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ON

An Analytical Model for the Analogue to Digital Broadcasting Transition:

A Case Study of Ghana

PROJECT REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE MENG COMPUTER ENGINEERING

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An Analytical Model for the Analogue to Digital Broadcasting Transition:

A Case Study of Ghana

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Thesis Title: AN ANALYTICAL MODEL FOR THE ANALOGUE TO DIGITAL TRANSITION: A CASE STUDY OF GHANA

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Abstract

Digital Broadcasting (DB) is an advanced technology that uses digital data to carry broadcasts over a set of radio frequency bands. This technology have been tested and already implemented in some countries like the USA, Japan and most countries in Europe, giving several advantages over the Analogue Broadcasting (which uses analogue waveform to broadcast).

With regards to the relevance of Ghana meeting the deadline for the Analogue to Digital Broadcasting switchover (which is June 17, 2015), this work was carried out to develop a model for quantifying and analyzing the performance of work done at any stage of the transition process. In this project, the activities or the components that affect the Analogue to Digital Broadcasting Transition (ADBT) process are identified. The steps for the determination of the parameters needed for the model are also stated.

The results of the model simulation for several scenarios indicate that, there is a positive correlation between the current state of any ADBT process and its future state. It was also observed that a change in any aspect of the ADBT process can affect other aspects as well as the overall performance of work done in the process. Therefore, this model would be efficient for the analysis of the performance dynamics of Ghana's digital broadcasting migration process. This will also enable stakeholders of the ADBT process to know the implications of their actions. Thus, the use of this model can contribute to a well planned ADBT in order to meet the set deadline.

Dedication

First and foremost, I dedicate this work to the Almighty God, whose grace brought me this far. Secondly, I dedicate this work to my parents, wife and daughter.

Acknowledgement

The Lord has been gracious and merciful by blessing me through the help of Dr. Koudjo M. Koumadi (my supervisor) and Professor Anthony Nzeako. I am grateful for their directions, contributions and corrections that made this work a success. I wish to acknowledge Mr. Oscar Nchor (the Director of technical production, Ghana Broadcasting Corporation) and the migration implementation team (from the National Communication Authority of Ghana) who willingly assisted me with the relevant information on this project. Finally, I am grateful to the head of the department, Dr. Robert A. Sowah and all who contributed to my success.

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List of Abbreviations

AB - *Analog Broadcasting*

ADB - *Analog to Digital Broadcasting*

ADBT - *Analog to Digital Broadcasting Transition*

ANFIS - *Adaptive Neuro Fuzzy Inference System*

ATSC - *Advanced Television System Committee*

DAB - *Digital Audio Broadcasting*

DT - *Digital Television*

DTT - *Digital Terrestrial Television*

DTMB - *Digital Terrestrial Multimedia Broadcasting*

DTTB - *Digital Television Terrestrial Broadcasting*

DVB-C - *Digital Video Broadcasting-Cable*

DVB-S - *Digital Video Broadcasting-Satellite*

DVB-SH - *Digital Video Broadcasting - Satellite services* to *Handhelds*

DVB-T - *Digital Video Broadcasting-Terrestrial*

DVB-T2 - *Digital Video Broadcasting-Terrestrial (Second Generation)*

E-DTMB - *Enhanced Digital Terrestrial Multimedia Broadcast*

HDTV - *High Definition Television*

ISDB - *Integrated Services Digital Broadcasting*

ISDB-S - *ISDB-Satellite*

SDTV - *Standard Definition Television*

TS - *Takagi-Sugeno*

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CHAPTER 1

INTRODUCTION

Broadcasting technology today was never like few decades ago. From the discovery of electronic communication circuit to date, several techniques continue to emerge as long as the search for efficiency of transmission and better service to the users never ceases. Television is one of the vivid examples of the many telecommunication areas which have witnessed diverse changes. It started with black and white transmission to coloured transmission with several stages of techniques developed in both cases. Though coloured television was a great discovery to humanity, the transmission was achieved by analogue signals until the early 1990s where transmission of digital signal was possible. Due to the numerous advantages that the digital broadcasting (DB) has over the analogue broadcasting (AB), the whole world is expected to broadcast digital signals only in few years to come. Ghana is currently making every effort to migrate to this new technology, where it is expected to meet a set deadline.

This project was embarked upon to contribute to the analysis of the dynamics of the digital migration in Ghana so as to know what aspect of the process requires changes to ensure timely switchover.

In this chapter, the background which gives an overview of this project work is first presented. This is followed by the problem statement which describes what this work intends to solve. The next section states the aims and objectives of this work. The significance of the study and its contribution to knowledge are also presented, followed by the scope of this work and ending with the final section which describes the structure of the project report.

1.1Background

Broadcasting generally refers to the process of transferring or distributing developed audio and video content from a centralized location to any accessible location through wireless, satellite or cable, and received by means of radio, television and internet media. Unlike narrowcasting that has relatively small audience, broadcasting is the most popular means of information (audio and video) distribution to a very large audience [1]

At the Regional Radio Communications Conference (RRC-06), held in Geneva, the deadline set for the cessation of international protection for analogue broadcasting (in the 174 – 230 MHz and 470 – 862 MHz bands) was June 17, 2015 [2]. Though some countries like the USA, Japan and most European countries have already completed the digital broadcasting migration, others, are still making frantic effort to ensure they meet this deadline.

Analogue broadcasting (AB) is a form of communication that uses analogue signal (continuous time varying signal) to transmit information (audio, video and text) from one point to another through a communication media. This type of broadcasting usually involves the direct variation (modulation) of a carrier frequency or carrier voltage level or carrier phase with the corresponding voltage level representation of sound or video. This communication existed in various forms for a long time until the introduction of digital broadcasting [3].

Digital broadcasting (DB) involves the use of digital signal to carry information over an allocated number of channels or frequencies. The need for this arose as a result of excessive demand on frequency allocation. The frequency allocation given to commercial operators in the digital age implies that more content can be broadcast. This is due to the potential of this technology that offers efficient use of frequencies.

There are several benefits that can be derived from digital broadcasting by the television broadcasters and their viewers, which make digital broadcasting preferred over analogue broadcasting. These include:

- Efficient use of spectrum: For a particular bandwidth that carries only one program channel in analogue broadcasting, it is possible to broadcast 10 television programs concurrently over the same bandwidth in the case of the digital broadcasting [4].
- More efficient infrastructure: DB offers a common platform for broadcasting, thereby reducing cost for all broadcasters and reducing environmental impact [4].
- Better quality TV: DB offers viewers with sharper and brighter pictures, reduced interference, better audio signal, and improved sound quality [4]. The use of better video compression scheme allows for the introduction of high definition Television (HDTV).
- The digital dividend: This refers to frequencies that would be freed after the migration from analogue to digital broadcasting and could be up to 80 per cent of the UHF/VHF spectrum or more [5].
- Industrial benefits: digital migration creates business opportunities for the Information and Communication Technology (ICT) sector as well as the local content developers [4]. This will also create market for manufacturers of digital TV antennas and Set-top boxes.

1.2 Problem Statement

During a workshop on Spectrum Management and Digital Broadcasting Transition in St. Vincent, May 2013 [6], it was observed that many countries, especially in Africa and South America haven’t covered much in the migration process. For example, as at January 10, 2013, Tanzania was the only country in Africa that had successfully migrated [1]. This concern raises a question, as to whether there is a way to measure or quantify the performance of their progress in the transition process. Several works have been done already concerning this relatively new technology, justifying the advantages of digital broadcasting over the analogue broadcasting. For example, a review on digital dividend was done in [7]. A possible propagation based solutions to the lack of spectrum in Digital switch-over is well discussed in [8], and many others focus on similar works. However, no extensive work has been done on any mechanism for analyzing the dynamics of the transition process, whereby the effect of any decision made in the process can easily be estimated. In Ghana, on January 13, 2010, a 26 member National Digital Broadcasting Migration Technical Committee was inaugurated to make policy recommendations to the government. This was to enable Ghana achieve a cost effective migration from analogue to digital broadcasting and to meet the deadline [2]. Though the committee is working hard on the migration process, there is the need for a transition model that incorporates all necessary parameters of change and the failure to implement the right actions?

In order to meet the deadline, it is important to know answers for the following questions: how rapid would be in the changes of the transition given their current pace or state of progress? Is there a way of making a quantitative analysis on the work done at any given time? Also, should they meet the deadline, how would they quantify their performance at the end of the process? These and many more questions are addressed in this work, which is aimed at making a significant contribution to the success of the transition process.

1.3 Aims and objectives

The main aim of this work is to find a quantitative method of analyzing the transition from analogue to digital broadcasting in Ghana with the following specific objectives:

- To identify the factors that affects the dynamics of the Analog to Digital Broadcasting Transition (ADBT) process.

- To develop a model that can be used to analyze the performance of the transition process at any stage of the transition based on identified factors of the ADB migration.
- To simulate the model developed.

1.4 Significance of the Work

The development of an analytical model will enable governments, owners and operators of television and radio broadcasting establishments to quantify the implications of their actions or inactions during the transition process. The possibility to quantify probable consequences of any decision or action in the ADBT (with this model) can always serve as a guide to achieving timely transition; actual performance can be quantified and compared with set target. Finally, this model can be applied to similar projects that involve technology transition.

1.5 Scope of the Work

This work focuses on the techniques that can be used to numerically quantify the performance of work done in the analog to digital broadcasting transition process using Ghana as a case study. The activities or components considered for the development of the model were selected after several interviews and survey conducted at the National Communication Authority (NCA) of Ghana and Ghana Broadcasting Corporation (GBC) and that those activities have great impact on the dynamics of the process. The quality of service considered in this work does not consider the evaluation from the end user's since most television viewers do not have digital receivers (set top boxes).

