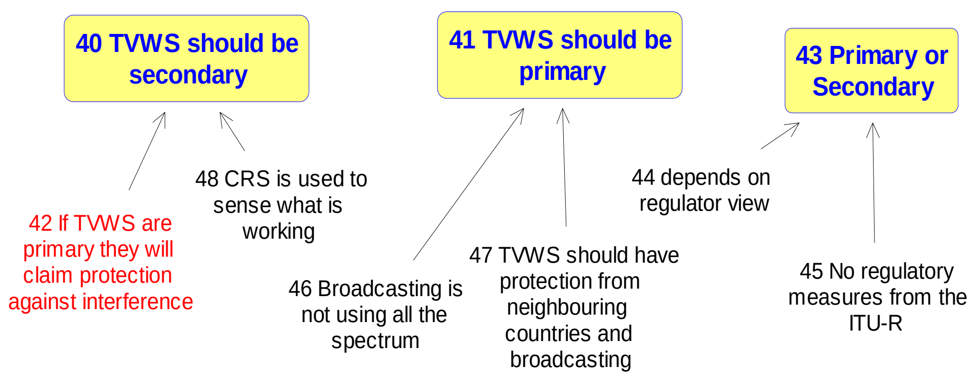

Figure 8-4: Perception on TVWS Service Status in Egypt

The analysis of the causal maps of the interviewees in the case of Egypt in Figure 8-4 shows that there is no agreement on the TVWS service status. Meanwhile, several observations could be noted. Firstly, protection is associated mainly with primary services (concept 42). This is why a primary status is needed to empower TVWS devices (concept 47) considering the low spectrum utilisation by the broadcasters in Egypt (concept 46). Furthermore, status was perceived a national issue (concept 44) especially that there are no guidelines from the ITU-R on that (concept 45). **These findings highlight that there are three different perceptions on the TVWS service status in**

Egypt: secondary status, primary status, and primary or secondary according to the perceived operation of TVWS.

8.5.2 UAE

Six interviewees out of nine of the UAE regulatory group were of the views that TVWS should have a secondary status. Moreover, it was clarified during the interviews with the regulator that the UAE added its name in the last WRC-12 in the footnote regarding using the 470 to 790 MHz for fixed and mobile service on a secondary basis for auxiliary production and program. Moreover, one interviewee from TRA of UAE argued that it is not clear whether TVWS devices would operate on a secondary or primary basis, as there is no formal definition for TVWS concept yet. Interviewees from the UAE broadcasters argued that these TVWS devices could operate as a secondary or primary according to the provided applications.

One interviewee from the mobile operator explained that if TVWS devices operate on a secondary basis, it would be valueless. In the interviewee's words "*you are selling nothing and nobody will take it*". One interviewee from TRA had the view that it is better for TVWS to operate in unlicensed bands (e.g. ISM) where they would have more available spectrum on shared access basis where no radio service has a priority over others. It was further explained that the bands 2.4 GHz and 5.8 GHz are dedicated bands in many countries as unlicensed and they do not have other primary services as ISM has the priority over all the other devices.

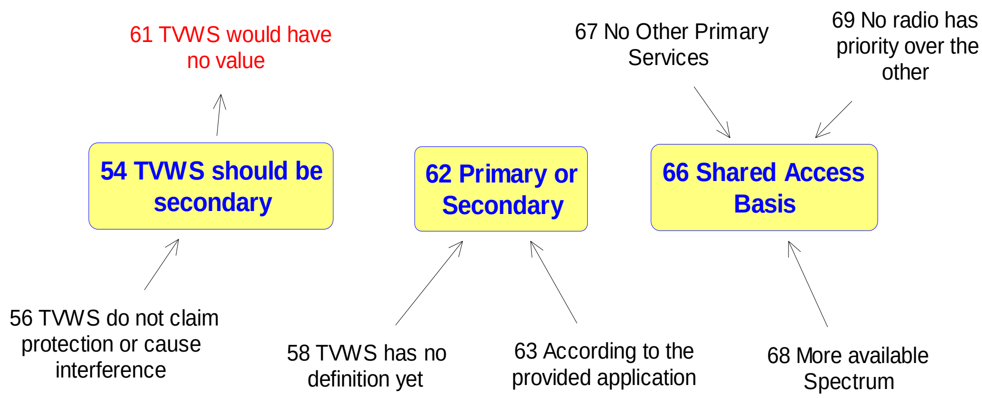

Figure 8-5: Perception on TVWS Service Status in UAE

The analysis of the causal maps of the interviewees in the case of UAE in Figure 8-5 shows that there is no agreement on TVWS service status. Firstly, it was acknowledged that a secondary status would make TVWS less valuable (concept 61), and that TVWS status depends mainly on its definition and provided application (concepts 58, 63). Secondly, some of TRA interviewees perceive TVWS devices to operate on a secondary basis as a reflection on how they will operate (concept 56). The third view reflects an operational perception for TVWS that is based on shared access rather than opportunistic access while not being limited to the TV spectrum bands. **These findings show that there are three different perceptions on the TVWS service status in UAE: secondary status, primary or secondary, and operating on shared access basis according to the perceived operation of TVWS.**

8.5.3 International Interviewees

Forty six interviewees from the international community did have three views on the service status of TVWS devices. The first view, which was shared by twenty interviewees, was that it should be based on secondary basis. In particular, interviewees from the TVWS group perceived the service status of TVWS devices as secondary due to the fact that the UHF band is quite valuable with its propagation characteristics to be allocated to unlicensed devices such TVWS as a primary service.

Most of the views from the broadcasting group were that TVWS should operate on a secondary basis for several reasons. Firstly, operating as a secondary service and having a license would imply control from the regulator but if it operates in a similar way to Wi-Fi on an unlicensed way, such control would be difficult to be implemented. Secondly, there is a need to provide protection to the broadcasting service and not claiming protection. Thirdly, one interviewee from the broadcasting group explained that the GE-06 plan does not allow having another co-primary service. This is due that in some cases, there is a deployed TV network for several years and introducing another service would mean re-planning the broadcasting frequencies. This is the reason why TVWS can only operate on a secondary basis.

Additionally, most of the views from the mobile group supported having secondary status for TVWS due that TVWS devices have low power and that the ITU-R is only concerned with issues at border areas. As expressed by one of the interviewees "*Secondary, definitely, the only reason broadcasters can listen to you talking about TV white space is because they're secondary*". Other reasons for having a secondary status for TVWS include giving TVWS some protection against other secondary services that may be allocated later on. More specifically, when two services are allocated in the same spectrum band in the RR on the same basis (primary or secondary), priority is given to the firstly allocated service.

The second view, which was shared by twenty interviewees, is that TVWS could operate on non-interference and non-protection basis according to the ITU-R Article 4.4 for different reasons. As expressed by this quote "*It is not secondary, it is below secondary, you cannot cause interference to secondary services*". The first reason is to wait until TVWS has a clear definition according to the RR as even stations of a secondary service have a definition in the RR. Secondly, it was further explained that while operating these devices, you cannot seek protection from neighbouring countries and they are used in low power applications. Thirdly, because TVWS work in opportunistic way, there would be no implication to some extent on their status. This is due that it becomes a matter of national regulator to ensure that these applications are not causing interference.

Another view is that from international regulation's point of view, there is no status, because these systems are not mentioned in the RR. In addition, it was clarified that an allocation in the RR is only needed in case of protection requirement for such application on the international level. It was also argued that TVWS is a national decision. In addition, this option was perceived to be optimum especially if there is no exiting allocation where TVWS could operate under. In other words, in case a country does not have a service allocation in the RR where TVWS devices could operate (e.g. secondary mobile allocation), these devices could operate on a non-interference basis.

The third view, which was shared by six interviewees, was that the TVWS status is related to a national decision on what type of systems is using those TVWS devices. Therefore, they could be associated with primary or secondary allocation. A senior interviewee from the regulatory group argued that service status is not related to the concept of opportunistic access and that the service status depends on the spectrum bands. Therefore, TVWS could be primary or secondary according to the status of the band and also according to the national laws and the definition of TVWS. He further explained that the national status of these devices is independent from the international status.

As expressed in his words "*In national licensing, the TVWS could be primary but you'll have to protect the broadcasting, so this status in the RR does not say anything about the status on national bases…people are mixing up the national decisions with the international decisions*". Another interviewee linked between the issue of not registering TVWS devices in the MIFR and the freedom regulators have regarding TVWS service status on the national level. In the interviewee's words "*If it is not registered in the MIFR, it is up to national regulator to think of primary or secondary status*". The previous three views are displayed in the following causal maps in Figure 8-6.

