OPTIMISING TELEVISION PROGRAMMING AND SCHEDULING

MHD HANI ALSHAMI

A Thesis submitted for the degree of

Doctor of Philosophy

Department of Management Science

Lancaster University Management School

Lancaster, United Kingdom

December 2016

Declaration

i. This work has been carried out at the Department of Management Science, Lancaster University Management School, Lancaster, United Kingdom. No part of this thesis has been submitted elsewhere for any other degree or qualification, and it is all my own work unless referred to the contrary in the text.
ii. The content of this thesis is accessible through Lancaster University repository. All data and material referred to in this research that belongs to a third party are referenced to their owner.
iii. The word length of the thesis does not exceed the permitted maximum for the PhD degree.

Abstract

Recent changes in the broadcasting industry and emerging digital media technologies have "disturbed" the traditional economic models supporting the media industry over the last decade, with viewers migrating from traditional media outlets to digital ones causing a severe drop in revenues. Consequently, the competition for viewers' ratings has intensified dramatically over recent years, with new economic models being introduced and others still under development.

In this context, the research presented in this thesis describes in detail an innovative computer model for optimising television programming and scheduling to maximise revenues under given constraints. The research methodology combines academic work along with practitioners' experiences to build an integer programming model that helps expert programme schedulers to place television programmes in time slots where they achieve optimum ratings within the limitations of the resources available.

In building the model, an extensive literature review and media industry experts' interviews and focus groups discussions were conducted. The value of the model was demonstrated by applying it to a real case as well as hypothetical scenarios for a television station and showing that the model increased potential viewership, on average, between 38% and 63%.

The software package used to solve the model should enable the media industry to solve large scale optimisation models using thousands of variables and constraints. This should help media planners and decision makers to plan for months, if not years, ahead.

Acknowledgments

First and foremost, I would like to express my sincere gratitude and appreciation to my advisor Professor Michael B. Wright. You have been a great mentor for me! I would like to thank you for your patience, motivation, and continuous support throughout my PhD study. Your guidance and advice helped me all the time with the research and writing of this thesis.

Besides my advisor, I would also like to thank Professor Stein W. Wallace and my annual PhD review committee members, Professor John Boylan, Professor Matthias Ehrgott, and Professor Konstantinos Zografos for their insightful comments and encouragement. Your hard questions encouraged me to widen my research from various perspectives.

My sincere thanks also go to my colleagues at Aljazeera Media Network, where I conducted this research, starting with the Director General, Dr Mustafa Souag, passing through the Channels Managing Directors, Programmes and News Directors, Content Editors and Producers, Programme Planners and Schedulers, Media and Market Researchers, and ending with the Strategy and Planning Team. I would like to thank you all for giving me the access to data required to complete my research and for your active participation in the interviews and focus groups that enriched my research. Without your precious support, it would not be possible to conduct and finalise this research.

I am also grateful to Mr Edouard Monin, Chairman and CEO of Ipsos MENA region and Mr Tarek Sheikh Shabab, Vice President of BD and CS at Ipsos MENA region for giving me the access to viewership data and for their support and participation in my research interviews. Their comments and feedback helped me a lot in finalising my PhD research.

Very special thanks go to the soul of my Father Eng. Mhd Chah AlShami, a former General of the Army in the Syrian Air Forces who passed away in 1991 and my mother, Mrs. Hanaa Bairakdar, a former elementary school principal, who both instilled in me the love of science and research and continuously encouraged me throughout my early steps in life and education to stay focused and to work so hard to achieve this step in my life.

Words cannot express how grateful I am to my family, to my mom and dad, brothers' Dr Mahmoud and Eng. Mohannad, my sister Mays, and my beloved wife Njoud for all of the sacrifices that you have made on my behalf. Your love and encouragement, your prayers for me were what sustained me thus far. Thank you for supporting me for in every step of my life.

To my beloved daughters Hala and Yara, I would like to express my thanks for being such good girls who are always cheering me up.

Finally, and most importantly, I thank God for helping me to overcome all the difficulties along the way. I have experienced Your guidance day by day. You are the one who helped me finish my degree successfully. I will keep on trusting You and praying for you throughout my life. Thank you.

Mhd Hani AlShami
Lancaster University
December 2016

Table of Contents

Dedication

This thesis is dedicated to my parents for making me be who I am, my brothers and sister, my lovely wife Njoud, and my little princesses Hala and Yara with my everlasting love,

List of Figures

List of Tables and Charts

Chapter 1

This chapter is divided into four parts. The aim of the first part is to give the reader a general background on the research problem. The motivation of this work is presented in the second part. The third part will focus on the research objectives and the methodology of this work. The remainder of the chapter is devoted to highlighting the research contribution to academia and real practice.

1.1 Background:

According to recent statistics published by Statistica Portal, global advertising spending in 2013 amounted to 516.47 billion U.S. dollars. eMarketer expects it to grow to 667.65 billion by 2018[1]. Television advertising is the dominant advertising medium attracting 40% of spending in 2014[2]. Researchers believe that, despite the healthy growth in television advertising expenditures, it is likely to fall back over the next few years as other advertising media are growing rapidly such as Desktop and Mobile Media. That will put pressure on marketers where they need to move their budgets to other media platforms to reach their targeted audience. Television officials sell their advertising time on air by forecasting the number of viewers of their television channels throughout the day. For this purpose, audience ratings are utilised along with forecasting models for viewership prediction.

Competition and the challenges of the current economy are forcing media organisations to reconsider their offerings. They must improve and diversify their income streams and reduce their costs while raising viewership ratings and simultaneously raising

[1] http://www.statista.com/statistics/273288/advertising-spending-worldwide/
[2] http://www.zenithoptimedia.com/

viewers' expectation and satisfaction levels. To do this, media organisations need to relook at their programme offerings and revisit their programme schedule to improve viewership ratings without replacing existing assets or incurring substantial investments.

Programme scheduling is at the heart of television planning. Putting together a television programme schedule, usually called a "Programmes Grid", requires experienced schedule planners/programmers working together to create and maintain the weekly/monthly programme schedules. This is usually a complicated and labour-intensive process that can prevent media organisations from reacting easily and quickly to unexpected changes in competition and viewership behaviours.

In 2009, the media sector faced a severe crisis resulting from two separate but equally damaging threats - one structural and the other cyclical. The structural threat was the emergence of digital technologies that "disturbed" the traditional economic models supporting the media industry. These online platforms enabled the viewer to migrate from traditional mass media outlets, which historically generated revenues through advertising, i.e. television and newspapers, to new media platforms, which have yet to develop a stable model for monetization.

The cyclical threat resulted from the remaining effects of the 2008 global credit crunch, which continues to reverberate throughout the world's economies. In 2008, television, radio and particularly newspapers experienced serious drops in revenue. All the main media organisations were negatively affected, and most were forced to restructure their operations in order to survive. For example, in 2009, Aljazeera Media Network embarked on an aggressive strategic transformation program to restructure and transform their broadcast and business operations to build more efficiencies/synergies between their different news and edutainment channels. This program helped the Aljazeera Media Network to increase the number of television channels and expand the news gathering operations around the globe by utilising its existing resources for a wider scope[3].

It is evident that successful media organisations need to attract the maximum number of viewers, retain their attention as long as possible, and make the most revenue from that brief period for which the viewer grants them their focus. This can only be achieved by delivering rich content and viewer experiences that meet and even exceed viewers' expectations.

One broadcasting network's gains could mean great losses for another. Viewership, revenue and profit are all at risk. Hence, it is crucial to fully utilise viewership ratings by putting together an optimum programmes grid by procuring and/or producing editorial content that appeals to viewership tastes. This should hopefully maximise the network's overall gains.

To better understand Broadcast Media and Viewership Research Industries, some of the technical terms and concepts, those are relevant to this research, are introduced and discussed in the following few pages.

A Television Programme, or a Television Show, is a **segment of content** broadcast on Television. It may be a one-off broadcast or part of a periodically recurring Television series[4].

Content, by definition, is "information and experiences that may provide value for an end-user/audience. Content may be delivered via any medium such as the internet,

---

[3] Interviews with Subject Matter Experts at Aljazeera Media Network 2011.
[4] http://encyclopedia.thefreedictionary.com/

television, and audio CDs, as well as live events such as conferences and stage performances"[5].