1.6 Structure of the Project Report.

The rest of this project report is broken down as follows: chapter 2 will be on literature review. This will include stating a related work on the digital migration as well as a related model of project transition. Chapter 3 will present the development of the model, which begins with an abstract view of the model to the actual model. Chapter 4 will be on the simulation of the model and analysis of the results. Chapter 5 will finally summarize and draw conclusions of the work.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter generally covers a review on broadcasting, beginning with the evolution of television broadcasting, describing how broadcasting techniques have evolved. The different types of analogue and digital broadcasting standards are also discussed. This is followed by a review on the status of ADBT (both worldwide and in Ghana). The related work on the ADBT and technology transition model is also reviewed. Some key components of the ADBT are also presented and finally, a review on types of modeling.

2.1 Evolution of Television Broadcasting

Experimentally, broadcasting was founded in 1906 in Massachusetts by Reginald Fessenden when he successfully transmitted significant power signal of voice and music [9]. Prior to this invention, radio communication was accomplished through the use of Morse Code. In order to interpret any received message, it required the need for trained radio operators who decoded the streams of dots and dashes used in Morse code.

Broadcasting became commercialized in 1920. Ever since its inception, there have been many developments and researches still ongoing in expectation of better quality of service as well as better spectral efficiency. For example, in television, there have been at least two major transformations: from the age of black and white television (TV) broadcasting to coloured TV broadcasting (both were analogue), and now to the current digital TV broadcasting.

Armstrong made an announcement of his invention of superhetrodyne circuit (a circuit which generates radio frequency nearly the same as an incomplete signal and electronically combines the two, resulting in lower frequency than original) that migrated the then existing radio to an electronic age.

2.2 Allocation of broadcast band in the Electromagnetic Spectrum

The electromagnetic spectrum is a set of possible frequencies that ranges from the extremely low frequencies (with very long wavelength) used in contemporary radio communication to extremely high frequency (with very short wavelength) used in gamma radiation. In principle, the spectrum is infinite and continuous but the limit of the short wavelength is known to be close to Planck length. These frequencies can range from the smallest wavelength with the size of an atom to as far as the size of the universe [10]. The frequencies within the spectrum have characteristics that make them suitable for a particular application. As shown in figure 2.1, the frequencies have been grouped into frequency bands with the second band being assigned to broadcasting. In this band, several broadcasting types can be found.

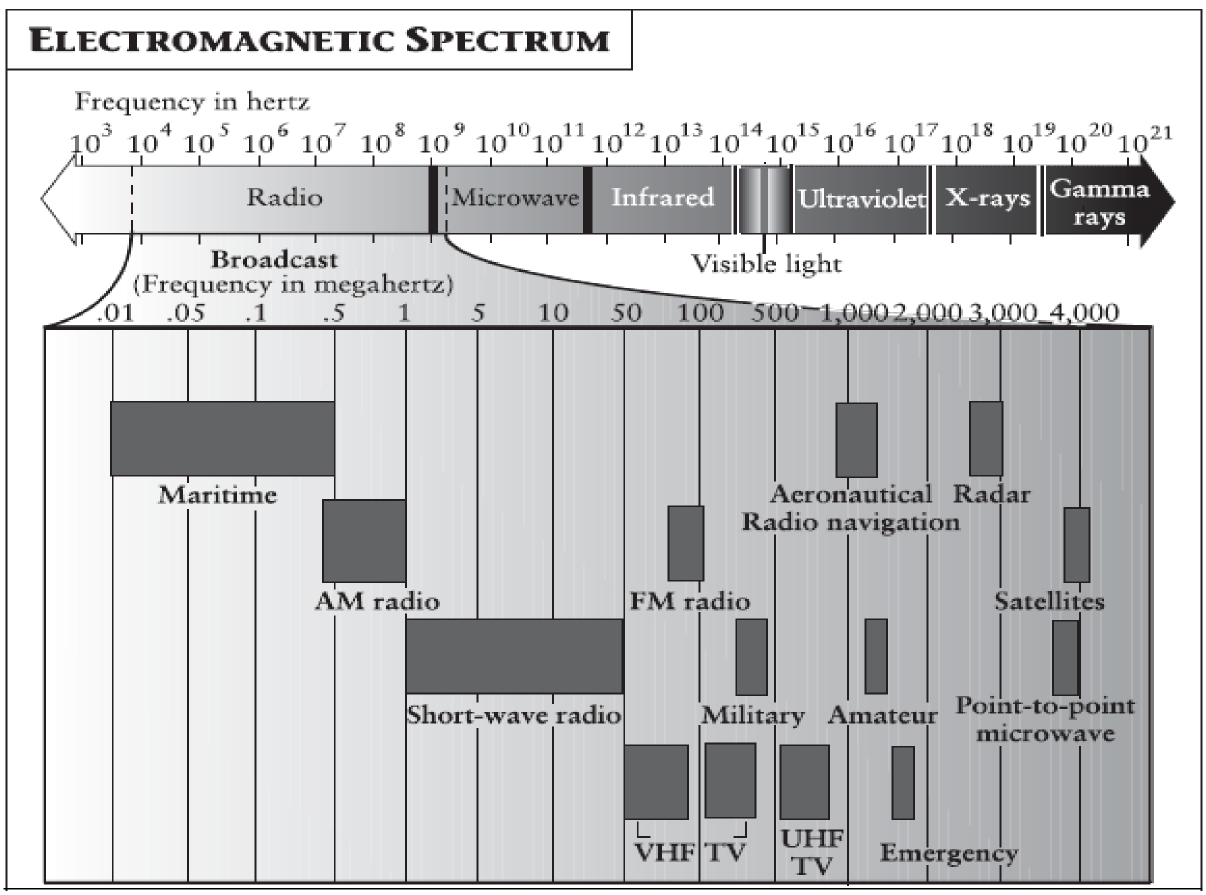

Fig 2.1: Frequency spectrum showing the broadcast band [3].

2.3 Analog Broadcasting (AB)

Analogue broadcasting began with black and white television to coloured television system. All analogue television systems use vestigial sideband modulation, which is a form of amplitude modulation whereby one sideband is partially removed. Eventually, the bandwidth of the transmitted signal is reduced, enabling the use of narrower channels (This makes it spectrally inefficient, compared to the digital broadcasting technology).

2.3.1 Analogue Broadcasting Systems

The analogue systems are made up of several components, these include; a set of technical parameters for the broadcasting signal, an encoder system used for colour encoding, and a system for encoding multichannel television sound (MTS) [11]. Currently any analogue television broadcaster operates on any of the three colour systems, known as:

1. National Television System Committee (NTSC)

2. Phase Alternating Line (PAL) and

3. SECAM, also written as SÉCAM (*Séquentiel couleur à mémoire*, [12] which is French for "Sequential Colour with Memory") (SECAM),

Figure 2.2 describes the global geographical distribution of the analogue television system which is being phased out.

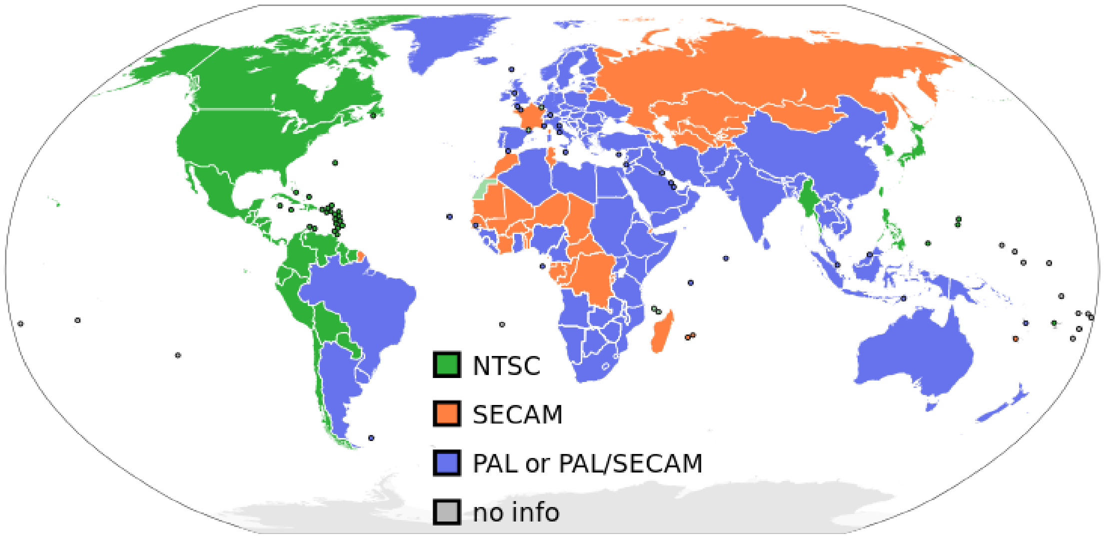

Figure 2.2: Analog television encoding systems by nation [13].

2.4 Digital Broadcasting (DB)

DB has several standard types which define the various compression schemes for both audio and video. Usually, one or more of these standards are adopted in a particular country.

2.4.1 Technologies of Digital Broadcasting

The state of the art digital broadcasting technologies are: Digital Satellite Broadcasting (DSB), Digital Terrestrial Broadcasting (DTB) and Digital Cable Broadcasting (DCB). For each of the digital broadcasting technologies, the following divisions can be found with regards to how they are used [14]:

- Data Broadcasting
- Digital Radio
- Digital TV

2.4.1.1 Data Broadcasting

There are several ways of achieving data broadcasting; generally, data broadcasting refers to the delivery of audio and video content directly to a computer. To accomplish this, a special data card for this multimedia is installed on the computer in order to convert the received data into format that can be processed. For any multimedia service request, there is a return path or connection from the computer back to the broadcast station.