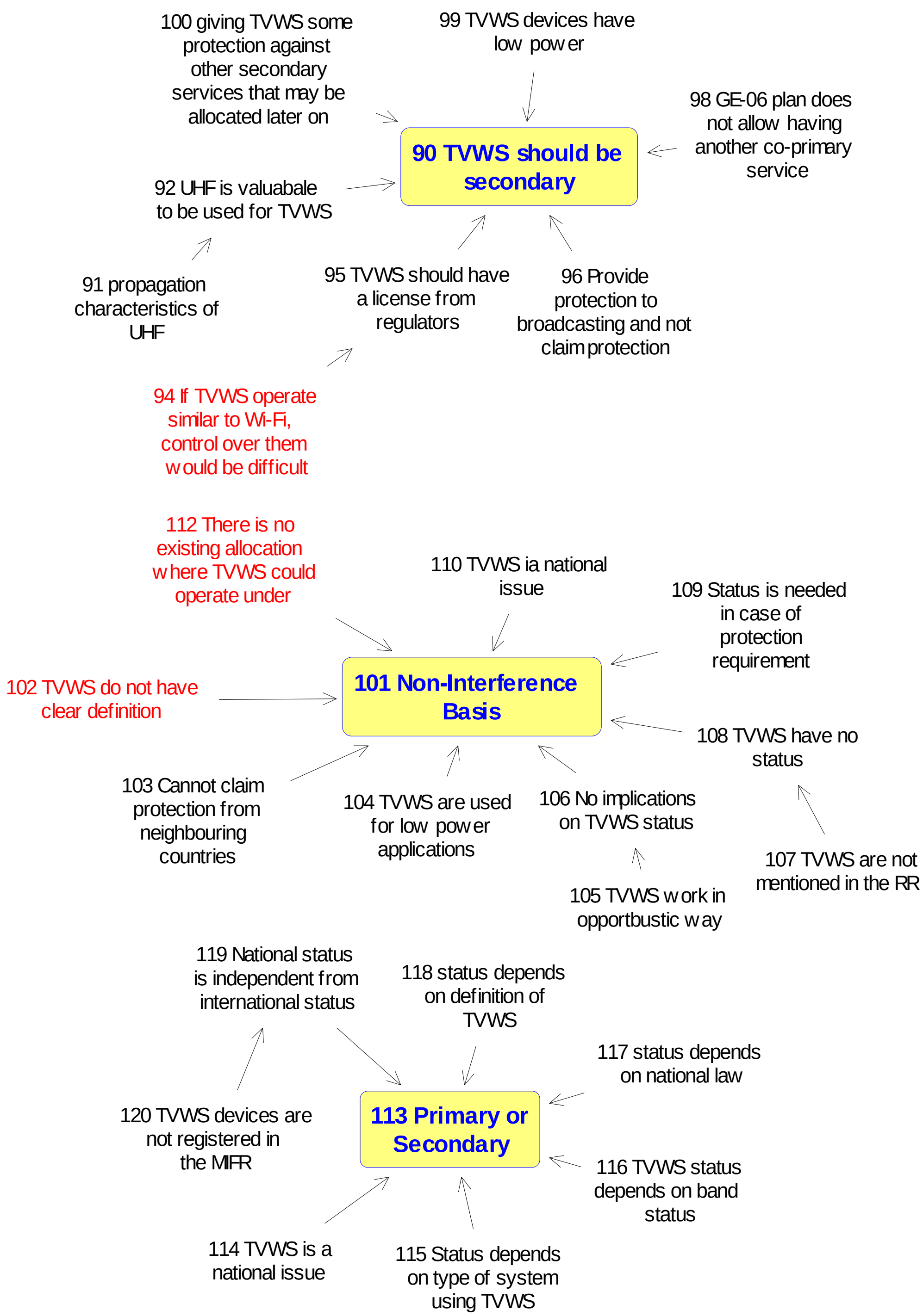

Figure 8-6: International Interviewees' Perception on TVWS Service Status

The analysis of the causal map of the international interviewees' on the TVWS service status shows that the status perception is related to the perception on the TVWS operation and application. Firstly, regarding the perception of TVWS status as a secondary service, concept 100 reveals that having a secondary service is a plus for TVWS devices as it provides protection against other secondary services that may be allocated in the future. Moreover, concepts (96, 98) show that a secondary service is essential in order not to negatively influence the a priori planning of the broadcasting service in the UHF band. On the contrary, concepts (99, 92) highlight the perception on TVWS devices as not critical applications. In addition, concept 95 reveals a critical point that having a status is important for regulators to have control over these TVWS devices. Furthermore, concept 119 conceals an interesting perception, which is that countries are free to have different services priorities than those in the RR.

Regarding the operation of TVWS on non-interference basis, concepts (102, 108) reflect the view of the prematurity of TVWS and their absence from the RR. Concepts (103, 104, 106, 109, and 110) show the perception of some of the international interviewees on the operation of TVWS as low power applications that do need protection and work on opportunistic way on the national level. Concept 112 shows that non-interference basis is a second option in case there is no allocation where TVWS devices could operate within (e.g. mobile). With respect to the case of having a status depending on the situation, it was revealed that service status is a national decision according to a country's perception on TVWS, its internal circumstances, and the band status in this particular country. **These findings highlight that there are three different perceptions from the international interviewees on the TVWS service status: secondary status, non-interference basis, or primary or secondary according to the perceived operation of TVWS.**

8.6 *Perception of the WRC-12 A.I. 1.19*

This section focuses on the discussion related to WRC-12 A.I. 1.19, which is related to the regulatory measures to introduce CRS and SDR. This is important as both technologies could be used for the concept of opportunistic access in general or for the case of TVWS specifically.

8.6.1 Egypt

Before examining the issue from the Egyptian interviewees' perspective, it is important firstly to investigate the NTRA position during the WRC-12 regarding A.I. 19. The interviews showed that NTRA did not have a specific position on this issue during WRC-12 despite of the official position of the ASMG which called for a WRC-12 resolution to provide a framework for guidance on the study of CRS as well as guidance regarding how the use of CRS should be administered (ASMG, 2011b). In particular, at the beginning of the conference, there was a support from NTRA to the European countries and the US position in terms of having no regulatory measures introduced in the RR for SDR and CRS, and then NTRA changed its position to support the Russian argument which called for a resolution by the WRC-12 to have more studies to ensure that CRS will be implemented in any services without any interference.

It was also found upon the analysis of the data that the WRC-12 decision on A.I. 1.19 has limited impact on NTRA of Egypt. More specifically, while NTRA agreed on the conclusion on A.I. 1.19 that CRS are technologies and not a radiocommunication service, it was expressed that there is no effect of the decision because the TVWS concept is not under consideration and because the situation of the concept is not well known which makes the TVWS application not preferable in Egypt. This is in addition to the view that the deployment of mobile service would leave no space for the TVWS. One view from NTRA was that the issue was not clear during the conference because that was no specific requirements from the Egyptian administration although the Arab countries were one of the initiators of studying the issue. It was also expressed that the regulator perceived the AI 1.19 discussion as a political one between Russia and the US.

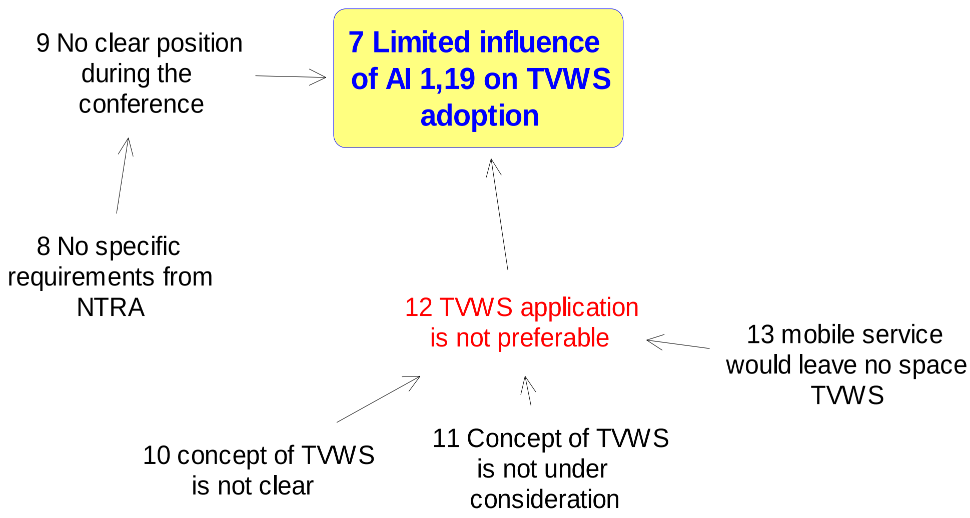

Figure 8-7: Perception on the Influence of WRC-12 Decision on A.I. 1.19 in Egypt

The analysis of the causal map in Figure 8-7 on the influence of WRC-12 decision on A.I. 1.19 in Egypt shows that such influence is limited due mainly that the TVWS concept is not preferable in Egypt (Concept 12) and because NTRA did not have clear position on the issue during the WRC-12 (Concept 9). **These findings show that the influence of WRC-12 decision on A.I. 1.19 on TVWS adoption in Egypt is limited.**

8.6.2 UAE

Interviewees from the UAE TRA confirmed the explanation provided in the Egyptian case study that the Arab countries and Russia were in favour of having SDR and CRS defined as a service during the WRC-12 in order to be in conformity with the RR. On the other hand, some European countries have already started using these systems and therefore, they did not want to have regulations from the ITU-R that may restrict them. Eventually, it was agreed to have the WRC-12 recommendation on CRS in trading with other positions such as the allocation of mobile service in the 694-790 MHz band. It was further explained that the RR deal with services and not technologies except in rare cases. As expressed by one of the interviewees “*If we said service, then it means that the RR must get involved. But if we said technology or system or other words, then the radio regulations are not involved*”.