The content of television programmes can be **factual**, as in documentaries, news, and reality Television, or **fictional** as in comedy and drama. It may be **topical** as in the case of news and some made-for-television movies or **historical** as in the case of many documentaries and fictional series. It can be **instructional**, which is the primary intention of educational programming, or **entertaining** as is the case in situation comedies, reality TV, or game shows, or for **income** as in advertisements[6]. Hence, programme genres are the main elements of programmes that are considered when building the programmes schedule.

The Programmes Schedule (Grid) is a printed or written list of programmes, television shows, news bulletins, etc., to be aired at a scheduled date and time.

The programming department in the television station is usually responsible for: producing and/or procuring television programmes; putting together a programmes grid; making sure the grid for the television station is properly listed in print, online, and onscreen guides; making sure that all departments within the television station know which episode of any given show is airing and at what time; and making sure everything is aired within the terms and conditions of the relevant contract.

The programmes director's job includes formulating and implementing strategies for the programmes department, developing budgets, goals and objectives. He is responsible for evaluating new and existing programmes to assess their suitability and

---

5 http://www.thefreedictionary.com/content/
6 http://encyclopedia.thefreedictionary.com/

the need for changes, using information such as audience surveys and market research. He plays a major role in decisions related to buying or producing shows.

To build a programmes schedule, “Audience Research” is needed. Audience Research is generally used to determine how many people are viewing, listening, reading, following, visiting, and/or sharing content on media platforms such as Television, Radio, Newspaper, Social Media and Online Media. Audience Research is the term that is used to refer to practices which help broadcasters and advertisers to determine who is listening rather than just how many people are listening[7].

Why is audience research needed? Simply because broadcasters and advertisers need to understand the content consumption behaviour and viewership habits (audience behaviour) in order to address consumers’ needs in the format of television programmes, films, articles, advertisements, etc. Audience Research helps content providers to understand their audience, track the viewership patterns and react faster to their needs.

An audience’s ever-changing needs and viewership habits usually require smart and instant measurement tools and techniques to understand and keep up with their fast changing base fully. In addition, the dramatic development in the information technologies area and the number of media platforms available to offer media content has fragmented every audience’s attention and has created a very competitive marketplace where content providers compete aggressively to attract viewers’ attention into their different media platforms and to try to extend that time of attention as much as possible.

[7] http://en.wikipedia.org/wiki/Audience_measurement

1.2 Motivation:

The research presented in this thesis was inspired by the author's work experience and the challenges he faced in his day to day job as the Head of Media and Market Research for Aljazeera Media Network between 2008 and 2014.

The following discussion is based on the author's experience in the field. Generally speaking, and to give readers a general idea of the main duties and responsibilities of the head of research scope of work, audience research analysis is an essential element of every television station programming cycle. The research arm of the broadcast media organisation is usually responsible for conducting quantitative and qualitative research to capture audience behaviour and translate it into meaningful information to help television officials to build their programme offerings and make programme placement and investment decisions.

During the author's time with Aljazeera, a number of research projects were conducted to analyse and understand the audience behaviour of Aljazeera News Channels. In one of these projects, the Nielsen Research Company was engaged to conduct face-to-face interviews and focus groups in 14 different Arab Countries with a sample size of 27,000. The outputs of the project helped in assessing the current position of Aljazeera Arabic amongst the main competitors in the Middle East and North Africa (MENA) region and helped in profiling the audience and their distribution geographically and analysing their viewership behaviour. The analysis was used in building the Channel's new strategy in terms of look and feel, content, distribution and, as a result, increased the total viewership of the Aljazeera Arabic News Channel.

Another major project was conducted for the Aljazeera English News Channel to analyse and assess the Audience Behaviour in 13 Asian and European countries with a sample size of 11,000. For this research project, the Ipsos Research Company was engaged to conduct the interviews and analyse results. The methodology used for data collection is CATI: the Computer Aided Telephone Intelligent system. The outputs of the project helped the Aljazeera English News Channel management team to understand their current footprint against all other news channels in both regions. Country by country data analysis was conducted to understand news consumption habits and a huge face-lifting exercise was completed to boost the channel's positioning in these markets. The change was made across all divisions including programmes division. Some programmes were stopped, others were introduced, and airing time was changed.

From the above discussion, considerable financial investments were put together to align Aljazeera News Channels with other News broadcasters in the region. The investment was both in the research itself and in the redesign of each channel's operations that included but was not limited to the renovation of some studios, broadcasting technologies, new content mix, etc. This investment helped Aljazeera to understand the competition better, to react to the changes in the marketplace and to reposition itself amongst its competitors.

A number of other research projects were conducted for the other television channels within the network such as the Aljazeera Documentary Channel. All the research projects' objectives were similar in their aim to understand the market and the viewers.

In addition to the previously mentioned projects, Aljazeera used to subscribe to monthly viewership rating data services from research companies in the region to understand and analyse the changes in viewership behaviour. The viewership ratings helped them to understand how many people were viewing a specific channel at a specific time on a specific day in a given country. This viewership data was used in different formats and combinations by the research team to report the findings to the television officials in order to help them in their decision-making process. A comprehensive overview of the audience research industry will be given in Chapter 4 of this thesis.

The below list of questions is an example of the issues raised by some colleagues from different departments and divisions at the Aljazeera Media Network during the regular monthly meetings with the research team:

- *What type of programmes should we invest in?*
- *What is the mix of programme offerings that can attract and retain high viewership?*
- *How can we convert viewers to our television channel?*
- *What is the best time of airing a specific television programme?*
- *Can we forecast the change in viewership in advance for a new programme?*
- *Can we test the impact of changing the airing time of a given television programme on actual viewership before the real change in the grid?*
- *What is the best time that can be utilised for commercials and advertisement?*
- *How can we maximise our revenues from selling advertisements?*
- *How can we attract more sponsors to our programmes?*

From the above discussion, it is clear that most of the concerns of media experts are common in this industry as most of them are recruited from similar media organisations. It can be concluded that there is a need to investigate more in the programme planning and scheduling techniques and strategies.

In this direction, preliminary interviews with a number of television experts at the Aljazeera Media Network were conducted. The interviews' discussions revealed interesting facts such as the lack of clarity on how research data can be used efficiently in making programme planning decisions. The initial interviews also showed the media experts' need for a system or a tool that can help them to better plan their resources for the benefit of their media organisations.

From the author's experience in the field, billions of dollars are invested in programmes and advertisements even though there is often a lack of clarity as to the return on investment.

The research presented in this thesis tests the viability of applying operational research concepts in the media industry similar to its broad application in other industries like aviation, hospitality, transportation, logistics, etc.

The contribution to the real practice of this work is to solve real life problems by enabling media practitioners to perform their jobs more efficiently and to help them in making more informed decisions by utilising the power of data intelligence and optimisation models. This is done by allowing them to try different combinations of content offerings considering constraints, resources availability, market competition and viewership expectation and to test the potential impact before they even go live.

The complexity of this work comes from the huge number of different combinations of programmes offered at various times that can make or break the television channel. Many decisions are involved in the process of programme planning for a television channel that can cost millions in losses or make profits by just making an irrational or a rational decision. Hence, this thesis suggests developing an intelligent decision-making tool to optimise the distribution of the pool of programmes, automatically utilising the research data as a baseline in making programme placement decisions.

It could be argued that programmes scheduling has become less important in recent years, in the presence of new media platforms that offer online digital content that can be consumed on demand. While this is true in some parts of the world, the statistics show huge demand on the traditional satellite television especially in developing regions such as the Middle East and North Africa region (MENA) where this study took place. Recent research shows that satellite will remain dominant as MENA TV penetration rises to 94.3% in 2014, according to Dataxis[8]. The report states that satellite television will reach 60.9 million viewers in the Arab world by the end of 2018, with free-to-air (FTA) household accounting for 87.5% of this figure. The report forecasts that digital satellite paid content would rise to 83.1% in the MENA region, from 4.13 million at the end of 2013 to 7.6 million at the end of 2018. Therefore, according to these figures, more than 87% of the satellite viewership will remain the dominant traditional content consumption power in the MENA region.