2.4.1.2 Digital Radio

Digital radio is a technology that converts analogue audio signal to digital format, and transmit a compressed digital format through digital modulation. Compared to analog radio, this technology allows more radio programs to be broadcast for a given spectrum. There is also very high audio quality and elimination of fading (an undesired phenomenon in communication) in the case of mobile communication. This implies that additional data casting services can be guaranteed for the end users, whilst allowing the decrease in the number of transmitters and transmitter power for a particular coverage area.

The major challenge in the development of digital radio is the high cost of digital radio receivers. This area requires the need for measures that ensures affordability in the migration process for developing countries.

2.4.2 Digital Television Standard Types

There are four classifications of digital television terrestrial broadcasting (DTTB) standards and these are:

1. Advanced Television System Committee (ATSC)
2. Digital Video Broadcasting-Terrestrial (DVB-T)
3. Terrestrial Integrated Services Digital Broadcasting (ISDB-T)
4. Digital Terrestrial Multimedia Broadcasting (DTMB)

Figure 2.3 describes the geographical distribution of DTTB technologies in the world

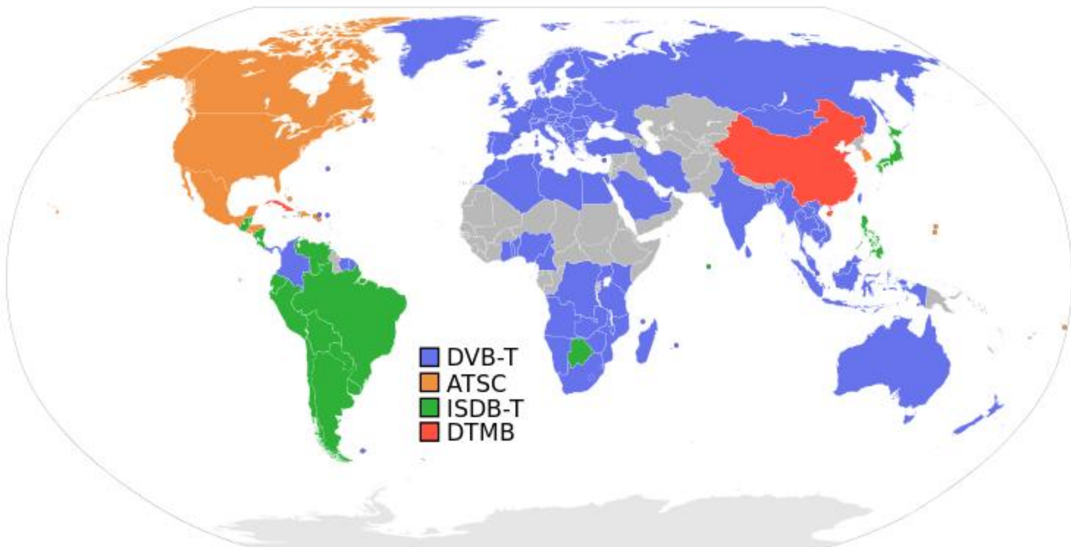

Figure 2.3: DTT Broadcasting Technologies by Country [15].

2.4.2.1 Advanced Television System Committee (ATSC)

As part of the Advanced Television Committee, ATSC is a standard organization which was created in 1982 to promote the establishment of technical standards for all aspects of advanced television systems [16]. ATSC standards are for the transmission of digital television over terrestrial, cable, and satellite networks.

In the United State, the technologies that applies to the transportation, formatting, compression and transmission of DTV was developed by the ATSC [16]. However, it became increasingly adopted in other countries. The standards developed for ATSC digital television are: the digital high definition television (HDTV), standard definition television (SDTV), data casting, multichannel surround-sound audio, conditional access and interactive services [16]. ATSC uses MPEG-2 for video coding and Dolby Digital for audio coding in both SDTV and HDTV

2.4.2.2 Digital Video Broadcasting (DVB)

DVB is a set of open standards for digital television which is managed by the Digital Video Broadcast Project (DVB Project). Though the work of DVB is based on the use of a set-top box (which is a digital to analogue signal decoder), it is possible that by means of broadcast networks, other systems can provide interactive services without the use of set-top box. The DVB Project has specified several standards for digital audio-visual coding. For example, MPEG layer 1 to layer 4 are standards used for audio coding, whereas the current standards for video coding are known as MPEG-1 to MPEG-4.

The classification of DVB is based on the medium by which DVB is carried out. These are:

Satellite: The following are examples of DVB using the satellite transmission medium: Digital Video Broadcasting – Satellite (DVB-S) and Digital Video Broadcasting - Satellite services to Handhelds (DVB-SH). DVB-SH is a system which provides IP based media content and data to handheld devices like mobile phones and Personal Digital Assistants(PDAs) through satellite.

Cable: An example in this transmission medium is the Digital Video Broadcasting – Cable (DVB-C). This also uses MPEG2 and MPEG4 standards for video and audio transmission over cable.

Terrestrial television: In this transmission medium, we have the Digital Video Broadcasting–Terrestrial (DVB-T); This is a standard adopted by DVB, European-based consortium for DTTV broadcast that was first published in 1997 [17]. However, this technology is also used in Japan, New Zealand and several countries in Africa. The DVB-second generation terrestrial (DVB- T2) is an enhanced service over its predecessor, DVB-T. DVB-T2 offers higher bit rate that allows better compression of video and audio data for transmission. The digital terrestrial television for handheld is known as Digital Video Broadcasting – Handheld (DVB-H) which uses mobile TV formats for broadcast.

2.4.2.3 The Integrated Services Digital Broadcasting (ISDB)

ISDB is a digital broadcast standard adopted in Japan in December 2003, for DTV and Digital Audio Broadcasting (DAB) used by the country's television and radio networks respectively [18]. ISDB is maintained by the Association of Radio Industries and Businesses, a Japanese organization which is also known as ARIB. This technology is also being adapted by almost all South America Countries.

There are different frequency band requirements for the various types of ISDB. This implies that, there are different modulation schemes used for transmission of video and audio. For example, 12 GHz band ISDB-Satellite (ISDB-S) uses Phase Shift Keying (PSK) modulation scheme, 2.6 GHz band digital sound broadcasting uses Code Division Modulation (CDM) and ISDB-Terrestrial (ISDB-T) in VHF and/or UHF band uses COFDM with PSK/QAM [18].

Apart from audio and video transmission, data broadcasting is also defined in the ISDB standards. It also uses internet as a return channel over several media such as 10Base-T/100Base-T, Telephone line modem, Mobile phone, Wireless LAN (IEEE 802.11) etc.

2.4.2.4. Digital Terrestrial Multimedia Broadcast (DTMB)

DTMB is the TV standard for mobile and fixed terminals used in the People's Republic of China, Hong Kong, and Macau. DTMB replaced an existing name which was known as DMB-T/H (Digital Multimedia Broadcast-Terrestrial/Handheld).

Some of the features include the use of 4.813 Mbit/s to 32.486 Mbit/s bit-rates that supports HDTV and multimedia services, interactive television and data casting services.

According to [19], Enhanced Digital Terrestrial Multimedia Broadcast (E-DTMB) can provide a new technique for embedded transmission of multiple services simultaneously over the existing DTMB.

2.5 Worldwide Status of the Analogue to Digital Transition.

The digital migration is a process that requires the switch over from the transmission of analogue signals used in broadcasting to digital signals. The status, according to [6] is as follows:

As at 2007, countries like Finland, Sweden and Switzerland had already completed the switch over. Germany had digital broadcast through Cable and satellite available by 2008. In 2009, Denmark and Norway completed and the following year (2010) was when several others like Belgium, Spain, Latvia, Estonia, Croatia, Slovenia and Luxembourg joined the digital broadcasting nations.

In North America, the USA migrated in 2009 whereas Canada and Mexico completed the process in 2011. However, several South American countries are still on the process.

In Africa, Tanzania and Mauritius are the most leading countries in the migration process. Several countries have different target date of completion. For example, South Africa's former target of completion was 2011 and it's now extended to 2013. Ghana is also making efforts towards meeting deadline with a current target date of December 2014,

2.5.1 Analogue to Digital Broadcasting Transition in Ghana

According to [20], Ghana become the first African country to start a digital terrestrial television service called SMART TV. This was launched by Next Generation Broadcasting (NGB), a Swedish multinational company, in collaboration with Ghana Broadcasting Corporation (GBC) and commercial roll-out in Accra and Kumasi in 2008. NGB is partnering Fox International Channel as the only platform to provide Fox entertainment in Ghana [20].

GOtv Ghana Limited has started digital television broadcast service dubbed "GOtv" using the latest generation digital video broadcast (DVB-T2) standard. This makes GOtv, currently, the only operator in the country to launch a DVB-T2 pay television service. It offers the greatest selection of local channels made in Africa for Africa as well as the best international channels which cost GH¢25.00 per month [20].

With advent of this new technology (DB), all licensed TV operators are expected to be on the DTT platform by the end of the analogue switch off (ASO).

2.5.2 The DTT Standards and Compression Scheme Adopted in Ghana

In Ghana, the DTT standard adopted by the Digital Broadcasting Migration Committee is DVB-T2, which has received the government's approval [21]. Some of the compression technology standards accepted for the DVB-T2 include: the Advanced Video Coding (AVC)/MPEG-4 (part 10) and High Efficiency Advanced Audio Coding (HE-AAC) [21]. This will also go with an interactive service which will use MHEG-5 as the Application Programming Interface (API) [21].