Regarding the influence of the decision of the WRC-12 on A.I. 1.19 on UAE adoption of TVWS, interviewees from TRA of UAR did have different views on such influence from the regulator. One view perceived the decision as providing the regulator with the choice to deploy CRS systems if needed which is not the case for UAE. This is due that there are no congested bands or lack of spectrum. The second view was that there was a recommendation issued from the WRC-12 to continue studying the regulatory impacts of these systems and at the end of the studies, there would be a confirmation that there is no regulatory impact.

The third view was that the influence is not clear because the TVWS concept is not under consideration as they are in a phase of transition considering that digital TV has not been launched, and analogue TV is still in operation. There is an additional challenge that was expressed which is the ducting phenomena, which adds additional burdens to study the concept well before its introduction. The fourth view is that the ITU has nothing to do with the accepting technologies, as there are procedures in the UAE to accept new technologies, which include checking CEPT standards or getting certificate from manufactures.

One view from the mobile operators was that CRS are already considered and used by operators as a technology but within the allocated radiocommunication service. However, for using CRS on a service basis, this should be decided by the regulator regardless of the WRC decision. Regarding the influence of the decision of the WRC-12 on A.I. 1.19, it was indicated that the decision does not encourage countries to adopt TVWS. Instead, it is financial benefits that would motivate such adoption. Figure 8-8 below shows the causal map representing the different views.

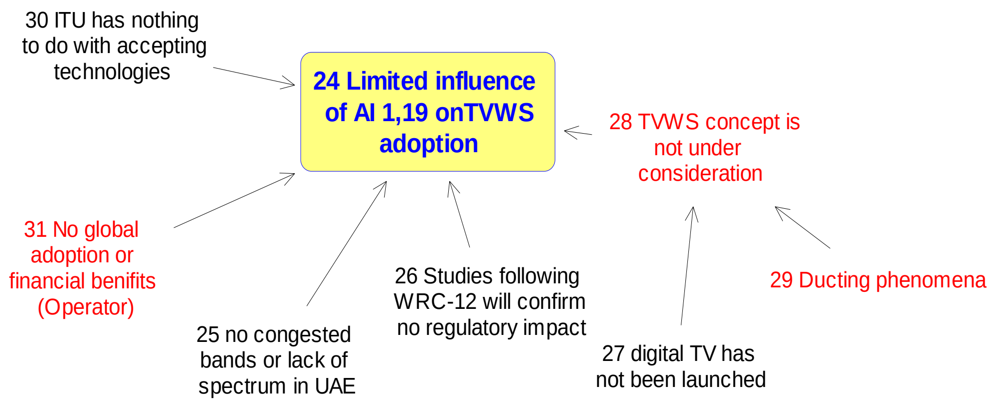

Figure 8-8: Perception on the Influence of WRC-12 Decision on A.I. 1.19 in UAE

The analysis of the causal map in Figure 8-8 on the influence of WRC-12 decision on A.I. 1.19 in UAE shows that such influence is limited due mainly that the TVWS concept is not under consideration in UAE for the regulator and operators as well (concepts 28, 31) and because TRA faces no congestion in spectrum (concept 25). Moreover, it seems that while there is a view that ITU is not concerned with technologies (concept 30), there is another view that studies following WRC-12 will confirm that (concept 26). **This leads to a general conclusion that the influence of WRC-12 decision on A.I. 1.19 on TVWS adoption in UAE is limited.**

8.6.3 International Interviewees

Regarding the discussion over A.I. 1.19 during WRC-12, it was explained by one of the interviewees that the debate at the WRC-12 was between Russia who wanted to have a resolution in the RR and between the European countries and the US who called for a resolution from the RA-12 to call for further study[18]. One interviewee from the WP1B, which was responsible of the A.I. 1.19 before WRC-12, explained that the reason for not having a WRC resolution on CRS was that there were no sufficient studies of the issue. Instead, the WP1B only managed to put definitions for CRS and

[18] Unlike WRC resolutions, RA resolutions are not binding.

SDR. Therefore, it was perceived premature to have a resolution on CRS. As expressed by this quote "*Imagine that you still define something, and you want me to give you a resolution! About what?*"

Another senior interviewee from the regulatory group clarified that during WRC-12, the Arab countries had concerns related to interference from these systems. Eventually, everyone agreed that further study is needed which was addressed by ITU-R resolution 58 from the RA-12. Moreover, the WRC-12 recommendation showed that CRS should follow the RR and it was a compromise that everybody was happy with.

Regarding the influence of the WRC-12 decision on A.I. 1.19 on TVWS adoption, the data analysis of the interviews with the international interviewees shows three distinct views by twenty seven interviewees. The first view, which was shared by seventeen interviewees, was that the decision does not encourage nor restrict the TVWS concept adoption because implementation of such concept could be accommodated within the current RR without any modification, as it is a national issue. It was further explained that the RR is a relationship between countries and opportunistic access is mainly a problem of protection inside a country between different usages. Moreover, one interviewee explained that CRS and SDR are already deployed in mobile cellular technologies.

The ITU-R interviewees were of the views that the decision does not restrict implementing TVWS and it was also expressed that there should not be any regulation on CRS because it is a radio which is able to adapt itself with the regulation which prevails in each frequency band. In an interviewee's words "*Cognitive radio is something which adapts itself to the RR and not the opposite*". It was also argued that the A.I. 1.19 was of a concern to countries that have a lot of cellular phone development and look at the next stages of cellular phones. On the other hand, the developing countries did not have specific interest. Therefore, there was no impact on them. The broadcasting group's interviewees agreed to the decision as they think CRS would be introduced independent of the WRC decision. Another view was that it does not encourage but it rather it permits such implementation.

The second view, which was shared by eight interviewees, is that such decision of the WRC-12 on A.I. 1.19 could be considered as encouragement for TVWS adoption because CRS is one of the ways to implement and use the TVWS, and to introduce opportunistic access in general. More specifically, the decision was a good outcome because it provided a definition for CRS and SDR, it did not stop opportunistic access, and it did recognise rather than restrict CRS and SDR. The decision was also perceived to give the developer of the technology a little bit of leverage over regulators who are not knowledgeable.

One senior interviewee from the TVWS group pointed out one advantage which is that at least the RR did not put barriers and it gave recognition to CRS and DSA and that the RR support them. As expressed by his quote "*The alternative could be that ITU could have just said that we are not ready, and sorry, we do not want to discuss it anymore*". Therefore, he perceived the WRC-12 decision to be a good outcome for the industry of TVWS. The third view, which was shared by two interviewees is that, the decision could be considered as discouragement. Firstly, the decision to have further study could lead to postponing the issue, as administrations will not adopt it because there are studies in the ITU. Additionally, one view was that encouragement could be in the form of setting aside band for CRS.

It is worth mentioning that the data analysis showed also that the influence of the decision depends more on the regulators themselves. In particular, interviewees from the US and UK explained that their regulators consider that unless the RR explicitly said you cannot do something, then you could can go ahead and do it. On the other hand, for some countries, until it is mentioned in the RR they cannot implement it. This was confirmed by one interviewee from the TVWS group who explained that some countries tend to be more conservative and will need some further clarification from the ITU, and for these countries, the WRC-12 decision on CRS could be considered as a non-decision rather than a decision. As expressed in his quote "*they're going wait for ITU to say something more definitive*". On the other hand, some other countries would look at the ITU and determine that they can move forward without further direction. The different views are presented in Figure 8-9 below.