As a whole, Dataxis believes that Pay-TV penetration is forecast to jump from 11.1% to 17.5% – up from 6.3 million subscriptions in 2013 to 11.4 million at the end of 2018, with total television penetration reaching 94.3%, or 66.4 million, while the number of regional homes receiving FTA terrestrial analogue signals will fall by 87.7% from 12.4 million to 1.53 million, and FTA digital terrestrial television (DTT) reception will rise 155% from 4.3 million homes to 11 million during the same period. Pay-DTT subscriptions will number 440,000 by 2018, says Dataxis. In addition, regional Internet Protocol television (IPTV) subscription is likely to witness a growth of 123%, jumping to encompass three million households at the end of 2018, from 1.21 million households

[8] www.dataxis.com, Global Business Intelligence (April 2016)

at the end of 2013. Analogue cable services will fall 17.3% from 890,000 to 736,000 across the MENA region.

Another research report by Informa[9] in 2015 includes Figure (1) below and states that "*Television* remains a resilient, growing, and increasingly dynamic platform in the Middle East. The region's TV market base currently stands at just 50 million TV households and is dominated by satellite television. Other channels of distribution, including cable and digital terrestrial television (DTT), remain relatively small, although Internet Protocol television (IPTV) is growing faster than the global average. But IPTV is still largely a GCC phenomenon focused on high-bandwidth markets such as the UAE and Qatar."

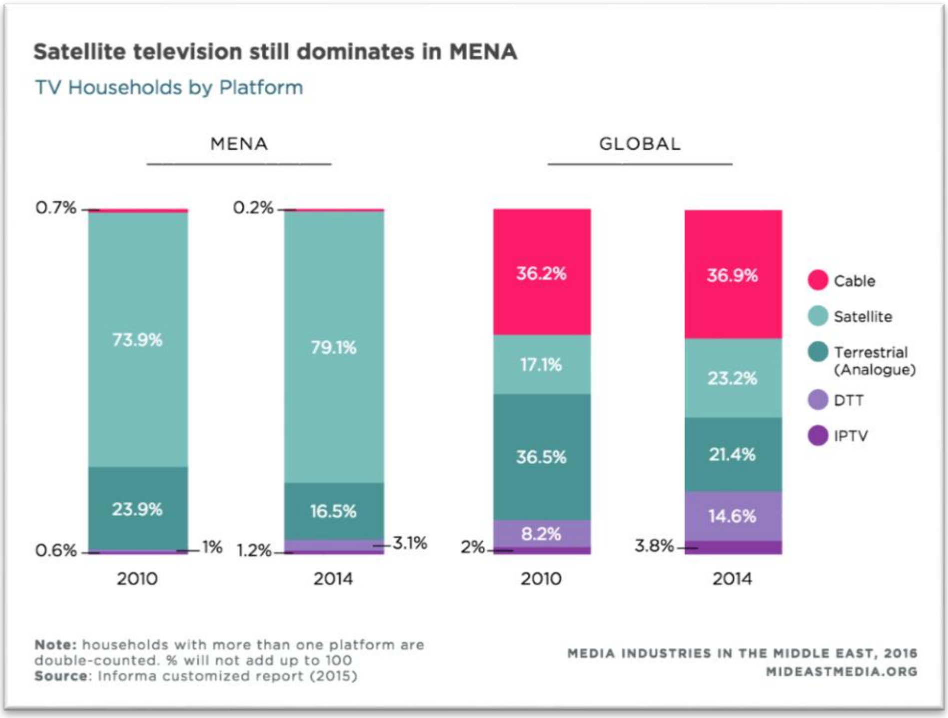


Figure (1): TV Household by Platform (2015)

9 http://www.mideastmedia.org/industry/2016/tv/

From the discussion above, traditional scheduling methodologies will remain of high importance to all media practitioners across the MENA region for many years in the future, and this will probably also apply to other developing regions around the globe.

According to the Head of Viewership Research at beIN Sports Network[10], this slow growth in digital media content consumption in the MENA region is due to socioeconomic and technological factors such as the cost of content, income levels, education levels, computer literacy, broadcast technology, television platforms, the availability and speed of the internet, etc. He said that “the premium content cost is very high that, in most cases, very few people can afford it”.

Simon Murray, in the fifth edition of the Digital TV Middle East and North Africa Forecasts report, said: “Gaining subscribers in the MENA is no mean feat as piracy remains rampant in most countries. More than half of the region’s homes receive free-to-air satellite TV signals. Furthermore, established pay TV operators now have to compete against new platforms as several IPTV operators put greater emphasis on Subscription Video on Demand (SVOD) than on traditional linear channel packages.”

In conclusion, and according to the above discussion and statistics, it can be concluded that scheduling television programmes will play a vital role in the future of the media industry, and that automation and optimisation of programme schedules can play an essential role in solving many problems of the people who drive this industry, especially in countries within the MENA region.

[10] BeIN Sports Network is a global network of sports channels owned and operated by beIN Media Group, a spinoff of Al Jazeera Media Network. http://www.beinsports.com

1.3 Introduction to Thesis:

The current section will focus on the research objectives and the methodology of the research, and will outline the thesis structure.

1.3.1 Research Objective:

The thesis's objective is to answer the following research questions:

- *What is the **Optimum Programme Schedule/Grid** that can attract the maximum number of viewers?*
- *What is the **Optimum Content Mix** that meets or even exceeds viewers' expectations?*
- *How should a TV network **React to its Viewership's** constantly changing behaviour?*

After investigating and outlining several attempts in academia to tackle the programme planning, scheduling and optimising problems, the research objective is fulfilled by developing an intelligent decision-making tool to allow programme planners and directors to optimise the distribution of the pool of programmes automatically by utilising viewership data and considering all other variables and limitations to produce optimum programmes grid to maximise viewership.

1.3.2 Methodology:

The research presented in this thesis has adopted the method of combining literature, academic work, and practitioners' expertise in order to develop an intelligent computer optimisation model that can solve real life problems in the media industry. To do so, a number of unstructured face-to-face and focus group interviews were conducted with broadcast media and audience research experts in order to understand the programme scheduling problem. In addition, a sample programme schedule and viewership ratings from industry were used to be fed into the developed optimisation model.

The author's experience in the audience research and broadcast media fields helped in the development and testing of the interactive computer optimisation model that was developed for the purpose of this study. The model was piloted and tested for a real case scenario as well as other hypothetical scenarios to test the viability of the proposed concept.

The research was planned to be completed in several phases. Initially, a basic computer optimisation model was developed to test the concept of distributing programme types of different qualities into the weekly schedule, where they attract the maximum number of viewers, considering resources availability and scheduling constraints.

The reason for building the basic computer model at first was to test the viability of the research ideas as well as the approach followed in the attempt to solve the television programmes scheduling problem. The basic model helped in showcasing the potential of what might be possible in terms of maximising viewership when all constraints and conditions are relaxed. This will eventually unleash the capability of the model and help the scheduler to test the positive or negative impact of changing programmes placement on the numbers of viewers before he/she starts introducing more constraints and limitations into the model. The basic model should allow programme planners to consider different programme scheduling scenarios before making scheduling decisions. However, it will not give him/her a realistic usable schedule that can be implemented as the model needs to be enhanced to simulate real case scheduling scenarios.

In the second phase of the research, the advanced interactive computer optimisation model was developed in order to give the user hands-on decisions and at the same time allow the user to use the model for real case scenarios. In the advanced model, comprehensive scheduling scenarios are considered, supply and demand constraints are tested, and the impact on viewership is measured. Cost and budget constraints are introduced in the advanced model in order to test the impact of budget availability on producing an optimum schedule considering the limitations on resources availability. By comparing the key outputs of the advanced model (viewership and costs) with the outputs of the basic model, the scheduler can see how much the constraints and his/her decision-making costs in terms of viewers and money. The user of the advanced interactive model can test different decisions and limitations scenarios until he/she reaches the right combination of programme mix and cost that is most suitable for his/her television station.

To build and solve both the basic and the advanced computer optimisation models, different software tools available in the market were tested. First, "**What'ss*Best*!**" from Lindo[11] was used to set up and solve the mathematical model. The mathematical model setup in the software was challenging, and it took a considerable amount of time to get the model run. Moreover, making changes to the model by adding/reducing constraints was also complicated and time-consuming when compared with the other software that was used for this research.

Another software package, "**Frontline Solver**[12]", was tested and later was selected to be utilised for the remaining parts of this thesis. "Frontline Solver" with a Gurobi Engine utilises Excel worksheets to set up and solve the mathematical model.