The terrestrial stations in Ghana are: GTV, TV3, TV Africa, Crystal TV, Metro TV, Viasat1, Net-2 TV, e-TV Ghana, Coastal TV, GhOne, Top TV, GoTv , U TVetc. All these stations are willing to migrate unto a common digital broadcast platform [20].

Also, all vendors and equipment suppliers have been advised by the Ministry of Communications to cease the importation of DTT decoders with immediate effect. However, the standard decoders approved by the technical committee can be imported [21].

2.5.3 The Ten Management Tips by Meredith Beal for the Digital Migration.

Meredith Beal is a Knight International Journalist Fellow, who works with African Media Initiative (AMI) members to develop effective business models, improve management structures, and create new revenue streams to support quality news coverage [4].

The ten management activities suggested by Meredith Beal, for ADBT are as follows:

“ 1. Communicate with your viewers to raise public awareness about the migration

2. Plan for a Dual Broadcasting Period.

3. *Identify gaps in signal coverage.*
4. *Help viewers with set top converter boxes.*
5. *Set up a telephone hotline for your viewers.*
6. *Conduct audience research.*
7. *Invest in the proper equipment.*
8. *Invest in training.*
9. *Provide technical support for viewers.*
10. *Do what you do best "*[4]

2.5.4 The Key Component and Activities Identified as Relevant to ADBT in Ghana

National Policy: There should be a National Digital Broadcasting policy that spells out policy target and policy timelines.

- The National Digital Broadcasting policy must have a strategic plan or program of action which must also go with plan target and timelines.
- Budgetary provision must be made in the most optimal way in order to achieve an overall quality transition.
- Implementation program or plan must be clearly stated to meet the national switchover target.

Human Capital: It is necessary that the following are considered in the area of human capital in order to avoid mistakes which could cost the nation as a whole.

- Quality of staff is very crucial. Therefore the right qualification (both Academic and Professional) as well as the right experience must be considered when employing staff.
- Right staff strength needed for the migration must be ensured because of the relevance of meeting the targeted date.

- No matter how experienced the staff is, it is important to ensure that the right training regarding all aspect of the transition is provided for staff.
- Working environment must be conducive in order not impede transition process.

Infrastructure: There must be considerations for both soft and physical Infrastructures. These should include:

- The availability of reliable electrical power and telecommunication systems.
- The physical structure, such as furnished office space and equipment Installation area are also relevant.
- These physical structures must not just be available but be in safe condition to both staff and equipment.

Equipment and Technology: Since there are no fixed rules on the DTT standards to be adopted by a particular country, the technical committees must take into consideration the necessary technologies that offer wide range of compatibilities regarding transmitters, antennas for transmission and receivers

- There must be the right quantity of equipment and coverage to ensure the existing analogue TV viewers are not left out.
- Quality is very important and should be given much attention no matter the budget allocation. This is to avoid future failures in the equipment.
- The availability of the equipment must be considered at any stage or phase of the transition. Hence the reliability, serviceability etc must be ensured.

2.5.5 Analogue to Digital Television Broadcast Planning

In order to achieve an effective transition process which is void of many potential problems, it is recommended that the transitional plans regarding all aspect are done as quickly as possible and solutions set out clearly in the plan. The planning process should involve various stakeholders including the private sector broadcasters, public sector broadcasters and the regulatory body, in order to avoid the perception that the transitional plan is a partisan political document.

In [22 and 23], the DTV broadcasting transition planning activities recommended include the following:

a. There must be an adoption by the government or parliament of a digitalization plan.

b. There must be regulations set out by a regulatory body which include: licensing policy and policy on the services rendered by broadcasters to their customers.

c. There must be a way of effectively accommodating the already existing broadcasting services (analogue) mode to the new technology (digital) mode for the period of the migration.

This implies that once the switch over takes effect, existing viewers should not experience difficulties with issues like loss of reception.

d. Various aspects of the broadcast infrastructure and technologies, including broadcasts via cable, broadband internet, direct broadcasting, satellites or other forms of reception must be considered in the plan. This is because they all affect the number of people that need to get the special digital-receiving equipment.

e. Planning must be based on the systems with current DTTB technologies that can meet the required data rate for compatibility (with current and future systems) whilst making room for existing systems.

f. It is required that digital planning takes into consideration, the existing analogue planning assumptions with regards to the reception environment. This implies that the outdoor receiver antenna height above the ground must be factored.

2.6 Related works on technology transition

"Transition from Analog to Digital Broadcasting: A spectral efficiency review" by Zainea, Emilia et al (2012)

In [24], their work was accomplished by collecting data from two locations on spectral efficiency measurement of 470-790MHz band which at the moment contains both analog and digital TV stations. The two locations were on a storey building, with one location on the ground floor and the second on the third floor which were 15m apart.

Discussion of work done by Zainea, Emilia et al (2012)

With the ground level, they measured spectral occupancy of 31.19%. Out of this, 10% was the spectral occupancy of the DVB-T signals and 2l.l9% represented the analog signals of 8 TV channels. Recall that DVB-T signal can carry up to 8 TV or more channels depending on the quality requirement.

At the second location (third floor), they measured spectral occupancy of 29.69%. Out of this, 19.69% represented the 14 analog TV channels. With the DVB-T, they could transmit up to 24 channels on the 3 DVB-T areas in the spectrum.

Their research result revealed that Digital broadcasting has better spectral efficiency than the analog broadcasting. However, with regards to this project, their work did not talk about the factors that affect the transition process, such that one can analyze the dynamics of a country's transition.

"Optimal Control Model of Technology Transition" by Hanson, D.A.,Kryukov Y., Leffer, S., and Munson, T.S. (2009))

This was about the transition from conventionally old to a new low emission technology for energy production [25].

The problem was that, though the new technology has lower emission rate of greenhouse effect, it had higher cost of generation.

They solved an optimal control problem arising in the modeling of technology transition by means of optimization software. This was accomplished by setting up a number of complex models having features like learning-by-doing, adjustment cost, and capital investment. They wrote the model in continuous time followed by discretization, using different approaches to transform them into large-scale nonlinear programs. A modeling language and numerical optimization methods were finally used to solve the optimization problem

Discussion on work done by Hanson, D. A., Kryukov, Y., Ley_er, S., and Munson, T.S.

An optimal transition from conventionally old production system to a new technology for energy production was computed.

In their work, three models were proposed, covering:

a) The concept of learning-by-doing and selecting the output schedules in order to maximize the discounted welfare without exceeding the emission cap was modeled without factoring the adjustment cost.

b) A model on Adjustment Cost; Here, Model one was modified by imposing an adjustment cost on the increase in new energy output.

c) Model on Capital Investment. The need to build up on the new technology is what motivated the adjustment cost and so a direct capital investment was modeled.

In each case an optimal control scheme was used to evaluate values that were cost effective in order to ensure a smooth transition.

However, this work did not mention any method or model for measuring the performance of work done in the transition process.

2.7 General description of modeling

The representations of the actual world objects, process, activity etc is termed a model. By modeling, we mean the development of a model, which usually does not have a specific rule or steps as guidelines.

The application of models are found in several disciplines like engineering, psychology, sociology, political science, statistical study etc. as it enables one to make predictions regarding the expected outcome for a given input to a system's model. This also implies that, by using models, expect, could describe the behavior of a particular system and make room for future events.

2.7.1 Types of Models

According Stark and Nicholas [26], Models can be grouped into three common types as

1. **Iconic models:** Models that represent the real thing with a scaled down version.

2. **Analog models:** These are models that use other media such as electric current to represent the modeled phenomena.

3. **Symbolic model:** These are mathematical models which depend on prefix, infix or postfix notations.

A model may also be categorized into any of these three:

a. **Cross Section**: This model refers to modeled variables of a particular period. E.g. A cross sectional regression model that applies to a specific period.

b. **Time Series:** In contrast to cross section model, this refers to modeled variables over a series of time intervals. An example is the moving-average model which is a way of solving univariate time series problems. By extrapolating from historic data, time series model can be used to predict the occurrence of future event.

c. **Combined or comprehensive:** This usually refers to a model of occurring events over many periods of time. It is a model that involves times series of cross sections. With this type of model, predictions can be made over several periods of time.

2.7.2 Mathematical Model

A mathematical model is a representation of mathematical concept organized in a specific format to describe a system. It is an abstraction of real world situation, system, activities, processes, etc often achieved by the manipulation with mathematical techniques and language.

Mathematical Models come in different types and levels of complexity. These include the modeling of dynamic systems, statistical modeling, game theoretic modeling, modeling with differential equations etc

In recent times the availability of highly efficient computers and software has lead to the emergence of contemporary classes of models. These types of models use a method based on complexity theory that takes care of uncertainties. By using computers, there is a large extent to which modeling can be achieved. This is because, software provide the flexibility of combining data, sound and graphics. Also, software provides interactive environment and the ability to create different kinds of mathematical models.

Different types of models may overlap, especially for models that involve different abstract structures. For example, a mathematical model is often combined with iconic model in simulation tools. Generally, a mathematical model may be a logical model, since logic is considered as a part of mathematics. It may also be classified as deterministic or statistical with regards to the approach and result the model provide.

Usually, a developed mathematical model is based on mathematical concept that must agree with the experimental measurement. Thus, where this condition is not met, further development is required once better theories are discovered.

A typical block diagram for a mathematical model is seen in figure 2.4 below.