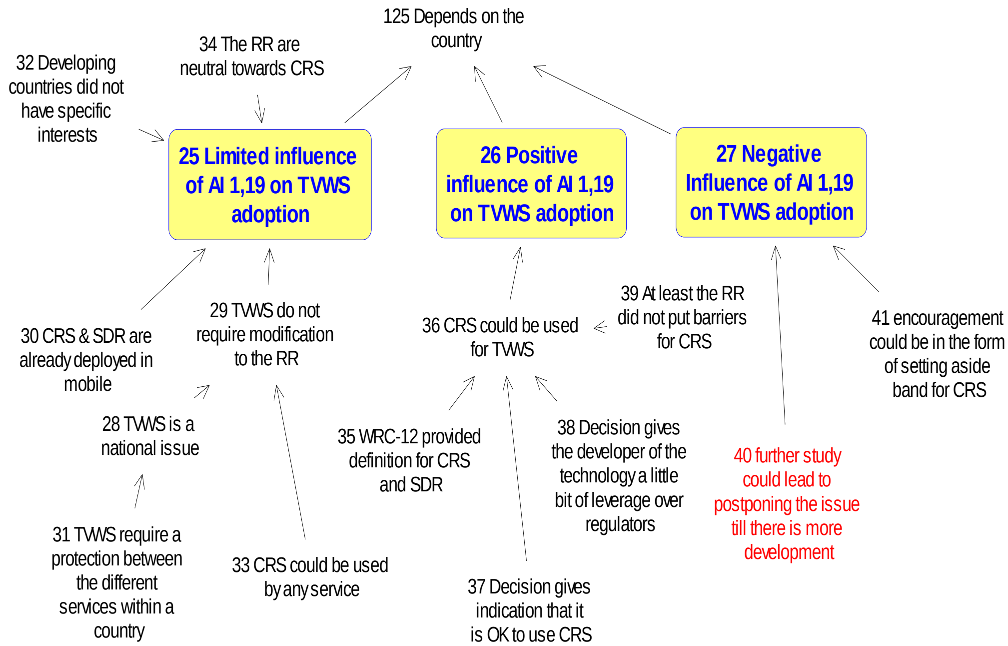

Figure 8-9: International Interviewees' Perception on the Influence of WRC-12 Decision on A.I. 1.19

The analysis of the causal map in Figure 8-9 on the influence of WRC-12 decision on A.I. 1.19 on the TVWS concept for the international interviewees reflects the different expectations of the interviewees from the ITU-R. In particular, for some interviewees, the decision was not enough to boost TVWS deployment (concepts 40, 41). On the other hand, the decision was perceived by others as indirect support to CRS (concepts 35, 37, 38, 39), which could be used for TVWS deployment (concept 36). The third view is a reflection of the perception of the neutral position of the ITU-R towards CRS and TVWS. In addition, it is related to the lack of interest of some countries in the discussion on A.I. 1.19 during WRC-12. Additionally, the influence depends in general on the countries' relationship with the ITU-R (concept 125). **This leads to a general conclusion that there are three different perceptions on the influence of WRC-12 decision on A.I. 1.19 on TVWS adoption from the perspectives of the international interviewees: limited, positive, and negative. Meanwhile, the influence is most greatly impacted by countries' relationship with the ITU-R**

8.7 *Comparison with the Case of R-LAN in the 5 GHz band*

While the third research question focuses on the issue of opportunistic access in the TVWS in the UHF band, it was inevitable during the interviews to address the case of having mobile allocation in the 5 GHz band for the application of R-LAN that was approved at WRC-03. This was for the purpose of comparing the international regulatory measures required for the TVWS with these special ones already adopted for the use of R-LAN in the 5 GHz as explained in Chapter 3. In particular, several interviewees commented on why the ITU-R decided some regulatory measures for the case of R-LAN in the 5 GHz in the WRC-03 unlike the case of CRS in WRC-12. It was also highlighted during the interviews that the mobile allocation in the 5 GHz was the first time to give unlicensed use (permitted application) a status of a service. Therefore, it was important to examine whether the interviewees think similar approach is needed for the TVWS.

In order to understand the origin of the issue, one interview was conducted with one senior interviewee who was the main proponent of the R-LAN issue during WRC-03. He described the topic development before the WRC-03 and explained that the issue was that the band was used by the military. Following that, the private sector thought of developing a technology to sense use of the band and shut off the device when the band was being used by a military radio, and there was cooperation between the military and the private sector to achieve that. The interviewee considered the WRC-03 allocation, as an innovation that managed to open up the spectrum in most parts of the world that otherwise would not have been available for commercial use.

Another interview was conducted with one senior interviewee who participated in the WRC-03 and observed the issue closely. It was explained that the idea was not to put R-LAN under a mobile or fixed service because the difference between the two services is blurring. Instead, the main aim was the global harmonization of the band. It was clarified that the developing countries were not against the discussion but it was the developed countries, which used part of the band for radar. Another clarification is that the allocation aimed to give more certainties for the band users for the future in case of potential future allocations in the band. The band had already at the time of the WRC-03 several existing primary allocations so that R-LAN was given a primary status but in a secondary priority compared to these existing allocations. In the next three sections, we shall explore the views of the Egyptian and UAE case studies in addition to the international interviewees on the comparison between the TVWS case and R-LAN in the 5 GHz.

8.7.1 Egypt

Interviewees from NTRA pointed out that some technology restriction may be required but the use of DFS specifically should be subject to study. This is due that measures such DFS are used mainly for indoor usage unlike the case of TVWS. In particular, TVWS devices operate in the UHF band, which is suitable, more for outdoor operation with higher transmitted power. In other words, interviewees from NTRA perceived that the use of DFS is associated with indoor usage, which is not the case for TVWS. Concern was expressed regarding that some users may choose not to use DFS.

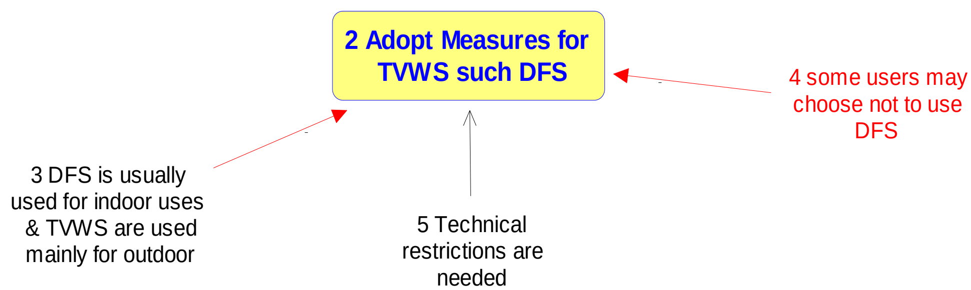

Figure 8-10: Perception on the Need to Adopt Measures for TVWS such DFS in Egypt

The causal map in Figure 8-10 shows that interviewees from Egypt are not in favour of similar measure for TVWS such as DFS except for the need of defining technical restrictions on TVWS deployment (concept 5). The map reveals also perception of NTRA on TVWS as outdoor solution and also on DFS as a difficult measure to be enforced. **Therefore, there is no need to adopt measures for TVWS such DFS in Egypt.**

8.7.2 UAE

The examination of the data on the UAE case study showed that Wi-Fi and TVWS are categorised differently by TRA as the former and later are categorised as shared access and opportunistic access respectively. In particular, while in the former no radio service has priority over others, in the later, once the primary user is not using the spectrum, the opportunistic user is allowed to use the spectrum. It was also expressed that shared access is more spectrum efficient than opportunistic access. In particular, shared access was perceived not to request a lot of spectrum to communicate and to have high data throughput while not causing interference internally. On the other hand, opportunistic access depends on the availability of the spectrum that is not used.

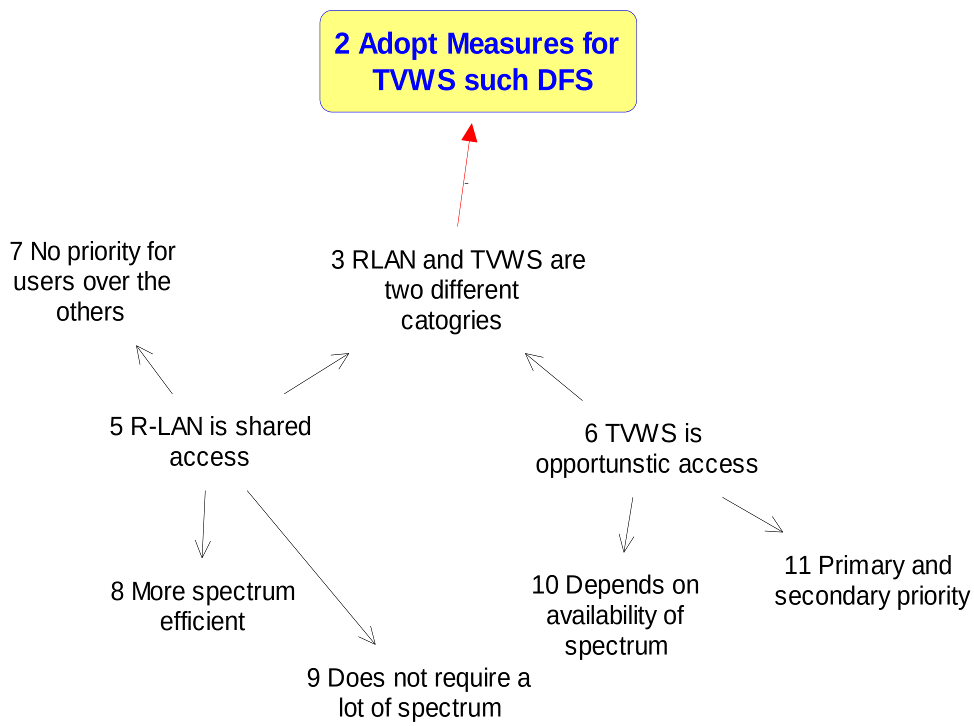

Figure 8-11: Perception on the Need to Adopt Measures for TVWS such DFS in UAE

The causal map in Figure 8-11 shows that interviewees from UAE are not in favour of similar measure for TVWS such as DFS mainly because TVWS and R-LAN are considered two different categories of use (concept 3). It also reveals that the opportunistic access concept adopted in TVWS is perceived less efficient than how R-LAN operate for several reasons (concepts 7, 8, 9). **Therefore, there is no need for similar measures for TVWS such as DFS in UAE.**

8.7.3 International Interviewees

The data analysis of the views extracted from twenty international interviewees showed two different views on whether such measures are needed for the case of TVWS. On the one hand, twelve interviewees expressed that having similar measures may not be needed for the TVWS case for several reasons. Firstly, the TVWS issue is not clear and still premature. This is due that the 5 GHz was a special case in need for a global market in a similar way to the IMT identification. In particular, unlike the case of the R-LAN, the TVWS has not yet a clear global market as it is specified by some countries for rural broadband coverage which is already provided by mobile with less cost. Therefore, what could be needed in the case of TVWS is a recommendation allows administration to negotiate on the border.