---

[11] What's*Best!* is an **Excel Add-In for Linear, Nonlinear, and Integer Modeling and Optimisation**
http://www.lindo.com/

[12] Frontline Solver (**Analytic Solver Optimisation) is an Excel Add-In for Linear, Nonlinear, and Integer Modeling and Optimisation**
https://www.solver.com/

The Excel sheet and the computer models are vital and inseparable parts of this work as we will see in the remaining parts of the thesis. More details and screen shots with further explanation is provided in the appendix of the thesis.

1.3.3 Thesis Structure:

The thesis report is structured as follows. In Chapter 1, a general background of the media and audience research industries is presented. A general introduction to the scope and the objective of the research is discussed followed by a section on the motivation of this work. The methodology of the research and the contribution to both knowledge and real practice is presented and reviewed as well.

In Chapter 2, a comprehensive literature review, detailing previous work in this area along with subject matters experts' interviews and focus groups feedback, is presented and discussed in detail. This chapter's outputs helped the author in the development of the logic of the proposed novel approach and in building the computer optimisation model that will be discussed in more detail in Chapter 3 of the thesis.

In Chapter 3, the logic of the model assumptions and the input and output parameters of the basic model are presented and discussed. The mathematical model is developed and described in this chapter and the way the model functions is presented. In addition, some examples of how the model is run and what the model is capable of doing are presented and tested by considering different programme type/qualities as well as short and long programme schedule scenarios. The potential challenges of running the basic model are discussed as well.

In Chapter 4, a comprehensive review of the audience research industry is presented to give the reader a clear understanding of available data collection tools and techniques, the advantages and disadvantages of each tool, challenges to the new media environment, understanding ratings and audience behaviour and data prediction. The need for ratings in broadcast media is described in more detail, and a business model of a sample media organisation is illustrated to give an idea of different operations and the dynamics of the television industry. Programme schedule building and the limitations of this industry are discussed in this chapter as well.

Chapter 5 is devoted to running and testing the advanced television programme scheduling model. In this chapter, different scenarios of running the model are given, and the potential use of the interactive model is described for more types/qualities of programmes and for short and long programme schedules.

In Chapter 6, the novel contribution of this thesis to research and real practice is presented and discussed. In addition, the research and development areas for future work to extend the findings of this research are outlined followed by a summary and conclusions section.

1.4 Research Contribution:

As literature contains very little evidence that analytical and computational approaches are used in modelling and optimising programme schedules in the television industry, the outputs of this thesis will potentially help to fill some gaps in the academic literature and real practice at the same time.

Together, the thesis findings and the advanced computer optimisation model present a clear understanding of the history and current practices of both industries. Media and Viewership Research industries are discussed in some detail in the thesis.

1.4.1 Contribution to Academia:

The current section will briefly summarise the thesis contributes to academia. This eventually should help the reader in understanding the importance of this work in comparison to the previous work.

- The proposed approach introduces a new way of utilising research data by giving a high weight for viewer expectation and demand in the market.
- The approach suggested in the thesis is different from previous work as the type, and quality of programme is placed in the schedule based on the forecasted ratings for a programme type rather than specific programme ratings.
- In literature, multiple traditional programme scheduling approaches will be discussed in Chapter 2 of the thesis such as Lead In, Tent Pull, and Counter Programming. This research suggests a new approach that is different from the previous approaches as it proposes a smart and intelligent decision making procedure taking into consideration experts' opinion by blocking time slots to run or not to run specific types of programme leaving the model to decide on the remaining vacant time slots.

- The quality of programme concept is introduced in this research as one of the main elements for scheduling decisions.
- All previous researchers have only taken prime time into consideration when scheduling programmes rather than considering the full day schedule as will be described in the proposed model in Chapter 3.
- The push-pull scheduling strategy proposed in this thesis will put experts' judgment together with viewers' expectation when scheduling programmes for television.

1.4.2 Contribution to Practice:

This section will summarise the thesis contributes to real practice.

- The novel contribution to real practice of this work is by proposing a tool that should help in solving real life programme scheduling problems. This tool should enable media practitioners to perform their job more efficiently and assist them in making better and informed decisions by utilising the power of data intelligence and optimisation models.
- The interactive computer optimisation model gives media practitioners a powerful tool to initially understand viewership demand in the market for different types of programmes and then to plan their production and content building according to available potential demand for their content.
- The upper and lower bounds on programmes per day parts and the full day will give media experts the flexibility and freedom to decide on the right balance of the programmes distribution in the schedule. Previous attempts did not take this into consideration as reported in the literature.
- Programme planning and cost benefit analysis becomes possible before making any real investment decisions as the model simulates different scenarios of

programme combinations and their potential impact on cost and viewership numbers.

- Short as well as long schedule planning becomes possible with the advanced computer interactive model. Knowing programmes schedule for a season or complete program cycle should help media organisations to align and schedule all their other resources such as studios, presenters, cameramen, engineers, etc. and make the best out of their financial resources.

Chapter 2

The aim of this chapter is to provide, through selective references from literature, a clearer understanding of the programmes scheduling strategies, scheduling decision's modelling, viewership ratings, and contribution to research. Interview discussions with Subject Matter Experts to highlight their views of the problem is presented and discussed thoroughly in the second part of this chapter.

2.1 Literature Review:

This section will provide an overview of the available programme scheduling strategies, analytical and computational approaches used in the past, viewership data usage in programme scheduling decisions, and the novel approach developed in this thesis to produce a practical tool to help media practitioners in their programme planning decisions.

2.1.1 Programme Scheduling Strategies:

Previous research in the area of programmes schedule building has investigated several scheduling strategies and optimisation methods. One of the most popular scheduling strategies is known as the **"Tent Pole"** or **"Hammocking"** or **"Sandwich"** strategy that was used for years by the big four American Television Networks (ABC, NBC, CBS and Fox). This strategy suggests introducing a new or a weak programme in between two confirmed strong ones, hoping that the strong programmes would act as tent poles, pulling up the ratings of the shows before or after them. A similar popular scheduling strategy is known as the **"Lead-in"** or **"Inheritance Effects"** or **"Audience Flow"** strategy that usually depends on introducing a new or a weak programme after a confirmed strong one hoping that the strength of the previous programme will increase the viewership of the one after.

Evidence supporting these strategies has been provided by Headen *et al.* (1979), Horen (1980), Henry and Rinne (1984), Tiedge and Ksobiech (1986, 1988, 2006), Adams (1997), Kelton and Schneider (1998), Eastman and Ferguson (2006), Webster *et al.* (2014) and Webster (1985, 2006).

In light of the dramatic increase in the number of television channels, media platforms such as Cable, Satellite, Online Media, etc. and the decrease of viewership ratings of the major American networks, a study to discover if the "Lead-In" impact has lost its positive impact on viewership ratings was completed by McDowell and Dick (2003). In their study, an analysis of the prime-time ratings for ABC, CBS, NBC and Fox comparing 3050 programmes ratings in 1992 with 2541 programme ratings in 2002. The study results confirmed the lead-in power on viewership ratings.

Another commonly used scheduling strategy is the "**Block Programming**[13]" that is used in broadcast and radio programming. It can be defined as arranging programmes on television or radio so that similar programmes are broadcasted one after another. The concept here is to provide similar programming genre to keep the audience interested in watching or listening (Eastman 1998). Another programme scheduling strategy, known as **"Counter-Programming"**, is also used in broadcast industry as literature confirmed. Counter-programming is simply defined as scheduling different content in response to competition in the same time segments in order to attract more audience from another television station airing a major event. Evidence supporting this strategy was provided by Uribe *et al.* (2011) and Tiedge and Ksobiech (1987). In light

[13] https://en.wikipedia.org/wiki/Block_programming

of the above discussion, it is evident that most of the previously mentioned programme scheduling strategies are comparable in leveraging the strength of a programme rating to another content's offering to potentially increase the new programme ratings.

A study to investigate whether viewers restructure their lives to accommodate television or whether television is made to fit into the existing structure of their lives was conducted by Gantz and Zohoori (1982). They concluded in their study that this is functionally related to the programming and the time period involved. Therefore, they identified the time at which the show is aired and the contents of the programme as the most important factors affecting television viewers' behaviour.