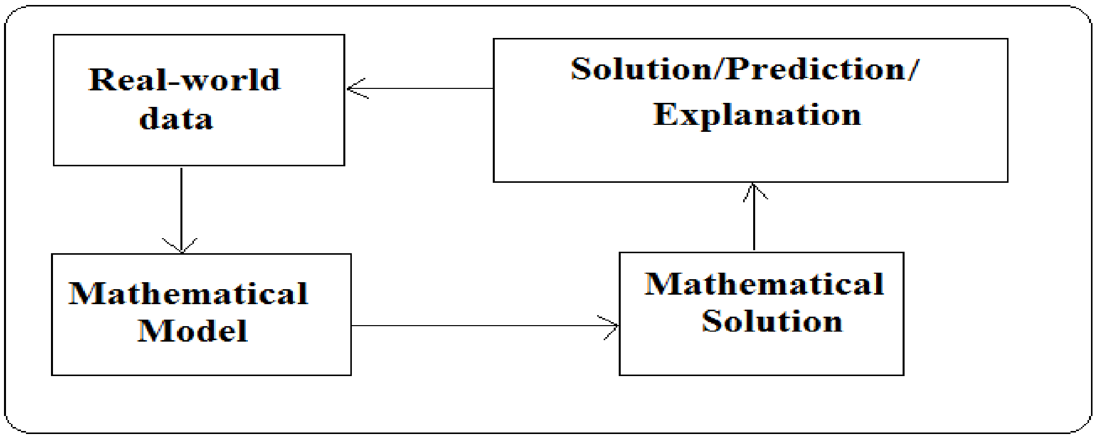

Fig 2.4: A block diagram representation of Mathematical Modeling.

2.7.3 Mathematical Model Classification

According to [27] a mathematical model can be classified as

a. **Analytical models**

Analytical model usually have a function or set of functions describing the behaviour of the system being modeled.

b. **Numerical models**

These are models that have a closed set solution. The solution is described with values.

2.7.3 Transition model

Transition model, depending on the discipline may have different definition. For example, in biostatistics, it refers to an extension of class of generalized model like linear regression, logistic regression, poisson regression etc.

In control theory, a state transition model usually involves the use of state-transition matrix whose product with the state vector $\mathbf{x_0}$ in an initial time $\mathbf{t_0}$ gives a new state $\mathbf{x}$ after an interval time $\mathbf{t}$. This implies that with the state-transition matrix, the general solution of linearized dynamic system can be obtained. The state transition is also referred as the matrix exponential. In the next chapter, a detail description to the state transition matrix and its application would be presented.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter focuses on the model development for forecasting the performance of the analogue to digital transition broadcasting in Ghana. First, the conceptual model is described to lay a foundation before the model development. The measurement techniques adopted for the four main factors were identified from a study of Ghana's ADBT are also described. The model development is also presented in detail. This is followed by a presentation on the training and validation of the model. Finally, the conclusion for the chapter is drawn.

3.2 The Background of the Conceptual Model

The conceptual model for analyzing Ghana's digital migration process in this work is likened to a system with multivariate inputs and outputs variables as shown in figure 3.1. The outputs of this system are determined by a function of the inputs variables and the previous conditions of the system.

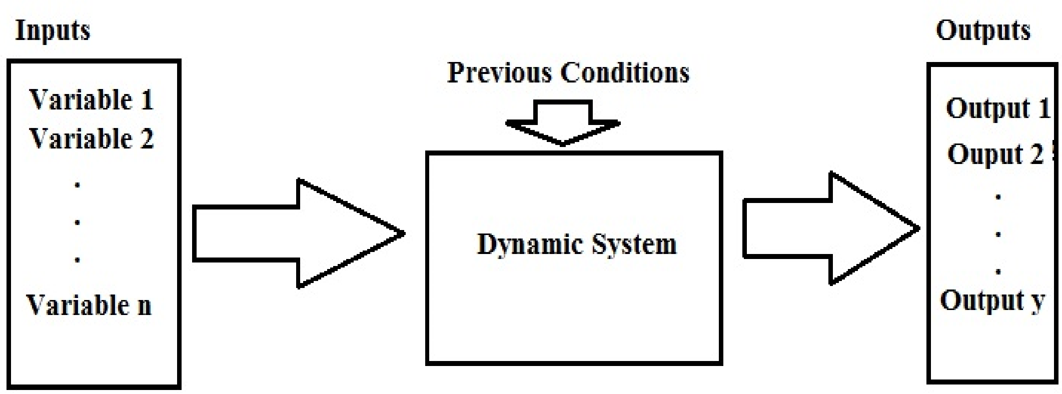

Fig 3.1: The Block Diagram of the Conceptual Model

The concept of fuzzy logic is a very useful tool that can enable us to model the factors that can affect the success of the transition process. Thus the knowledge of the values of the inputs or factors of the transition at a particular time ($\mathbf{t_n}$) together with the previous conditions at time ($\mathbf{t_{n-1}}$), can be used to predict the performance or completion level at time ($\mathbf{t_{n+1}}$) by means of fuzzy inference system (fis). The output function of this system can be realized by a set of rules **R** where each rule is assigned a weighted value. The rules are also based on the fuzzy values of the inputs variables where each variable may have two or more fuzzy partition. To explain the details of the model we first discuss how the data was obtained, followed by the model development.

3.3 Data

The data used for the model was gathered from a survey (through a rating-scale) conducted at the National Communication Authority (NCA) and Ghana Broadcasting Cooperation. This was possible through a section of technical personnel of the implementation team who willingly assisted in the assessments after being thoroughly briefed on the concept of this work. Prior to the assessment, application for assistance was put forward to the Director General of NCA. This data is an assessment of monthly status of the ongoing transition from January 2007 to April 2014. In this work, the factors for forecasting the performance of the migration or the completion level are: the country's expenditure, human capital, infrastructure and Quality of services. These factors were measured by using a scale from 1 to 5. The completion level, which is the key aspect of the transition, was also measured from the perspective of the implementation team in terms of percentage level of completion.

In an attempt to obtain the mathematical model for analyzing the dynamics of the ADBT, several approaches were reviewed. However, fuzzy logic modeling was the most appropriate technique adopted in this work. This is because the measurement of variables considered as factors of ADBT success were based on the perceptions of ADBT implementation team.

Considering the block diagram of the conceptual model, the current state of the four different input data described as the country's expenditure, human capital, infrastructure and quality of service are not enough for forecasting the future level of completion. Thus both the current and previous values of the completion status of the transition are considered as additional inputs for the model. This technique was adopted from [28] where half-hourly electricity demand was forecast from current temperature, current power demand, previous temperature (previous day's) and previous power demand (previous day's). The tables below describe the original data table format, the fuzzified data and the actual format of the data used for the model.

Table 3.1: A Snapshot of Raw Data.

Expenditure	**Infrastructure**	**Human Capital**	**Quality of Service**	**Completion Level (%)**
1	2	3	1	10
1	2	3	3	15
4	3	2	4	45
3	3	4	4	50
3	4	4	4	60
4	4	4	4	65

Table 3.2: A Snapshot of Fuzzified Data.

Inputs Without Previous Condition				**Related Output**
Expenditure	**Infrastructure**	**Human Capital**	**Quality of Service**	**Completion Level (%)**
Insufficient	Low	Average	Inadequate	10
Insufficient	Low	Average	average	15
Sufficient	medium	poor	adequate	45
Average	medium	good	adequate	50
Average	Enough	good	adequate	60
Sufficient	Enough	good	adequate	65

Table 3.3: A Snapshot of Fuzzified Data for the Model

Inputs with Previous Condition						**Related Output**
Expenditure (x_1)	**Infrastructure (x_2)**	**Human Capital (x_3)**	**Quality of Service (x_4)**	**Previous Completion Level (x_5)**	**Current Completion Level (x_6)**	**Forecast Completion Level (%) (y)**
Insufficient	Low	Average	Inadequate	low (10)	low (10)	15
Insufficient	Low	Average	Average	low (10)	low(15)	45
Sufficient	medium	poor	adequate	low (15)	medium(45)	50
Average	medium	good	adequate	medium (45)	medium(50)	60
Average	Enough	good	adequate	Medium (50)	high (60)	65
Sufficient	Enough	good	adequate	High (60)	High (65)	67

3.4.1Fuzzy Model: Fuzzy Inference System (Fis) Structure

The structure of the Sugeno type fuzzy inference system in this work represents the structure of conceptual model for the analogue to digital broadcasting process. This process requires the necessary factors or inputs which dynamically interact to produce an output. As seen in figure 3.2, the inputs are: Previous Completion Level, Expenditure, Infrastructure, Human Capital, Quality of Service, and Current Completion Level. The final output of the system under consideration is the Forecast Completion level. The fuzzy system is where a set of rules are defined on the input variables to obtain all possible output values.