Secondly, the use of DFS was related to sharing complications between radar systems and R-LAN in order to ensure that they could co-exist. One interviewee explained that one main difference between the TVWS and the R-LAN in the 5 GHz is that the latter utilised bands where there are operations by satellite services so that it is not enough to get agreement with neighbouring countries. This is in contrary to the TVWS devices which operate in bands used by terrestrial services only and therefore, interference could be resolved mainly on the border areas only.

One interviewee explained that until there is a mobile allocation in the band, you cannot have similar measures and you will work according to the RR Article 4.4, which cannot have associated conditions. One other view was that there is no need to put such detail in the RR. It was also expressed that the TVWS concept in the UHF band is perceived as a short-term solution. One point that was clarified is that DFS has shortcomings as it has limited ability to adapt in the future. Therefore, if TVWS devices radios are querying a database for policy instead of adopting DFS, they could adapt over time to work with new versions of radar or other technologies in that band.

One the other hand, eight interviewees suggested that having similar measures for the case of TVWS would achieve economies of scales, reduce the cost of the equipment, and give strong directions to the industry that this frequency is secured to develop this specific service. As expressed by one interviewee "*It would be helpful to the ITU to say that you can have opportunistic access to TV bands, and here are the mechanisms we recommend*". This was confirmed by one interviewee from the TVWS group who argued that such decision would improve the ecosystem because the more consistent the use and availability of bands around the world, the more investment radio providers will put into it.

On the difference between IMT spectrum identification and R-LAN mobile service allocation, one interviewee from the mobile industry group explained that they are different because IMT identification implies moving the incumbent from the band and makes them available for IMT. On the other hand, R-LAN operates on a non-interfering basis without affecting the incumbent services. In addition, one interviewee pointed out that there is no association between the allocation and having opportunistic access as while R-LAN in the 5 GHz has a primary service allocation, it is considered by many regulators to operate according to the RR Article 4.4.

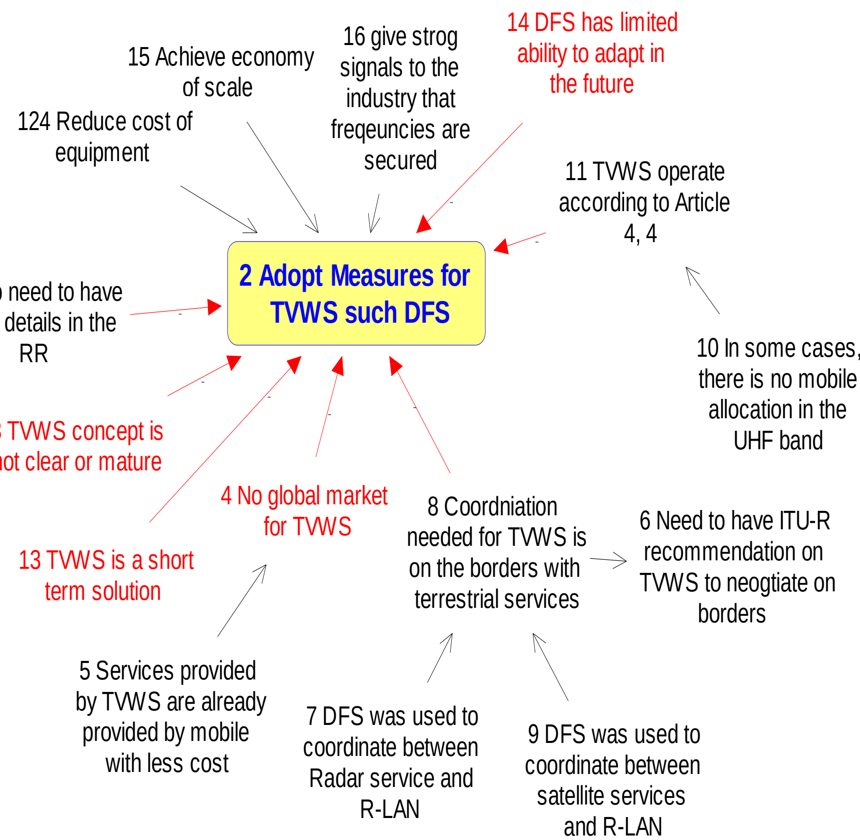

Figure 8-12: International Interviewees' Perception on the Need to Adopt Measures for TVWS such as DFS

The analysis of the causal map in Figure 8-12 of the international interviewees' perspectives shows that the views on having measures for TVWS such as DFS reflects the views on the concept of TVWS per se. For instance, some were of the views that such measures are not needed because of deficiencies in the TVWS concept (concepts 3, 4, 13). Some other views were that such measures are not suitable for the operation of TVWS, which is different than the case of R-LAN in different aspects. In particular, the 5 GHz band where R-LAN operates needs co-ordination with different types of services than those operating in the UHF band (concepts 7, 9). On the contrary, TVWS devices need coordination on borders with terrestrial services (concepts 6, 8).

Other views reflect deficiencies in the measures adopted for R-LAN, which may restrict the concept of opportunistic access (concept 14). Moreover, concept 11 reveals the influence of service status of TVWS on the need for regulatory measures similar to the case of R-LAN. On the other hand, concepts (15, 16, and 124) show the perception that these measures used for R-LAN in the 5 GHz could enable similar success and wide adoption for the case of TVWS. **These findings show that there are two distinct views on the need for measures for TVWS such as DFS based on perception on TVWS service status, deficiencies of TVWS, deficiencies of DFS, difference between operation of R-LAN and TVWS, and positive influence of such measures on the TVWS adoption.**

8.8 *Conclusions*

This chapter has addressed the interaction between the international spectrum management regime and national spectrum management policies with a focus on the case of opportunistic access in the TVWS. In general, both NTRA of Egypt and TRA of UAE expressed several concerns over TVWS including interference and security concerns, which reflect the lack of confidence in the TVWS concept and the importance of exclusive access for the regulator to handle unauthorised access. Meanwhile, operators in the two countries seem to prefer exclusive access to the spectrum to guarantee service quality and to secure their investments.

The examination of the applicability of the concept in Egypt shows that by law, only the broadcaster can access spectrum allocated exclusively to broadcasters. However, it seems that there is a shortage in the spectrum available to the operators, which may motivate them to consider the TVWS solution. In the UAE, while there is a similar deployment to the TVWS in the broadcasting spectrum, such deployment does not cause interference due to its static nature and fixed structure. Moreover, the additional mobile allocation in the broadcasting spectrum has deceased significantly the TVWS chances. In addition, unlike the case of Egypt, none of the operators showed interest in the concept probably because there is much available spectrum for the two operators.

The analysis of the Egyptian interviews regarding the interaction with the international regime shows the followings. Firstly, the interaction between the international regime and Egypt spectrum policy does not prevent Egypt from deploying TVWS in practice. However, there are concerns related to delay of deployment or interference. In particular, the a priori planning of the broadcasting service in the UHF band may delay or cause interference to the deployment of TVWS. Furthermore, not having an alternative allocation where TVWS could operate is a restriction. On the other hand, elements of flexibility include the possibility of TVWS to operate on secondary basis. Besides, Egypt has ultimate flexibility as long as there is no interference to other countries.

Secondly, there are three different perceptions on the TVWS service status in Egypt: secondary status, primary status, or primary or secondary according to the perceived operation of TVWS. One view is that TVWS could operate on a secondary basis in order not to claim protection against interference. The second view is that protection is associated mainly with primary services. This is why a primary status is needed to empower TVWS devices considering the low spectrum utilisation by the broadcasters in Egypt. The third view is that status was perceived a national issue especially that there are no guidelines from the ITU-R.

Thirdly, the influence of WRC-12 decision on A.I. 1.19 on TVWS adoption in Egypt is limited mainly due that the TVWS concept is not preferable in Egypt and that NTRA did not have clear position on the issue during the WRC-12. Fourthly, there is no need to adopt measures for TVWS such DFS in Egypt. More specifically, while there is a need to define technical restrictions on TVWS deployment, measures such as DFS are used for indoor operation while TVWS is an outdoor solution, and they are difficult to be enforced.