Furthermore, some studies confirmed that viewers do not have a tendency to change television channel until they are confronted with objectionable content, a phenomenon called "**Tuning Inertia**" as described by Head and Sterling (1987) and Adams (1997).

The time of the day is very important for programme scheduling decisions. More precisely, it is evident that the **"Prime Time"** or "**Peak Time"** is the most valuable time of the day in terms of viewership ratings. Evidence supporting this argument was provided by Eastman *et al.* (1995), Adams and Eastman (1997), Reddy *et al.* (1998), and Eastman and Ferguson (2006). A Prime Time is usually the block of broadcast programming taking place during the middle of the evening for television programming. The duration and start/end time can be different for every country/region. For example (in the United States), from 19:00 to 22:00 (Central and Mountain Time) or 20:00 to 23:00 (Eastern and Pacific Time)[14].

[14] https://en.wikipedia.org/wiki/Prime_time

While the strategies discussed so far focus on scheduling programmes based on positioning programme during the day parts, the following concepts concentrate on modelling programmes scheduling decisions and understanding viewers' behaviour.

2.1.2 Modelling Programmes Scheduling Decisions:

As literature contains very little evidence that analytical and computational approaches are used in modelling and optimising programme schedules in the television industry, however, the following are some attempts found in the published literature to tackle similar problems.

A model for predicting and understanding individual television viewing choice was presented by Rust and Alpert (1984). In their study, they concluded that viewing behaviour is very sensitive to changes in the television schedule. Consequently, a programmes schedule has a huge impact on the type and size of the audience that media organisations attract, and the task of creating an effective schedule is a vital element of network programmers' and planners' responsibilities.

Head (1985) describes the task of scheduling the programmes of a station, cable or network, as "... a singularly difficult process." while Michael Dann (1989), a veteran network programme executive and consultant, stated that "... where a show is placed is infinitely more important than the content of the show"[15].

A model that predicts shows ratings that are placed in new time slots, for specific times and on specific dates, was presented by Gensch and Shaman (1980 a and b) and Henry and Rinne (1984 a). Although the aim of these models was not to automate or to

[15] New York Times, February 26, 1989, p. 42

optimise the television schedule, yet it helped in better prediction of viewing habits for different days, times and seasons.

Qualitative viewership research, referred to as "**Competitive**" research, is also used by scholars to investigate the willingness of viewers to watch a particular programme if it was aired at the same time slot as a competitor's programmes, as described by Stipp and Schiavone (1990). This approach is effective and commonly used in building television schedules since it gives a good insight of viewers' needs and expectations. However, this approach does not involve any quantitative and computational capabilities in the scheduling process.

Horen (1980) was one of the first pioneers in this field. In his work, he studied the impact of scheduling programmes on audience ratings. The author developed a forecasting model for audience ratings that is based on five years of historical data estimates for hypothetical schedules. A heuristic fitting procedure yields a model which has consistent estimated parameters and explains about 70% of the variance. He claims that the previous year's ratings of a programme and competing programmes in its time slot are the best predictors of its ratings. Also important is the time, day and lead-in audience. In his study, he incorporated the resulting estimates in a combinatorial model, representing the decision of a programme scheduler seeking to maximise ratings.

He formulated the scheduling problem as an integer programming model. The objective function represents the forecasted ratings summed over all time slots for any schedule decision. He introduced a number of constraints to ensure that each programme is scheduled only once and each time slot is filled. He incorporated in the model the lead-in effect in the formulation. The model formulation represents an assignment problem of scheduling *n* number of half-hour programmes into a week of *n* number of half-hour time slots.

He applied the developed IP model to three major broadcasting networks case study (CBS, NBC, and ABC), each competing to maximise individual ratings for four seasons (September to April 1970-1971 through 1973-1974). A typical sized problem of scheduling 23 programmes of various lengths into a week of 40 half-hour time slots (65 Rows × 800 Columns). The twelve optimisation problems resulted were run as linear programming problems.

The results of the optimisations show that rescheduling programmes can, on average, substantially increase a network's audience size (11.6%) and advertising revenue ($61 million per year). However, the optimal programme scheduling for one network generally decreases the ratings of a competing network's ratings.

Horen's study has been limited to increasing viewership ratings while neglecting some other important elements such as the cost and profitability. A schedule which simply maximises ratings, may not be the most profitable for the network. Another drawback of the model is neglecting the show characteristics in relation to lead-in effect (Reddy *et al.* 1998).

Another relevant study undertaken by Rust and Echambadi (1989), investigated the programmes scheduling problem using an extension of the audience flow model of individual viewing choice presented by Rust and Alpert (1984). They have formulated a heuristic method for scheduling a television network's programmes in order to maximise the network's share of audience. The audience flow model was developed as a method of predicting an individual viewing choice. The individual choices then are aggregated to provide ratings estimates. In their study, they accounted for viewership segmentations as particular programmes popularity can be different for each segment.

The scheduling problem concerns assigning 20 or more programmes of varying lengths to about 44 half-hour time slots. They broke up the problem into two stages; assignment of programmes to day, followed by the assignment of programmes to time slots. The general idea of the day-assignment heuristic is to set a probability for each programme to be assigned in each day and then assign the programmes stochastically. The degree of success achieved by schedules involving that particular programme x-day combination is then used to adjust the probability that that day will be selected for that specific programme in the next iteration. The heuristic iteratively adjusts the assignment probabilities until no further improvements are found in the objective function.

The heuristic optimal scheduling model was illustrated on three main US networks ABC, CBS, and NBC for four days (Monday, Wednesday, Thursday, and Friday) for the prime-time. The original schedule involved 11 programmes for ABC, 12 programmes for CBS, and 10 programmes for NBC, spanning 24 half-hour time slots. Their test results were impressive: ABC, CBS, and NBC realised an increase in channel share of 11%, 36%, and 78% respectively for the optimal schedule that optimises one network while keeping the other two networks the same.

The authors claim that the proposed method can be used either to evaluate candidate programme schedules or to select the schedule which maximises heuristic objective functions. Managerial constraints, such as requiring children’s programmes to be shown before 8 pm, for instance, can also be accounted for in the model.

Several drawbacks can be noticed such as; the model does not model reality perfectly, the scheduling heuristic does not necessarily find the optimal schedule, although that the suggested schedules are considerably better, the model does not take into consideration viewers resistance to schedule changes. The model needed further testing and validation as recommended by authors.

Later, Horen's (1980) model was revised and extended by Kelton and Schneider (1998). In their study, they formulated network television scheduling problems as integer programmes to maximise viewership for three different competitive environments; ***Myopic (non-competitive)*** where they assume no competitive reactions to the scheduling decisions for a particular network, ***Nash competitive*** as more realistic scenario considering competitors responding to network own scheduling decisions, and ***Cooperative problem*** where each television channel determines the optimum schedule in a monopoly environment by not allowing shows to migrate between networks.

To provide input data for the scheduling models, they developed and estimated a regression model in which show-part ratings are regressed on variables that influence television viewership, including day, time slot, show attribute and competitive effects, as well as lead-in from the previous show part.

In each competitive environment, the problem was formulated as a binary integer program. The solution to which is an optimal assignment of show parts to the same number of time slots. Time slot is considered as half-hour and show part is a half-hour segment that can be part of a longer show. The objective is to maximise the total weekly ratings subject to a number of constraints; each time slot is filled with exactly one show part, each show part is assigned to an exactly one-time slot, and the show parts of multi-part show are shown consecutively and on the same day.

The model was illustrated under the three different competitive environments and succeeded in reaching substantial optimisation gains which are not diminished much by competition. They claim that although there are competitive effects, there are also other significant influences on television ratings including lean in and attribute effect.

Their study neglected to consider the show quality impact on viewership ratings. In addition, the authors assume a fixed number of shows to fill a given number of time slots. This assumption is valid if scheduling for given set of programmes. However, it might not be as true if scheduling for unknown number of shows as actual programmes schedule can suffer from low or excess in the supply and/or demand of the pool of programmes to be scheduled. Another shortcoming of their model is not being able to segment viewers, resulting in shows not being scheduled in the same evening that appeal to similar audience groups. Moreover, the limitation of computation capabilities prevented them from formulating and solving large-scale model that can accommodate longer schedules.