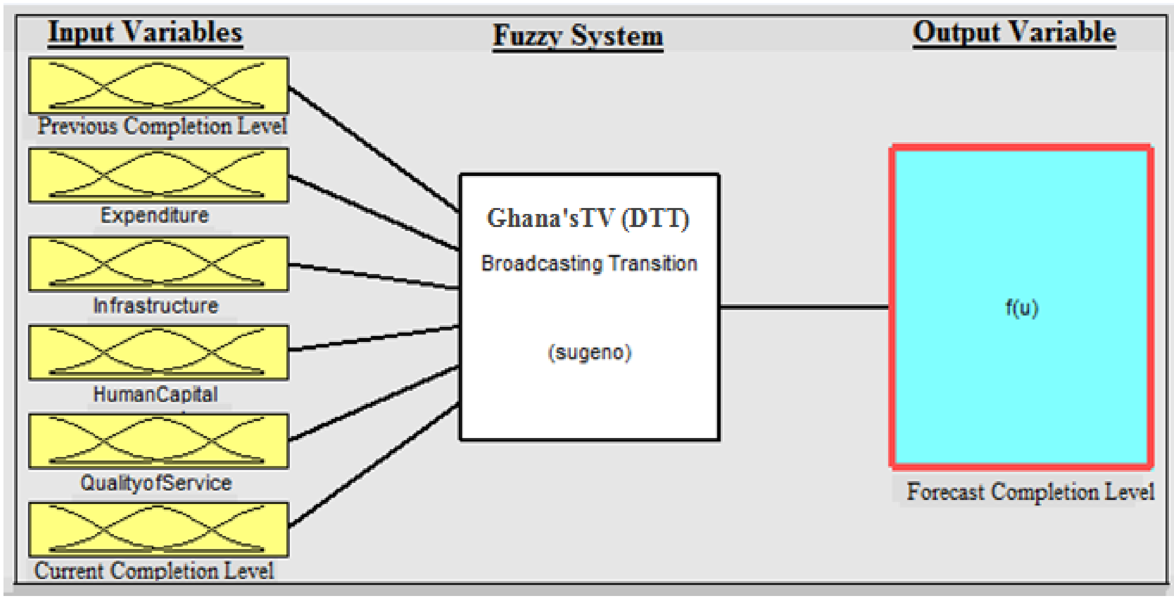

Figure 3.2: The structure of the Sugeno-Takagy Fuzzy inference System

The model has several stages which begins with the membership function determination, followed by rules determination at which point the fuzzy inference system (FIS) can be obtained. For Mamdani type FIS, the knowledge of a set of very good rules can be very good for prediction. However to avoid the tedious work of setting all the necessary rules, Matlab Toolbox for Takagi-Sugeno (TS) type FIS enables us to train and validate the model. This toolbox is known as ANFIS, an acronym for adaptive neuro-fuzzy inference system that uses either back propagation or a hybrid of back propagation and gradient descend methods to learn the parameters of the membership functions from a given set of data.

3.4.2 Fuzzy Model: Membership Function

Membership function determination is key to model performance. Several membership functions have been proposed in the past. These include triangular, trapezoidal and bell shaped membership functions. In this work, triangular membership function was used for all inputs variables.

The triangular membership function $\mu(x)$, is specified by three parameters $\{d_1, d_2, d_3\}$ with $d_1<d_2<d_3$. Where d1, d_2, d_3 :R→[0,1] From a given set of variables (**x**), the corresponding k^{th} membership function (μ_k) for each input variable is given as:

$$\mu_k(x_i) = \begin{cases} 0 & if \;\; x < d1 \\ \dfrac{x-d_1}{d_2-d_1} & if \; d_1 \le x \le d_2 \\ \dfrac{d_3-x}{d_3-d_2} & if \;\; d_2 \le x \le d_3 \\ 0 & if \;\; x > d_3 \end{cases} \qquad (1)$$

This can also be expressed in (2) as:

$$\mu_k = \max[\min(\frac{x-d_1}{d_2-d_1}, \frac{d_3-x}{d_3-d_2}), 0] \qquad (2)$$

The parameter $\{d_1, d_2, d_3\}$ with $d_1<d_2<d_3$ determine the x coordinates of three corners of the underlying triangular membership function. Figure 3.2 shows the triangular membership function with d_1, d_2 and d_3 parameter.

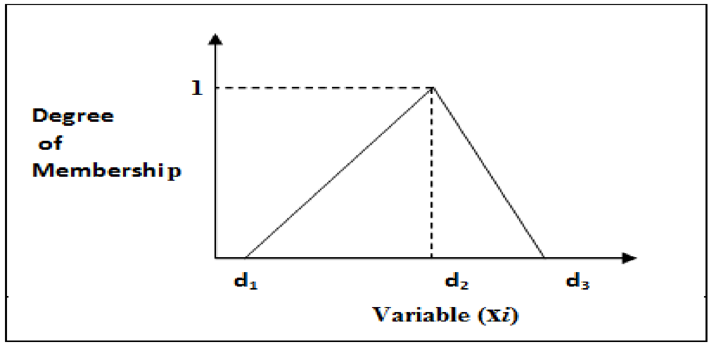

Figure 3.3: The Triangular Membership Function

In all the variables, triangular membership functions are defined with deferent parameters. Figure 3.4 illustrate the Human Capital triangular membership function

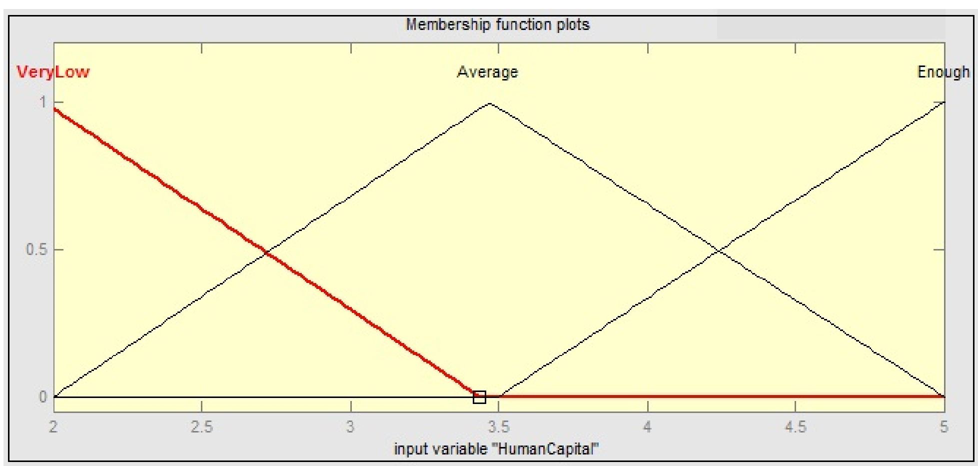

Figure 3.4: The triangular membership function for Human Capital.

3.4.3 Fuzzy System:Fuzzy Rules Development

The fuzzy system was obtained by deducing If-Then rules from the data set gathered from the survey. However, Anfis was used to specify the number of membership functions for each input variable.

In a parameter varying systems where there exist a number of working state characteristic variables **m**,and **q** inputs and single output can be described by the Takagi-Sugeno fuzzy model consisting of R rules[29].

Thus i-th rule can be represented as:

$$\begin{aligned}&\text{Rule i: } \textit{if } z_i \textit{ is } A_1^{i,k1}, z_2 \textit{ is } A_2^{i,k2}, \ldots, \textit{ and } z_m \textit{ is } A_m^{i,km} \\ &\textit{then } y^i = a_1^i x_1 + a_2^i x_2 + \ldots + a_q^i x_q \qquad (3) \\ &i = 1, 2, \ldots, R. \qquad k_j = 1, 2, \ldots, r_j.\end{aligned}$$

Where R is the number of rules in the TS fuzzy model.

$\mathbf{z_j}$ is the **j**-th characteristics variable, which reflects the working state of the systems and can be selected as input or other variables affecting the parameters of system dynamics.

$\boldsymbol{x_l}$ ***(l*** **=1,2, ...,** ***q)*** is the ***l***-th model input. $\boldsymbol{y^i}$ is the output of the **i**-th rule.

For the i-th rule, $A_j^{i,kj}$ is the k_j-th fuzzy partition number of z_j. | a_l^i is the coefficient of the consequent. $\mathbf{r_j}$ is the fuzzy partition number of $\mathbf{z_j}$. Thus, we let $\mathbf{r_j} = \mathbf{r}$ (where r is determined by both the complexity and the accuracy of the model).

Given a set of working state variables ($\mathbf{z_{10}}$, $\mathbf{z_{20}}$, **...**, $\mathbf{z_{m0}}$) and the model input variables ($\mathbf{x_{10}}$, $\mathbf{x_{20}}$, **...**, $\mathbf{x_{m0}}$), then the output of the TS model under such working states can be calculated by the weighted-average of all $\mathbf{y^i}$ as:

$$y = \frac{\sum_{i=1}^{R} u^i \, y^i}{\sum_{i=1}^{R} u^i} \qquad (4)$$

where $\mathbf{y^i}$ is determined by consequent equation of the **i**-th rule.

The truth-value $\boldsymbol{\mu^i}$ of the **i**-th rule can be calculated as:

$$\mu^{i} = \underset{j=1}{\overset{m}{\Lambda}} A_{j}^{i,k_j}(z_{jo}) \qquad (5)$$

Furthermore, equation (5) can be rewritten as:

$$\frac{\sum_{i=1}^{R} u^{i}\, a_{1}^{i}\, x_{1} +, \ldots, + \sum_{i=1}^{R} u^{i}\, a_{q}^{i}\, x_{q}}{\sum_{i=1}^{R} u^{i}} \qquad (6)$$

From [29], the TS fuzzy model can be expressed as an ordinary linear equation under certain working states since the truth-value μ^{i} is only determined by the working state variables. As μ^{i} varies with working state, TS fuzzy model is a coefficient-varying linear equation. For all possible varying ranges of working states.

The TS fuzzy model reflects the relationships between model parameters and working states. Therefore, the global dynamic characteristics of the parameter varying systems can be represented.