The analysis of the UAE interviews reveals the followings. Firstly, the interaction between the interaction between the international regime and UAE spectrum policy does not prevent UAE from deploying TVWS in practice. Firstly, there is flexibility in case there is an allocation in the UHF band in addition to the broadcasting service, which is the case for UAE. The RR provide the UAE with ultimate flexibility providing no interference is caused to other countries However, there are concerns related to the influence of additional mobile allocation in the 694-790 MHz on the broadcasting services in the UHF band.

Secondly, there are three different perceptions on the TVWS service status in UAE: secondary status, primary or secondary, or operating on shared access basis according to the perceived operation of TVWS. The first view is that TVWS devices should operate on a secondary basis, as they do not cause interference or claim protection. The second view is that the TVWS status depends mainly on its definition and provided application, and the third view is that TVWS devices should operate on shared access basis.

Thirdly, the influence of WRC-12 decision on A.I. 1.19 on TVWS adoption in UAE is limited due that the TVWS concept is not under consideration in UAE for the regulator and operators as well. Additionally, TRA faces no congestion in spectrum, and the ITU-R is perceived to be not concerned with technologies. Fourthly, there is no need for similar measures for TVWS such as DFS in UAE. This is due that TVWS and R-LAN are considered as two different categories of use where TVWS is opportunistic access and R-LAN is shared access.

The analysis of the international interviews highlights the following findings. Firstly, the international regime and national policies regarding the concept of opportunistic access in the TVWS combines elements of restriction and flexibility as well. Meanwhile, the interaction is most greatly influenced by countries' perception on the TVWS concept and relationship with the ITU-R. Restrictive elements include not having a service allocation where TVWS devices could operate, having additional mobile allocation, and the a priori planning of the broadcasting service in the UHF band. On the other hand, TVWS can operate on non-interference basis according to the ITU-R article 4.4. Moreover, unlicensed operation is allowed by the RR on the condition of not causing interference.

Secondly, there are three different perceptions from the international interviewees on the TVWS service status: secondary status, non-interference basis, and primary or secondary according to the perceived operation of TVWS. The first view is that the operation of TVWS on non-interference basis reflects the views of the prematurity of TVWS. The second view is that non-interference basis is considered to be a second option in case there is no allocation where TVWS devices could operate within. The third view is that service status is a national decision according to a country’s perception on TVWS, its internal circumstances, and the band status in this particular country.

Thirdly, there are three different perceptions on the influence of WRC-12 decision on A.I. 1.19 on TVWS adoption from the perspectives of the international interviewees: limited, positive, and negative. Meanwhile, the influence is most greatly impacted by countries’ relationship with the ITU-R. The first view is that the decision was not enough to boost TVWS deployment. The second view is that the decision is perceived as indirect support to CRS, which could be used for TVWS deployment. The third view is that the influence limitation is a reflection of the perception of the neutral position of the ITU-R towards CRS and TVWS.

Fourthly, there were two distinct views on the need for measures for TVWS such as DFS based on perception on TVWS service status, deficiencies of TVWS, deficiencies of DFS, difference between operation of R-LAN and TVWS, and positive influence of such measures on the TVWS adoption. On the one hand, such measures are not needed because of deficiencies in the TVWS concept, and not suitable for the operation of TVWS, which is different than the case of R-LAN in different aspects. On the other hand, measures used for R-LAN in the 5 GHz could enable similar success and wide adoption for the case of TVWS. The main findings related to the concept of opportunistic access in the TVWS are summarised in Table 8-1 below.

Case Studies	**Main Conclusions**
Egypt	• NTRA of Egypt expressed several concerns over TVWS. • Operators in Egypt are in favour of exclusive access to the spectrum. • Only the broadcaster can access spectrum allocated exclusively to broadcasting service by law. • There is a shortage in the spectrum available to the operators,

	which may motivate them to consider the TVWS solution. • The interaction between the international regime and Egypt spectrum policy does not prevent Egypt from deploying TVWS in practice. However, there are concerns related to delay of deployment or interference due to the a priori planning of the broadcasting. • There are three different perceptions on the TVWS service status in Egypt: secondary status, primary status, or primary or secondary according to the perceived operation of TVWS. • The influence of WRC-12 decision on A.I. 1.19 on TVWS adoption in Egypt is limited. • There is no need to adopt measures for TVWS such DFS in Egypt.
UAE	• TRA of UAE expressed several concerns over TVWS. • Operators in UAE are in favour of exclusive access to the spectrum. • There is a similar deployment to the TVWS in the broadcasting spectrum in UAE. • The additional mobile allocation in the broadcasting spectrum deceases significantly the TVWS chances in UAE. • None of the operators in UAE showed interest in the TVWS concept probably because there is much available spectrum for the two operators. • The interaction between the international regime and UAE spectrum policy does not prevent UAE from deploying TVWS in practice. However, there are concerns related to the influence of additional mobile allocation in the 694-790 MHz on the broadcasting services in the UHF band. • There are three different perceptions on the TVWS service status in UAE: secondary status, primary or secondary, or operating on shared access basis according to the perceived operation of

	TVWS • The influence of WRC-12 decision on A.I. 1.19 on TVWS adoption in UAE is limited. • There is no need for similar measures for TVWS such as DFS in UAE.
International Interviewees	• The interaction between the international regime and national policies regarding the concept of opportunistic access in the TVWS combines elements of restriction and flexibility as well. Meanwhile, the interaction is most greatly influenced by countries' perception on the TVWS concept and relationship with the ITU-R. • There are three different perceptions from the international interviewees on the TVWS service status: secondary status, non-interference basis, and primary or secondary according to the perceived operation of TVWS. • There are three different perceptions on the influence of WRC-12 decision on A.I. 1.19 on TVWS adoption from the perspectives of the international interviewees: limited, positive, and negative. Meanwhile, the influence is most greatly impacted by countries' relationship with the ITU-R. • There were two distinct views on the need for measures for TVWS such as DFS based on perception on TVWS service status, deficiencies of TVWS, deficiencies of DFS, difference between operation of R-LAN and TVWS, and positive influence of such measures on the TVWS adoption.

Table 8-1: Summary of Research Findings for the Concept of Opportunistic Access in the TVWS

9 Conclusions

9.1 *Introduction*

Largely overlooked in the current debates on spectrum management is the influence of the international spectrum management regime on national policy reform. To address such influence, this thesis has investigated main research question 'How do the international radio spectrum management regime and national radio spectrum management policies interact?' More specifically, the thesis has handled the interaction with a focus on three main concepts: radiocommunication service allocation flexibility, technology selection neutrality, and opportunistic access in the TVWS. These concepts were selected because they are main components in the alternative spectrum management approaches to the traditional 'command and control'.

A multiple-cases strategy was adopted where the focus is on two of the Arab countries, Egypt and UAE. Primary data was mainly collected through semi-structured interviews with 113 participants from the two cases studies and the international spectrum management domain. The main research findings are presented in Section 9.2. Section 9.3 then highlights the research contributions theoretically and practically. Finally, Section 9.4 shows the limitations of the research following by proposals for future research in Section 9.5.

9.2 *Key Findings*

In general, this research has addressed three main research questions with a focus on two case studies, Egypt and UAE, while taking into account the views of the international interviewees. In particular, this thesis has investigated the interaction between the two spheres of national policies and the international regime in order to discover points of impacts on domestic preferences.

The first research question '**how do the international radio spectrum management regime and national radio spectrum management policies interact with regard to radiocommunication service allocation flexibility?**' addresses a main element of the spectrum market and spectrum commons approaches to national spectrum management.

The investigation of the issue from the perspectives of the international interviewees has revealed that the RR restrict national regulators’ flexibility regarding radiocommunication service allocation only towards neighbouring countries unless a country reaches an agreement with these countries, and also in bands where special radiocommunication services operate. Additional flexibility could be provided via having multiple services allocations in the same band or through having another allocation on secondary basis, via footnotes, or operating according to article 4.4.

The examination of the Egyptian and UAE cases has shown that both countries have tendency to follow the RR to take advantage of global harmonisation and protection against interference while being mostly against the concept of radiocommunication service allocation flexibility. Regarding the interaction with the international regime, there is flexibility in the RR by deviating from it as long as not causing interference and by having multiple allocations in the same spectrum band. Restriction for NTRA of Egypt is in bands where there is a broadcasting service in operation while for TRA of UAE the RR could be restrictive in case there is an urgent need to introduce specific service allocation in the UAE while it is not allocated in the RR. In addition, several elements of the international radiocommunication service allocation framework were examined as shown in the followings.

Firstly, the concept of a priori planning mostly does not restrict regulators’ flexibility regarding service allocation if a country managed to get the approval of neighbouring countries. Both of NTRA of Egypt and TRA of UAE consider that there is a need to revise the GE-06 planning agreement to take into account the emerging need for additional mobile allocations. Furthermore, while the Egyptian case revealed that the broadcasting requirements agreed by the RRC-06 conference are considered as a constraint because some of them were not needed, the concept of a priori planning was perceived to be of an importance for a small country such as UAE. Moreover, UAE has issues in changing the GE-06 plan considering the difficulties to reach agreement with its neighbouring countries.