Another study by Reddy *et al.* (1998) has provided a further analytical approach to find the optimal schedule in the television prime-time. The authors proposed a further generalisation of Horen's model by introducing more realistic variables in the model. Their approach is to build a generalised, mixed-integer, near-network flow model to determine the optimum programme schedule. Their model is related to assignment problems with intermediate nodes, arcs with multipliers (creating a generalised network). An approach, similar to Horen's, of one half-hour programme part, was adopted in their model formulation and solving. The objective function represents the contribution to the objective of the half-hour shows. Supply, demand and programmes flow constraints were formulated taking into consideration the lead-in effect in the viewership ratings. Binary constraint was introduced to enforce binary condition on all arc flows.

The authors' model incorporated more realistic assumptions such as the cost of each show, scheduling for longer time periods, expert judgments, and utilising manager inputs to maximise profits.

They demonstrated the optimisation model viability in the television network programming environment by testing various models. The cable network was not identified for confidentiality reasons. The network aired 10 different half-hours and 16 hour-long shows of 6 general show types for 13 weeks to fill 42 half-hours in the 8-11 pm prime-time period, Monday through Saturday.

The model solution provided an optimal schedule that generated an increase of 2% in overall profitability, representing over $6 million annually for the cable network. Although their work has delivered impressive results, the model has used historical ratings of a specific show in order to predict future ratings of the same show, neglecting the overall viewership demand of show types/genres for each time segment as proposed by in this thesis. This concept will be discussed in more details in the following chapters.

Goettler and Shachar (2001) presented an empirical study of spatial competition and a methodology to estimate demand for products with unobservable or difficult to measure characteristics such as television programmes. The authors used a panel data on viewers' choices to identify: the attribute space over which firms compete, product (programme) location on these attributes, and the distribution of viewers' preferences. The theory was tested on a case study of four television broadcasters in the USA. They developed a model for data estimation where in each time period an individual chooses from among six mutually exclusive and exhaustive options: TV off, ABC, CBS, NBC, FOX and non-network programming such as cable or public television. Data estimate was completed for the weekday prime-time hours (8:00 pm – 11:00 pm) using individual level data from Nielsen Media Research. The dataset contains each individual's demographic data and viewing choices at each quarter-hour of a sample week in Nov 1992. The estimated programme locations revealed that firms used counterprogramming (i.e., differentiated products in each time slot) and homogeneous programming (i.e., similar products in each night). Then, they employed the "iterative-improvement" approach of combinatorics optimisation to find the approximate best-response schedules. To demonstrate the effectiveness of the model, they applied the methodology to the network television industry which yields an estimate that is consistent with experts' views. Although their work was not focusing on reaching an optimal schedule, however, they managed to increase the total predicted weekly ratings by 13.3%, 6.1%, and 15.7%, respectively, for ABC, CBS, and NBC while FOX decreased by 6.8%.

Another study by Danaher and Mawhinney (2001) has adopted a different approach by rescheduling television programmes to maximise the total ratings for one network across a week. The authors designed a choice experiment model in which television programmes are rescheduled and presented to respondents to explore their preferences. They developed a model for programme modelling preferences and validated their experimental procedure and the model. The results reflected an increase in the predicted total weekly ratings during prime time by 18% for the network. The projected increase was achieved only by rescheduling eight programmes in the network existing prime-time line-up. Unfortunately, their model also has its limitations; the choice selection criteria used in the study may have been tedious for respondents, and the choice sets assume that respondents know all the shows offerings which is usually not the case in the television industry.

Further analytical approach was provided by Brusco (2008). The author presented an enhanced branch-and-bound algorithm to obtain optimal solution related to the advertising slots scheduling problem. This research explores similar, however, not directly related to the programme scheduling problem. The study extends Bollapragada *et al.* (2004) approach that aimed at improving the revenues and productivity associated with television network's sales system. The author investigated the ISCI (Industry Standard Commercial Identification) rotator problem that requires the assignment of a set of commercials videotapes to time slots such as multiple airing of each tape in the set are as equally spaced as possible. In addition, a fast-simulated annealing heuristic algorithm for solving larger television scheduling problem was developed. The outputs showed enhanced optimal solution to the advertising scheduling problem.

Another related study by Ghassemi Tari and Alaei (2013) focused on the problem of commercial message scheduling during the peak of viewing time. Particularly, the authors developed a steady-state genetic algorithm and formulated and solved the problem as combinatorial auction-based mathematical programming problem. A profitable and efficient mechanism for allocating the advertising time to advertisers was developed by which the revenue of television channel is maximised while the effectiveness of advertisement is increased. In addition, they applied a particular mutation procedure that helps the genetic algorithm to overcome the premature convergence by preserving the proper population diversity during the searching process. To illustrate the model viability, they conducted a computational experiment using a data from local television station to evaluate the efficiency of the proposed algorithm. The results revealed that the final solutions of the test problems solved can be considered to be very close to their associated optimal solutions, the time to obtain the solutions of the test problems is acceptably low, and the proposed algorithm has an appropriate ability to preserve the population diversity and is capable of obtaining high-quality solutions for the problem.

Recently, Lupo (2014) focused on the problem of multi-objective optimisation for programmes scheduling. Particularly, the author developed an integer programming mathematical model that aimed at ratings maximisation and cost minimisation. He used forecast engine to obtain the required data for the model. A number of constraints were added to the model to assure that each time slot on each day will be filled by exactly one show-part, assure that each time slot on each day is allotted by only one show-part, assure the proper sequencing of show parts of a multiple show, binary constraints, and other important constraints to incorporate editorial decisions in the model such as airing particular show in a specific time. He adopted a multi-step Pareto frontier method, that is, the set of non-dominated "trade-off" solution to solve the multiple-objective optimisation problem (for further details on the multi-step procedure refer to Lupo, 2014 and Khalili-Damghani *et al.* 2012). The author illustrated the model by using a case study for Italian television channel (TGS, *Telegiornale di Sicilia*). In particular, the days of nine weeks over the 2010-2011 and 2012-2013 television seasons with reference to the television prime-time (7:00 pm – 12:00 pm) have been selected, due to data availability and the degree of the "ordinariness" of the weekly schedule, and a total of 2520 individual observations of show-parts ratings and costs have been collected and analysed. Furthermore, 48 binary variables for the interactions between show typology and day of week, 152 binary variables for the interactions between show typology and day time slot, 8 binary variables for the interactions between rerun and show typology, and 8 binary variables for the interactions between show typology and cooperative programming factor have been considered in the model. In addition, five production typologies are considered; inner and external production, in outsourcing, in co-production, and free production.

The forecast engine coefficient has been estimated by using statistical commercial software SPSS. In light of the above, the TGS channel programme schedule was optimised using a commercial software Lingo. The model obtained a number of television scheduling configurations whereas a decision maker can view and select the setup that represents the best compromise among the considered objectives.

The author's model and methodology recognises the importance of taking into consideration programmes cost and viewership ratings when optimising the grid. However, other important criteria have been ignored in the model such as quality of the programme for instance.

While the topics discussed so far focuses on scheduling strategies and modelling programmes placement decisions to help television stations build an optimal schedule that increase viewership, the following concepts concentrates on audience research data and viewership rating prediction that are required to utilise the previously mentioned strategies/models.

2.1.3 Viewership Ratings:

Previous work in the area of Audience Research has investigated several viewership research types available and different ratings forecast strategies to predict future viewership behaviour changes. Rating analysis is the analysis of audience size and composition data produced by audience research firms for use in the media sector (Napoli 2011). Scholars across variety of disciplines have been interested in developing predictive models of audience behaviour to identify patterns related to audience exposure to media content (Webster and Phalen 1997). A comprehensive overview of the audience research and viewership ratings will be provided in Chapter 4 of this thesis.

Accurate viewership forecasting is crucial to television planners and schedulers as they rely on it in programmes buying, producing and scheduling decisions. Fournier and Martin (1983) and Webster and Phalen (1997) claimed that advertisers are willing to pay for more reliable audience information. Television networks typically reschedule programmes when actual audience sizes do not reach projected levels. Advertisers are refunded when this happens, but they are not compensated for the disruption to their media plan (Meyer and Hyndman 2006).

A study by Napoli (2001) has investigated possible determinants of forecasting error for new prime-time network television programs. The author claims that, historically, audience shares for new season programmes forecasts have been very inaccurate. Through an integration of audience behaviour theory and decision-making theory, his study attempted to identify factors that explain the magnitude of uncertainty, and hence the magnitude of forecasting error, surrounding the predictions for new programmes.