3.4.3 Problem Formulation

The objective of this work is to represent the dynamics of the ADBT process in a single nonlinear model as a set of local linear models. Each local model should be able to represents the relationship between the input variables x_1, x_2, x_3, x_4, x_5, *a*nd $\mathbf{x_6}$ which represent Expenditure, Human Capital, Infrastructure and Quality of Services, Previous Completion Level and Current Completion Level respectively, and the observed variable y in a certain range of operating conditions.

In summary, a function f for this relation as can be expressed in a form of set of fuzzy rules as given in R_1. Thus the proposed fuzzy model structure can be successfully represented by means of fuzzy If-Then rules.

$$y = f(x_1, x_2, x_3, x_4, x_5, x_6) \quad (7)$$

R_1 : If x_1 is A_{11} and x_2 is A_{12} and x_3 is A_{13}

and x_4 is A_{14} and x_5 is A_{15} and x_6 is A_{16} then

$$y^1 = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5 + a_6x_6 \quad (8)$$

By the use of the antecedent and appropriate membership functions of the rule we can define the fuzzy region in the product space. The antecedent variables give the condition of the transition factor status.

In this work, the same formulation described above was applied to six similar model where each model differ from another in terms of the number of membership functions for all model inputs.

3.4.5 Model Training and Model Validation

First of all, the whole data set gathered in this work was divided into two parts, namely: training data and validation data. The division of data was achieved through a Matlab script which randomly selects validation data set without replacement with a ratio of 75:25 for training and validation data respectively.

Six sets of training and validation operations were performed on the same data sets. The essence of this was to identify the option that gives a model with highest accuracy of prediction. By means of Matlab Anfis Toolbox and commands, the models were trained and validated. However, each pair of training operations was performed concurrently.

In all cases the parameter learning methods used was a hybrid of back propagation and gradient decent.

Table 3.4: Models with different pattern of membership functions

Model	Training method	Membership function pattern for x_1, x_2, x_3, x_4, x_5, *a*nd x_6.	Number of training epochs
Model 1	Hybrid	3,3,3,3,3,3	40
Model 2	Hybrid	3,3,3,3,4,4	40
Model 3	Hybrid	4,3,3,3,3,3	40
Model 4	Hybrid	3,4,3,3,3,3	40
Model 5	Hybrid	3,3,4,3,3,3	40
Model 6	Hybrid	3,3,3,4,3,3	40

3.5 Conclusion

In this model, the focus was on obtaining very minimal errors as possible. All errors of the test were the root mean squared errors (RMSE) which is reported in Chapter 4. The model selected as the best in this work is also based on the one with the lowest RMSE

Since this type of model consist of several local models and not in general a global type like linear regression, when this model predicts with very high error on a new set of data, the model can be retrained.

CHAPTER 4

RESULT AND ANALYSIS

4.0 Introduction

Having completed the development of the model for forecasting completion level of transition of broadcasting in Ghana, we further perform tests cases on the data gathered from the survey in order to understand the relationships in the input variables on the output variables. In this chapter a detailed report of the simulation result is presented. This section will also address the implications of the test results in each case in order to establish relevant facts which can be considered in the ongoing ADBT migration process.

4.1. Test Results

Training and validation results are presented in figure 4.1 to 4.6. These results are root mean squared errors which are very useful in performing model accuracy analysis. In order to have a fair distribution of sample for testing, the test data set was obtained by first randomizing the order of the samples and selecting first 22 data points which represent a 25% of actual data.

Model 1

The first model was developed with three (3) membership functions in all the input variables. Thus the membership function pattern was 3,3,3,3,3,3 for Expenditure, Infrastructure, Human Capital, Quality of Service, previous completion level and current completion level respectively. The result for training and validation on datasets for 40 epochs is presented below in figure 4. 1. In the plot, the training error was obtained as 0.26579%, whereas the validation error was obtained as 1.9627%. The result shows that the training and validation errors decrease monotonically. Therefore the parameters of the model were well learnt.

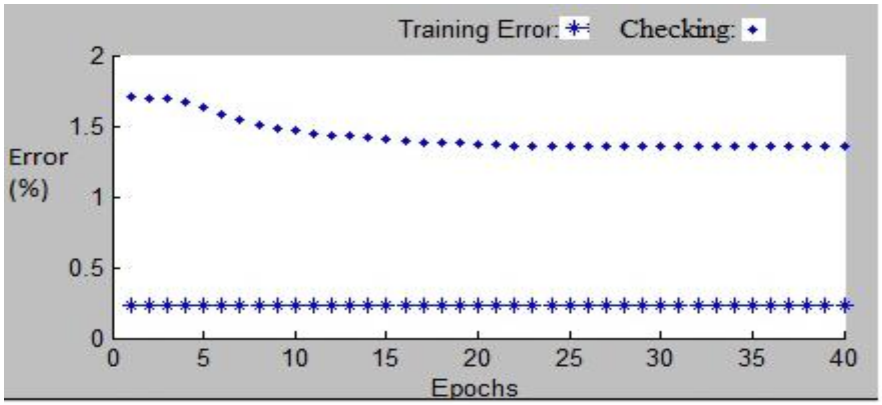

Figure 4.1: Training and Validation for Model 1

Model 2

The second model is a modification made to model 1. After the first model testing, the second model considered changes in number of membership functions (from 3 to 4) in previous completion level and current completion level. Therefore with input membership function pattern of 3,3,3,3,4,4 the training error of 0.16202% was obtained and the validation error was 2.61286%. From epoch 1 to epoch 4, there was a case of over fitting but from epoch 5 to epoch 40 there was a monotonic decrease of errors. Thus, this model achieved good learning as seen in figure 4.2.

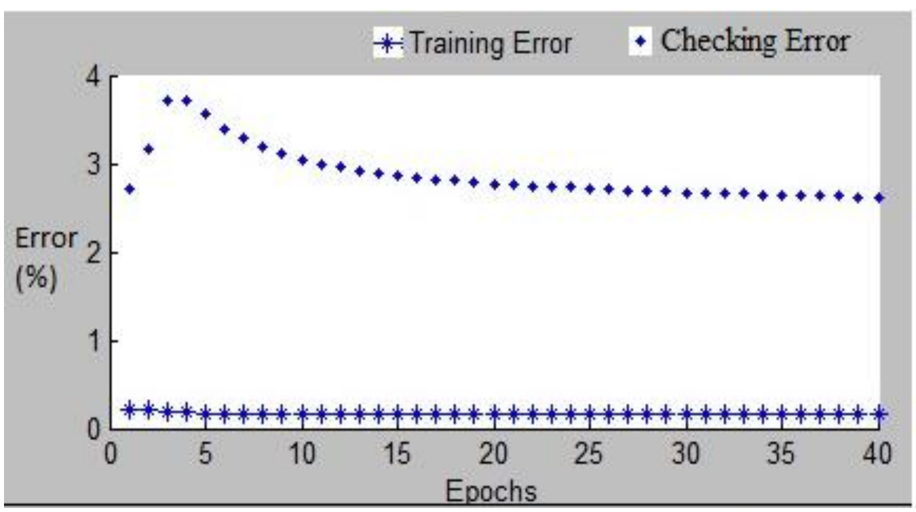

Fig 4.2 Training and Validation for Model 2

Model 3

In this model, only the number of membership functions of the Expenditure was made 4 with the remaining variables having 3 input membership functions each. With membership function pattern of 4,3,3,3,3,3 the result indicates that the training error was 0.26575% and the validation error was 1.8165%. In figure 4.3, there was overfitting until up to epoch 20 and then to gradual decrease monotonically. However this model produced the least prediction error.

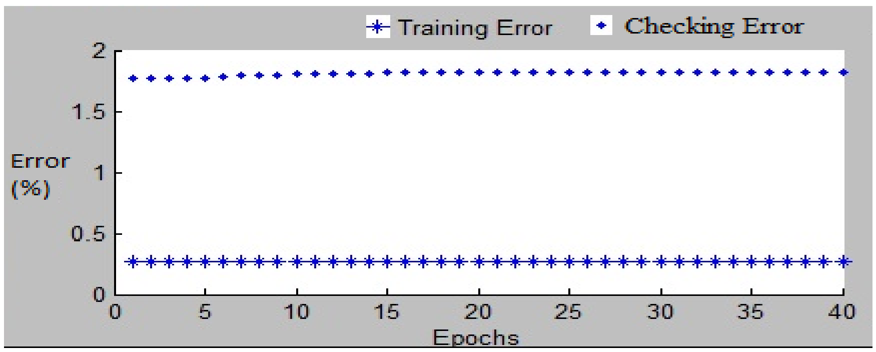

Figure 4.3: Training and Validation for Model 3

Model 4

In this model, only the number of membership functions of the Infrastructure was made 4 with the remaining variables having 3 input membership functions each. With membership function pattern of 3,4,3,3,3,3 the result indicates that the training error was 0.26627% and the validation error was 1.96269%. This model generally achieved good learning as seen in figure 4.4.

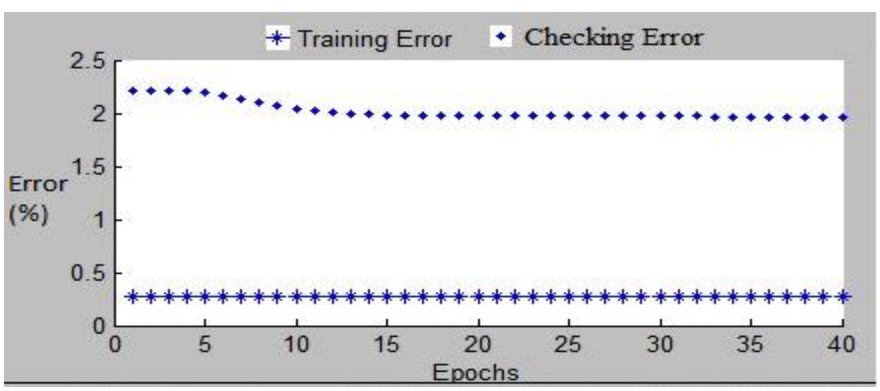

Figure 4.4: Training and Validation for Model 4

Model 5

In this model, only the number of membership functions of the Human Capital was made 4 with the remaining variables having 3 input membership functions each. With membership function pattern of 3,3,4,3,3,3 the result indicates that the training error was 0.26575% and the validation error was 1.96853%. The parameter learning done in this model was similar to model 3 but this model has higher validation error.