Secondly, service allocation decision-making procedures accommodate several elements of flexibility but they could be used by some of the countries to restrict others and they could be restrictive in terms of timing. For both of NTRA of Egypt and TRA of UAE, the procedures do not restrict them considering that Egypt is relatively slower than others in terms of advancement in deploying new technologies and for UAE, the agenda of WRCs is flexible according to the requirements of the participant countries.

Thirdly, footnotes could provide flexibility in different ways while they may restrict other countries' flexibility considering that footnotes could only be introduced or modified at WRCs. This applies to Egypt and UAE considering that failure to add a footnote does not restrict TRA of UAE from introducing a service.

Fourthly, while MIFR is not in line with radiocommunication service flexibility in principle as there should be a specific declared radiocommunication service, MIFR is perceived by the international interviewees to be not much used. On the other hand, other countries assignments in MIFR could restrict country's flexibility considering that some of these assignments may not exist in practice. For NTRA of Egypt, restriction accommodated in MIFR does not have an effect on NTRA in practice while TRA of UAE is restricted by the misuse of MIFR by UAE's neighbouring countries.

Fifthly, while the three regions system provides more flexibility to each region countries to decide on service allocation and to countries that have special interests in terms of service allocation, there is more difficulty for region 1 countries due to the high number of regional groups in the region. Moreover, flexibility for these countries that lie on the borders between regions is negatively influenced. For both of NTRA of Egypt and TRA of UAE, they are constrained in general by the proximity of region 3 to region 1 while having the advantage of reaching decisions easily within region 1 regarding service allocation. However, UAE is more vulnerable to the restriction imposed from the proximity between regions 1 and 3 due to the fact that UAE is closer to region 3.

The second research question '**how do the international radio spectrum management regime and national radio spectrum management policies interact with regard to technology selection neutrality?**' addresses a main element of the spectrum market and spectrum commons approaches to national spectrum management.

The investigation of the issue from the perspectives of the international interviewees has shown that while being part of the IMT family of standards provides support to the applicant technologies, there are other elements that may have stronger influence on decisions regarding adopting a particular technology. Besides, IMT standardisation has positive (supportive), negative (opposing), and neutral elements in terms of the influence on regulator's decision regarding technology neutrality according to the perception on technology neutrality and on the IMT standardisation process per se.

The examination of the Egyptian and UAE cases has shown that both countries acknowledge the merits of technology neutrality. However, while TRA of UAE applies technology neutrality, operators in Egypt are strict to the technologies specified in their licenses. Additionally, in both countries, being part of the IMT family of standards is an advantageous to national regulators in selecting technologies. Regarding the interaction with the IMT standardisation with respect to technology neutrality, for both of NTRA of Egypt and TRA of UAE, IMT standardisation has a positive influence on regulator's decision regarding technology neutrality while in UAE, being limited to IMT standards is not considered to be fully neutral.

Regarding the influence of the IMT definitions on perception of 3G and 4G services definition, the data analysis of the international interviewees has shown that while one view is that there is mutual influence between the IMT definitions and definitions of 3G and 4G, the other view is that there is no influence because the ITU-R has taken several actions not to influence the market terms. Moreover, the IMT standardisation process is perceived to have mostly no influence on the discrimination between technology generations on the national level. However, national regulators could use the IMT-2000 and IMT-Advanced labels to justify such discrimination. The examination of the cases of Egypt and UAE has revealed different perceptions. While NTRA of Egypt perceptions on mobile technology generations' definitions are largely influenced by IMT standards, this is not the case of TRA of UAE and operators in Egypt and UAE.

The examination of the international interviewees' perspectives on IMT spectrum identification revealed that such identification has a positive impact on regulator decision towards selecting technologies from the IMT family. However, the extent of such influence is dependent on the country. Furthermore, IMT spectrum identification has elements of flexibility and restriction on the concept of technology neutrality. For both of Egypt and UAE, IMT spectrum identification supports regulators' and operators' decision on selecting technologies from IMT standards to operate in these IMT identified spectrum bands. Regarding the influence on technology neutrality, while IMT spectrum identification provides flexibility to NTRA of Egypt in technology selection, it is considered as restriction on TRA of UAE flexibility.

The third research question '**how do the international radio spectrum management regime and national radio spectrum management policies interact with regard to opportunistic access in the TVWS?**' addresses a main element of the spectrum easements approach to national spectrum management.

The examination of the international interviewees' perspectives has revealed that such interaction accommodates elements of restriction and flexibility as well. Meanwhile, the interaction is most greatly influenced by countries' perception on the TVWS concept and relationship with the ITU-R. For both of NTRA of Egypt and TRA of UAE, the interaction with the international regimes does not prevent them from deploying TVWS in practice. However, NTRA has concerns regarding the negative influence of the a priori planning of the broadcasting service in the UHF band on TVWS deployment. TRA of UAE has the concern that the additional mobile allocation in the broadcasting spectrum deceases significantly the TVWS chances in UAE. Operators in both countries are in favour of exclusive access to the spectrum to secure their investment and to have protection against interference.

Regarding the radiocommunication service allocation of the TVWS devices, the international interviewees have three different perceptions: secondary status, non-interference basis, or primary or secondary according to the perceived operation of TVWS. The Egyptian and UAE interviewees share similar views on TVWS service status with the international interviewees. However, one view from NTRA of Egypt is that a primary status could be needed to empower TVWS devices considering the low spectrum utilisation by the broadcasters in Egypt. Moreover, one view from TRA of UAE is that TVWS devices should operate on shared access basis, as it is perceived more efficient than opportunistic access.

Regarding the influence of WRC-12 decision on A.I. 1.19 on TVWS adoption, the international interviewees have three different perceptions: limited, positive, and negative. Meanwhile, the influence is most greatly impacted by countries' relationship with the ITU-R. This is evident in the two cases of Egypt and UAE where the influence of WRC-12 decision on A.I. 1.19 on TVWS adoption in both countries is limited due mainly that TRA of UAE faces no congestion in spectrum and that the TVWS concept is not preferable in Egypt.

With regard to the need for similar measures adopted in the case of R-LAN in the 5 GHz for TVWS, the international interviewees have two distinct views on the need for measures for TVWS such as DFS based on perception on TVWS service status, deficiencies of TVWS, deficiencies of DFS, difference between operation of R-LAN and TVWS, and positive influence of such measures on the TVWS adoption. In both of the two cases of Egypt and UAE, there is no need to adopt such measures for TVWS.

In general, the examination of the three research questions has shown that the international regime does not prevent adopting radiocommunication service allocation flexibility, technology neutrality, or opportunistic access in the TVWS. However, there are different elements of flexibility (support) and restriction (opposing) that have an influence on regulators' flexibility regarding radiocommunication service allocation, regulators' tendency towards technology neutrality, and deployment of opportunistic access in the TVWS. These elements are dependent on country's geographical position, country's relationship with neighbouring countries, perceptions on technology neutrality, perception on the TVWS concept, size of country market, being advanced in technology, interpretation of the international regulations, national telecommunication market status, and usage dependency on the international regime's elements (e.g. footnotes).

Meanwhile, the examination of the two cases has shown that there is a tendency to follow the ITU-R radiocommunication service allocation, adopt IMT standards, and favour exclusive access over opportunistic access in order to gain the benefits of global harmonisation, international roaming, ensuring compatibility and coexistence, achieving economies of scales, securing operators' investment and most importantly, protection against interference.

9.3 *Research Contributions*

In general, this research complements existing research on the interaction between international regimes and national policies. In particular, Mazar (2009) has analysed in his Ph.D. thesis how and why culture and geography influence the allocation and licensing of the radio frequency spectrum in different nations. Ard-Paru (2013) has studied in his Eng.D. thesis the transformation of international regulation into national regulation for spectrum commons in Thailand. Ratto-Nielsen (2006) has examined in his Ph.D. thesis the relationship between domestic preferences and the changes in the international telecommunications regime.

More specifically, this research is a key step towards investigating whether the international spectrum management regime is an obstacle for national spectrum management policy reform. This is due that one of the research's contributions is building a theoretical framework that maps the interaction between the international spectrum management regime and national spectrum management policies while showing elements of flexibility and restriction.

Firstly, the research has shown the different aspects of restriction and flexibility from the service allocation elements in the ITU-R (e.g. a priori planning, decision making procedures, footnotes) on the national regulators flexibility regarding radiocommunication service allocation. Secondly, the research has explored the interaction between the IMT standardisation activities at the ITU-R and national regulators' decision with regard to technology selection and neutrality in particular. Furthermore, two elements have been closely examined namely the influence of IMT on technology generations definition and the influence of IMT spectrum identification on technology selection and neutrality on the national level.

Thirdly, the research has highlighted the flexible and restrictive elements of the international spectrum management regime that have an influence on the TVWS adoption on the national level. Related topics have been explored such as TVWS devices radiocommunication service allocation status and the influence of discussion on the international level on CRS and SDR on TVWS adoption. The research has also revealed the views on the need for similar measures for the case of TVWS to those adopted for the case of R-LAN in the 5 GHz.