The study focuses on new prime-time programmes aired by the Big Four broadcast networks in the United States (ABC, CBS, NBC, and FOX). The findings indicate that the presence of a returning network lead-in or lead-out significantly reduces the amount of forecasting error. In addition, the study has indicated that forecasting error has increased significantly over time due to the complications to the process of predicting audience behaviour accompanied with the recent additions to the media mix such as satellite and internet in addition to the uncertainty about viewership behaviour associated with these changes. The author suggested that content and audience characteristics must be incorporated into the analytical framework for better model outputs. Some other scholars argued that viewership ratings forecast has been very inaccurate in the past (Forkan, 1986 and Rust and Echambadi, 1989).

Danaher *et al.* (2011) studied all previous television rating foresting models and found the majority have been fit to data in which there are only a few number of channels and forecast for only the short time horizon. The authors compared eight different new forecasting models, ranging from the naïve empirical method to a state-of-the-art Bayesian model-averaging method, with the previous old models. They looked at data from a market in a very recent time period. The results showed that new models perform better than previous ones. They also highlighted the negative financial impact of using poor forecasting models. Thus, they claim that better model can potentially save the television advertising industry somewhere between $250 million and $586 million per annum as improved forecasting results leads to better advertising compensation.

Another study by Danaher and Dagger (2012) uses a little-known version of the nested logit model that is suitable for aggregate choice decision data since television ratings are aggregate measures. The study extends Dubin *et al.* (1992) model to include television programme random effects (attractiveness effects of each programme) such as the time of broadcast and genre for instance. The authors developed a novel method for predicting program random effects for programmes that have not previously been broadcast. They included both time and programme covariates in the model to measure their impact on viewership behaviour. The results showed that the annual trend, time-of-the-day, season and day-of-the-week have more influence on viewing choices than the programmes themselves. The study compared the model's forecasts with those of several other models and showed that it noticeably outperforms these models (overall forecasting error of 1.08 rating point when compared with 1.46 that is obtained by common historical prediction methods).

2.1.4 Novel Contribution to Literature:

From the above discussion, with the increasingly rapid changes that are shaping the television industry, programme scheduling has become more important and challenging today than any time in the past. It is clear that there is a strong need for systematic approaches that uses the advanced computational capabilities to produce television programmes schedules that reacts to viewer's ever-changing behaviours.

This thesis investigates the programme scheduling problem and the use of analytical approaches in an effort to build an optimal grid that attracts the maximum number of viewers. This research extends Horen's (1980) and Kelton and Schneider's (1998) approaches and develop novel methodology and approach to solve the programme scheduling problem. The objective of this research is to develop an interactive tool that helps television broadcasters to plan/schedule their production to maximise viewership. Therefore, an integer programming optimisation model was formulated and solved to assign "*Programme-Types*" (rather than specific pre-known existing programmes) to potential time slots where they, potentially, receive optimal viewership taking into consideration a number of constraints and limitations of the television station's different resources including budgets. The interactive optimisation model will be discussed and illustrated with more examples in Chapter 3 and Chapter 5 of the thesis.

The literature reported multiple traditional programme scheduling strategies, such as Lead In, Tent Pull, Counter-Programming, and others, that are used widely in the media and broadcasting industry. The application and impact of such concepts is very important and is taken into consideration in building the new model. Additionally, as literature reported the importance of television experts' opinion in the programme scheduling decisions, in this thesis, the proposed model is developed in a way that television experts' opinion is combined in the decision-making optimisation framework along with viewership data to maximise viewership.

Moreover, the scholars' attempts discussed in published literature have ignored the total available demand per-programme type/genre. Instead, they only took into consideration the specific pre-known existing programmes rating as the main factor in predicting the programmes future viewership demand. In addition, a number of forecasting procedures were developed and used to predict future ratings in order to replace and/or reschedule programmes hoping to attract larger audience and eventually increase the overall television network ratings. Although this argument has some validity, however, this research proposes a novel approach of using the viewership ratings. According to the new approach, viewership ratings, per programme-type, are extracted from raw data sample that was provided by Ipsos Research Company. Then, the data is used in the developed optimisation model in order to drive scheduling decisions that maximises the television network's viewership within certain supply and demand constraints. Those ratings represent the overall demand of a specific type of programme that can be targeted by different television networks.

Although some attempts were more successful than others, it was noticed that most of the previous scholars only considered the television prime-time when building and optimising the programmes schedules. While prime-time is very important for television channels as viewership peaks the most, however, other day-parts are important as well. This research concentrates on all day parts throughout the scheduling horizon. This will give television planners a comprehensive overview and control over their programme airing times, repeats, re-runs, etc.

Another challenge reported in literature is the viewership data availability and accuracy. Therefore, as this topic is beyond the scope of this thesis, the research concentrates on the use of data rather than the data collection and prediction procedures.

In addition to the data availability problem, limited computational capabilities in the past had prevented researchers from considering longer schedules along with larger numbers of decisions variables and constraints. The software tool used in this research is advanced and can handle large number of data and solve long schedules as claimed[16] by the software developers.

The literature reported very limited attempts of using analytical decision making approaches for television programmes scheduling. Likewise, it did not cover important programme attributes such as the programme type and quality of a programme. Previous attempts were not very successful in viewership segmentation while scheduling for television. In this research, programmes, per type/quality, are assigned in the weekly grid using analytical and computational approach according to the available viewership demand.

Viewership segments are represented in the model as all schedule decisions are derived from viewership expectations. Viewership ratings can be drilled down to a level where all viewers' attributes can be identified such as; gender, age, education level, income level, etc. This will help in assigning programmes in time slots that corresponds to viewers' expectations per segments. This approach will guarantee fair and balanced distribution of programmes across day-parts and week-days taking into consideration different viewers' characteristics.

[16] Frontline Solver full commercial license can handle and solve unlimited number of variables and constraints. www.solver.com

In addition, the proposed computer optimisation model is an interactive tool that give the end users the option to try/test different setups and combinations before finalising their schedule. This approach is very unique and is different from previous models as it puts the media practitioners at the heart of schedule building and gives them more flexibility while utilising the power of optimisation models.

The proposed model was illustrated by using a number of different real cases as well as hypothetical scenarios and successfully managed to schedule programmes and increased viewership numbers dramatically. This will be discussed further throughout the next few chapters.

Due to very few attempts reported in the literature about programme scheduling strategies and automation, and as part of this research, a panel of experts in Media and Research Industries were interviewed individually and in groups in order to understand their needs, the challenges they face and what is currently in place, better helping the research to present a practical solution to programme scheduling problem.

2.2 Subject Matter Experts (SMEs) Views of the Problem

For better understanding of the programme scheduling problem and the challenges faced in the day-to-day operational environment of programme directors, planners, schedulers, and viewership researchers, several unstructured, face-to-face, and focus group interviews were conducted with Subject Matter Experts (SMEs) in the media and research industries. This section outlines the methodology used in the interviews and summarises the outputs.

2.2.1 Data Collection Methodology

To gather television practitioners' opinions on the subject matter under study, a generic qualitative research approach was used to conduct this part of the research. This approach offers flexible and open-ended discussion questions and focusses on people's experiences more than general beliefs and opinions (King and Horrocks 2010). Below is a list of interview approaches and techniques that were used in this thesis to collect and analyse data.

- Unstructured interviews: in this type of interview, the interviewer approaches the interviewee with the aim of discussing a limited number of topics and frame successive questions according to the interviewee's previous response. Topics are discussed and covered in great detail. The relationship between the interviewer and interviewee is important to conducting a successful interview. The interview can be recorded so interview data can be analysed later (Edwards and Holland 2013).
- Face to face interviews in a free format (Sapsford and Jupp 2006): this type of interview is very labour intensive, nonetheless can be the best way of collecting

high-quality data. This approach is preferable when the subject matter is very sensitive, if the questions are very complex, or if the interview is likely to be lengthy. This method offers a greater degree of flexibility when compared to other interview methods.

- Focus group discussions: in this type of research interview, the data is collected from a group of people rather than from a series of individuals. This approach is widely used in the market research field. This approach allows group interaction among participants that has great potential for greater insights on the subject matter (Liamputtong 2011).