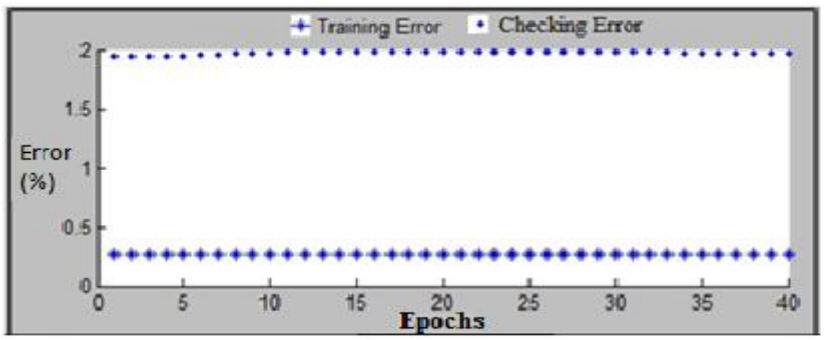

Figure 4.5: Training and Validation for Model 5

Model 6

In this model, only the number of membership functions of the Quality of Service is made 4 with the remaining variables having 3 input membership functions each. With membership function pattern of 3,3,3,4,3,3 the result indicates that the training error was 0.26579% and the validation error was 1.94295%. This result also indicates that the model had good learning curve.

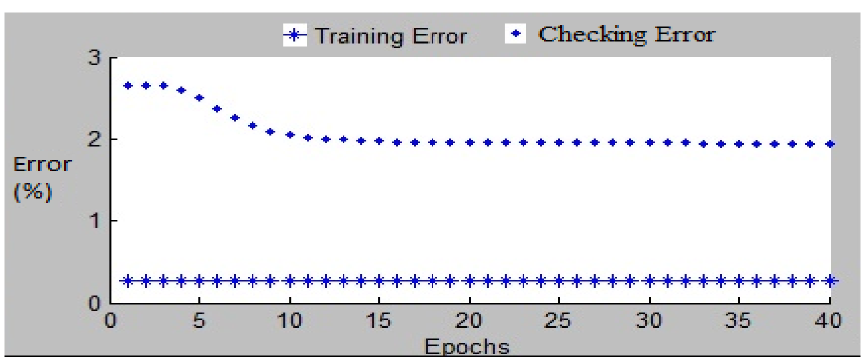

Figure 4.6: Training and Validation for Model 6

4.2: Analysis of Results of all Models

The training and validation result in each of the above models indicates that there were generally low prediction error values as given by the models. However, more analysis can be performed on the Table 4.1 which summarizes the results of all training, validation and testing errors obtained in all six models. All errors are given in root mean squared value.

Table 4.1: Comparison Table of Prediction Errors of the Models

Models	**Prediction Errors (Root Mean Squared Errors)**			
	Training (%)	Validation (%)	Testing (Test data) (%)	Testing (All Samples) (%)
Model 1	0.26579	1.9627	0.5349	1.0081
Model 2	0.16202	2.6129	1.5680	1.3139
Model 3	0.26575	1.8165	0.5418	0.9870
Model 4	0.26627	1.9627	0.5349	1.0091
Model 5	0.26575	1.9685	0.5271	1.0682
Model 6	0.26579	1.9430	0.5300	1.0489

It can be observed that, the training errors were very similar with the exception of model 2 which had much lower error. For validation, prediction errors were also similar in all cases except for model 2 which had the much higher error. Generally, the table indicates that the pattern of validation errors is related to that of the testing errors which is not the case in comparing pattern of training errors to that of testing errors. The least prediction error for test data was given by model 5; however, the least prediction error for the whole sample data was given by model 3 which is also consistent with the least validation error. This is because the data point of 22 testing data from the whole sample of 88 is not large enough to give conclusion of the best model.

Thus by comparing all RMSE's, Model 3 is the best model. This selection process is also consistent with work done [28].

Using model 3 the actual and the predicted Ghana's DTT transition completion level in percentage is presented in figure 4.7.

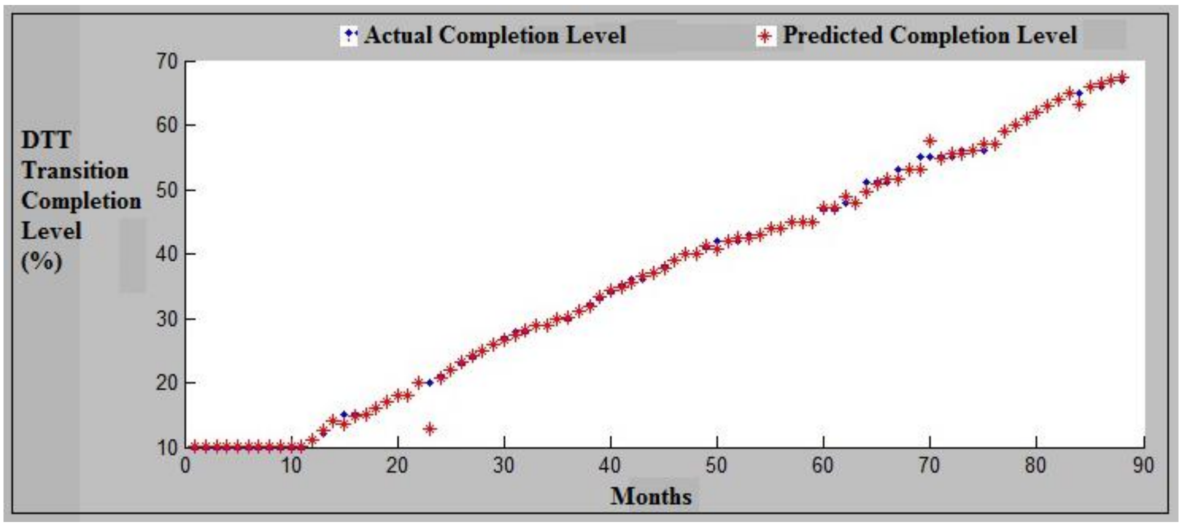

Figure 4.7: Actual and predicted DTT completion level (From January 2007 to April 2014)

The graphical result in figure 4.7 shows that model 3 predicts with very low errors (0.93894%). Further interview with the technical team revealed that major changes occurred in: 2008 when GTV first launched a pilot transition, from 2012 to date major changes occurred for TV Operators like Go TV, UTV, ViaSat1 and Sky Digital. Thus, the highly dynamic periods are the reasons for areas of mismatch in prediction curves. It was also observed from the study that where completion level remained constant for the first 11 months was due to initial stage of the transition process where no funding had taken place and fewer activities were performed. Where there are gradual increments of completion level was mostly caused by the availability of good funding and Infrastructure.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.0 Introduction

This chapter covers a summary on this project. Thus, the relevant findings in the course of the study as well as the findings in the simulations are presented. This is followed by a conclusion to the project and finally, recommendations for the ADBT process and future work are also given.

5.1 Summary of Findings

The availability of very good expenditure is not enough to guarantee good transition but also the need for very good human capital and infrastructure are very important to ensure good transition. According to the study, Ghana's transition is highly driven by the availability of good funding and Infrastructure, since human capital and quality of service are in very good state now.

From the simulations run, it is observed that the interactive nature of the components of the transition process, like Infrastructure, Human Capital, and Expenditure, can be used to determine how rapidly the transition process can take effect. It is also observed that when timelines are not adhered to, it will leads to further delay in the implementation of the ADBT. This may require more manpower in order to meet deadline.

In Ghana, the technical committee which was set up for the Digital Transition process had made meaningful contributions regarding DTT standard recommendations and implementation plans. However, funding of the migration project which would have been a better choice for transition is still a major challenge.

Though the government does not currently have a common platform for the Digital Terrestrial Television network, the migration is ongoing but with a low pace. This is because the individual network operators are all finding a way of changing to this new system in order to remain in operation after full switchover is effected.

5.2 Conclusions

The concept of fuzzy logic has been successfully applied to the modeling of the performance of Ghana's analogue to digital broadcasting migration process.

With the results of a number of simulations under several scenarios, it is possible to state that any decision made in the course of the implementation will be reflected in the final outcome of the transition process. Thus, the model could be used to compare achievements or progress of work done at any stage of the transition.

5.3 Recommendations

Decisions made in every aspect of the ADBT should not be done in isolation, but must take into account the effect it will have on other aspects of the transition. In order to meet the deadline set for analogue broadcasting, it is recommended that every aspect of the transition must be addressed or managed efficiently. For example, funding should be well managed in the area of DTT infrastructure with the ultimate aim of meeting the deadline.

Due to the unavailability of common DTT platform for the country, the Government may encourage individual operators to migrate before the deadline set by ITU. However, to ensure smooth transition like the case of Tanzania and Mauritius, the government is recommended to subsidize the cost of set-top boxes to enable the numerous Ghanaians who may not afford digital television sets.

Further work in this area should consider mechanism for parameter control design for other technological transition process similar to the ADBT.

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