The research's outcome is argued to bring added value to the spectrum policy debate with regard to the acceptance of national regulator to the alternative regimes of the command and control. In particular, the research is a key step towards reaching a practical national spectrum policy that takes into account the different stakeholders' interest and the different elements of the international regime.

Firstly, regarding service allocation flexibility, the research has explored to the proponents of the concept of service allocation flexibility two cases studies (Egypt and UAE) where there are legal and practical constraints against adopting the concepts. It has also shown how the regulators, operators, broadcasters in these countries are against the concept while being in favour of global service harmonisation. In addition, while the two countries have the freedom to deviate from the ITU-R service allocation, they simply do not. It was also evident in many parts of the research that flexibility implies using fixed service and broadcasting service allocations for mobile service. This is due to the fact that convergence has enabled introducing different application through the end users' mobile terminals. This should motivate scholars in spectrum policy to revisit their proposals that are based on Coase's idea and to examine whether they are still needed.

Secondly, regarding technology neutrality, the examination of the two cases studies has shown that while both countries admire the technology neutrality concept, they have preferences towards IMT standards although the ITU-R recommendations on IMT are not binding in nature. The research has also shown that being part of the IMT family is not enough to be adopted. This may explain why WiMAX was not successful although the technology proponents (IEEE, Intel) managed to include it in the IMT family after extensive discussions.

Also, the research has examined the perceptions on what is perceived to be technology neutrality considering that almost all technologies are part of the IMT family. Therefore, even if a regulator is neutral, most probably the winning technology would be IMT. This raises a question on whether being neutral within IMT is considered to be full neutral or not. Regarding the influence of the IMT definitions on 3G and 4G definitions, the EDGE case in Egypt has shown that while the ITU-R has taken several actions not to influence the market terms, still there is an influence. More specifically, operators and regulators may use the ITU terms to support their positions if needed.

Thirdly, regarding opportunistic access in the TVWS, the examination of the two case studies has shown that operators are in favour of exclusive access to secure their investment and to have protection against interference. The two case studies have also shown that participants link between the two concept of service management liberalisation and opportunistic access and link between the discussions on service allocation flexibility and CRS in the ITU-R. This may indicate that the success and wide adoption of smart technologies such as CRS may boost the implementation of the two concepts of service flexibility and opportunistic access.

While the examinations of the concept of opportunistic access in the TVWS reveal several objections, it is argued that this was not only related to the concept of opportunistic access per se but also to the UHF band status where TVWS devices operate. In particular, TVWS proponents were quite unlucky considering that most countries are waiting for the DSO to be finalised in 2015 and the additional mobile allocations in the 700 MHz and 800 MHz, which squeezed the broadcasting spectrum. It is proposed that opportunistic access proponents may attempt to examine other spectrum bands where there is no incumbent user such as the broadcasters.

From the practicality viewpoint, this research highlights the limitations and shortcomings of the international spectrum management regime (e.g. interference resolving, misuse of MIFR, decision making procedures, three regions). Firstly, this research is important to the stakeholders from the ITU-R because it highlights the perceptions that the ITU-R is ineffective when it comes to resolving cross border interference because there is no deterministic procedure over countries causing the interference. This may call for establishing regional ITU-R measurement stations to resolve interference conflict and to find sources of jamming or harmful interference.

The research has also exposed the political nature of the international spectrum management regime where countries may use the technical discussions within the ITU-R for political purposes. More specifically, footnotes and MIFR could be used to restrict others and to trade off positions in WRCs. The issue of fake or non-existent assignments in the MIFR and how they are used as part of the negotiations between countries was mentioned by several interviewees. This calls for more active role of the ITU-R to distinguish between actual deployments and unreal ones.

Regarding the decision-making procedures, this research has shown how countries trade off positions on unrelated items in WRC. In addition, it was mentioned how other services representatives rather than mobile may participate in the IMT discussions just to block IMT access to the spectrum. It was also shown how countries and companies may use the procedures to block others for political or commercial reasons rather than technical ones. This may calls for revising the WRC decision-making procedures to have more active role of the ITU-R in order to make sure that the discussion is purely technical. Another proposal is to have separate conferences for important topics in order not to have influences from other agenda items and also not to wait four or five years to conduct a WRC.

The GE-06 plan was criticised by many interviewees due to the need to be revised considering the additional mobile allocations in the 700 MHz and 800 MHz bands. In particular, it seems that for some countries, the timing of the RRC-06 conference was early for them. Interviewees from Egypt highlighted an important note that although they manage to get most of their requirements at the conference, there requirements were exaggerated and mostly not needed. In other words, the conference enforced Egypt to acquire assignments for the broadcasting service while the same country was in favour of additional mobile allocation in the UHF band just one year later (2007). This may call for another regional planning conference to revise the GE-06 plan in the band 470- 694 MHz. Another proposal is to have a mobile allocation in the whole 470-694 MHz band to provide the flexibility to the different countries to deploy broadcasting or mobile service.

The proximity between the ITU-R regions 1 and 3 and how this may restrict countries on borders should also motivate the ITU-R countries to revisit the three regions allocation. In particular, the research showed how such proximity motivates Iran to join the GE-06 plan although the plan was concerned with region 1 countries only. A proposal would to have one region instead of two that accommodates region 1 and region 3 or even to divide the three regions into six regions to reflect the six regional spectrum management organisations.

Besides, the research highlights specific issues that have never been explored before in the literature via interviewing people that were involved in the discussion. This includes the case of EDGE and WiMAX in Egypt, the issue of R-LAN allocation in the

5 GHz in the WRC-03, and the debate on 4G in UAE. Besides, there is little precedent for conducting similar research using interviews with senior policy makers in the two case studies of Egypt and UAE due to the conservative nature of these countries. This was facilitated by having the researcher working for the NTRA of Egypt and being familiar with the culture and language of the Arab region. Additionally, from the viewpoint of methodological contribution, this research has applied new software advancements in coding and mapping to such large amount of data, which could be useful in research on policy analysis in general.

9.4 *Research Limitations*

Several limitations of this study should be acknowledged. Firstly, the number of case studies was limited due to limitations in research time and resource, practicalities due to language barriers even within the Arab countries and also due to the disturbance of public order in some other countries (e.g. Syria). The number of case studies was further limited due to the emerging difficulties in getting access to the Saudi Arabia case data. Secondly, due to the sensitivity of some of the issues, it was difficult to get access to some of the stakeholders that are involved in the spectrum management on the national level such. However, this is not limited to the selected case studies but it applies to other countries as well especially if the researcher is a foreigner.

Thirdly, within the Egyptian case study, being an employee for NTRA made some interviewees, especially from the operators, sceptical about the research. However, this was largely overcome by assuring the interviewees that their data would be used only for the purpose of the research and that they can withdraw their data anytime. Within the UAE case study, the same problem was faced with the operators. However, this was overcome by a proper introduction and reassurance from the UAE TRA to the operators that their data would be used for the purpose of the research only. In both cases of Egypt and UAE, the interviews were conducted in informal setting and in the absence of others in order to encourage the interviewees to talk freely.

Fourthly, it was not possible to conduct similar number of interviews for each category (e.g. broadcasting) under the international interviewees group. However, this was mainly due to the different distributions of these categories' participation in the ITU-R. In particular, the number of national regulators' participants is usually larger than the number of other participants from other categories. This was overcome by highlighting these groups' views when needed (e.g. TVWS group in RQ (3)). Fifthly, it is worth highlighting the temporal nature of the findings. More specifically, the research was conducted in the period between January 2012 and December 2014 following the WRC-12, which was held in January 2012 and before the WRC-15, which is expected to be held in November 2015. While the period between the two WRCs could be considered as a period of stability in terms of international spectrum regulations, the WRC-15 may issue important resolutions that would need following up on some of the research topics.

9.5 *Future Research*

While this research represents an important step towards exploring the interaction between the international regime and national policies, the limitations mentioned in the previous section call for several future actions in order to overcome these limitations and to extend the current study. Firstly, the number of case studies could be extended to other Arab countries that do not participate in the ITU-R activities to examine whether the influence of the international regime is conditioned by active participation in the ITU-R. The results of the research could also be shared with the interviewees to further examine the findings and to get their feedbacks. Quantitative measures could be applied to extend the number of stakeholder on the international and national level. For instance, a survey could be sent to all of the ITU-R countries to spread the examination to countries in other ITU-R regions (e.g. regions 2, 3) and to other regional organisations (e.g. CEPT).

Additionally, the research could address in the future geographically isolated countries to examine the influence of the international regime in such case especially for region 2 countries. There are others areas regarding spectrum national policy that may need examination such as the concept of opportunistic access in general rather than in the TVWS specifically in addition to the spectrum commons approach. In addition, while this research focus on three radiocommunication services namely fixed, mobile, and broadcasting, national spectrum management policies address other services such as satellite and amateur.

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Appendices

An accompanying CD contains the appendices for this thesis. Below is the Table of Contents, for reference purposes.