The reason for choosing these specific interview approaches was the nature of this social research. Open-ended discussions and face-to-face dialogues with industry experts are very important to collect required insights on the subject matter. The interview discussion outcomes have revealed some issues and challenges in the programme scheduling area and broadcasting television planning in general.

A sample of subject matter experts with strong knowledge and experience in the Television, Broadcasting and Viewership Research industries was selected to help in this academic research. The way the participants were selected was by considering the programme planning and scheduling cycle in the television station. In this cycle, some media experts are usually involved in making decisions regarding programme selection, production, airing time, budget requirements, etc. In Chapter 1, section 1.1, a clear description was provided for the type of specialties that are required in a media organisation. Therefore the participants were selected based on their job descriptions and their roles in the development of programmes. Experience and seniority were the main factors when considering a candidate for an interview or focus group discussion. The following are a sample of roles that were selected for interviews: programme director, programme producer, programme planner, managing director, research director, and others.

2.2.2 SMEs Interview Outputs

More than twenty interviews and focus group discussions with programmes, news, operations and business process experts were conducted at Aljazeera Media Network between 2011 and 2016. The interviews were conducted in three phases: before, during and after the model building. The outcome of the interviews with SMEs helped in formatting, modelling and testing the model inputs and outputs. In the following few pages, the main findings and industry challenges are presented and discussed in more detail.

In the initial phase of the interviews, the priority was to study the television industry in more detail and to understand how programmes are selected and scheduled. In the interview with the Aljazeera Network's Director of Programmes, he stated that television stations usually have programme planning committees who are in charge of the editorial content, budgeting, programme planning and programme scheduling decisions. The members of such committees are experts in their fields and have the authority to make final decisions with regard to programme planning and scheduling. They are usually selected from the main functions of the television station such as programmes, operations, creative, production, marketing, distribution and strategy and research departments. The key decisions of that committee include but are not limited to the selection of editorial content, the number of hours of programmes to procure or produce, budget requirements and placement decisions. In his interview, he described the main components of a daily programme schedule that usually include different programme types, qualities and styles of programmes such as news bulletins, political debate shows, promotions and advertisements for a typical news channel.

In another interview, the Managing Director of Aljazeera Arabic stated that *"the strategy and the type of the television station dictate the right balance between news and programmes distribution in the day schedule"*. For example, since the Aljazeera News Channel is mainly focused on news and current affairs, top priority is usually given to breaking news, news programmes, political debates, etc. A lower priority is given to all other types of programme such as documentaries for example, while the remaining time in the schedule is left for promotions and advertisements respectively.

In response to the question of using viewership data in making programme selection and scheduling decisions, the Scheduling Manager of Aljazeera Arabic mentioned that the research and viewership data are heavily used and utilised in the programme planning and scheduling process. However, he stated that *"the main disadvantage is that the process of doing so is still subjective and uses very basic tools such as Excel spreadsheets and PowerPoint presentations"*. Programme assignment to a specific time slot, i.e. programme placement, is usually based on experience and the time of the day or week, since some parts of the day have more viewers than other parts as the research confirms. Parts of the week are also heavily considered in the placement decisions as he mentioned.

The interviews and focus groups feedback confirmed the scientific literature review that every part of the week has its specific viewers' profiles and characteristics. Therefore planners tend to schedule programmes according to the programme's relative importance during day parts, different days or week parts. Hence, a higher weight is given for the peak-time (Prime-Time) where the viewership ratings are at their highest on a specific day of the week. This manual process is usually performed based on experience. For news channels, such as Aljazeera, CNN, and BBC for instance, and due to the nature of news, having a very flexible and dynamic schedule is a must in order to react quickly to breaking events such as wars, earthquakes, etc. Although news cannot be scheduled according to viewers' expectations, it can sometimes be planned ahead of time – for example, the planning process for the coverage of the American elections. However, the remaining parts of a day's schedule can be planned more effectively as the interview results suggested.

The interview discussions revealed that the content decision-making process is a science by itself and cannot be completed in isolation of viewers' wants and expectations. The interviews with the SMEs show that they rely on research data in making their content building decisions; however, they confirmed that this data is not used efficiently. Alternatively, they rely on their strong experience in the field when making such decisions.

Furthermore, the interviews' outputs highlighted a very rigid decision-making process when it comes to changing a programme's airing time or even changing some parts of its content. Some of the interviewed media experts claimed that existing programme airing times should not be changed/rescheduled due to the potential high risk of losing existing viewers. However, no scientific evidence to support this statement is found in the published literature. Therefore, further research is required to study the impact of changing an existing programme airing time on viewership, but this topic is beyond the scope of this thesis. However, the proposed model promotes increased viewership when changing some programmes to another time slot as will be discussed in Chapter 3 and Chapter 5.

According to feedback from programme editors, producers and planners, television programmes are classified according to their weights, grades, or importance to the television station. Every television channel has its classifications. Some television stations like the Aljazeera Media Network, for instance, have identified three weights for programmes, namely A, B and C where a programme of quality "A" is considered of a higher ranking to the organisation than programme "C". Television stations can have different classifications. However, the content offerings of a specific television station usually dictate the number of programme classes they use.

In this research, for simplification reasons, only three main grades are considered, namely as "A, B and C" where programme of quality "A" is considered of a higher ranking to the organisation than programme "C". The grading criterion is based on the programme attributes such as content type, the cost of the programme, host of the programme, etc. Therefore, the Scheduling Manager of Aljazeera Arabic claims that every programme is assigned in the schedule according to its type and quality. Furthermore, he stated that some time-slots in the weekly grid could be booked ahead of time and kept aside for specific programmes such as news bulletins for instance. Also, he claims that advertising agencies can also play a vital role in the scheduling process by requesting to book specific time slots during the day/week for different advertisements. These pre-booked time slots sometimes force programme planners to plan around them to try to make the best of the daily schedule left for scheduling. For example, an advertising agency can book some time slots in the weekend prime-time for the launching of new product for one of their clients. In this case, programme planners will not have the same flexibility to schedule programmes as they would if the time slots were free.

The Manager of Programmes at the Aljazeera Documentary Channel stressed in his interview that the success or failure of a programme depends on three main important elements: editorial content, the cost of production, and, most importantly, time of airing. Thus, it can be confidently concluded that the daily/weekly/monthly programme schedule is a crucial factor in the success of content providers. This argument is confirmed in literature as well (Gantz and Zohoori 1982).

The interview feedback with the Manager of Scheduling at Aljazeera Arabic confirmed the great impact of the ***"Lead in"*** strategy in boosting the viewership ratings of a weak or new programme by keeping some of the current existing viewers of the previous strong programme.

Another important scheduling strategy revealed from interviews discussions is what is called the "***Train effect",*** which is a placement strategy where a series of different programmes is scheduled in sequence feeding into each other, to keep the audience interested and attached to their television screens. Although this sounds logical, no scientific research has been found which analyses this concept in more detail.

Moreover, from the author's experience as the Head of Media and Market Research at Aljazeera Media Network and according to audience research findings, it was noticed that viewers' behaviour is very sensitive to changes in the programme schedule. Currently, programme planners depend heavily on their experience, expert instinct, historical data and subjective judgment in building a programme schedule. Programme schedules, if not compiled well, can negatively impact viewership ratings.

As discussed earlier, content type, quality, cost, host of a programme, and the time of airing are very important factors influencing the success or failure of television stations. However, the available programme hours and archives, which are sometimes limited by the network's capacity and financial resources, play a vital role in deciding the programme grid. Therefore, planners sometimes repeat old and "***consumed***" programmes in the low months of viewership to fill in the air time as explained by the Scheduling Managers at Aljazeera. Hence, the available hours of production and programme content versus the available airtime is one of the main issues that face every media organisation and needs to be given special attention.

Television programming and planning is much easier if programme planners are planning and scheduling for one television channel only. However, it becomes more complicated when scheduling for a network of multiple channels as explained by Aljazeera Programme Directors. Aligning programme schedules can be very complex especially if the network channels share the same type of programme offerings. The goal is to capture the maximum number of viewers and keep their attention for as much time as possible. However, if viewers choose to leave the channel, planners should try to attract their attention to a different channel within the same network instead of leaving to another competitor. That is known as internal competition, and it is very hard to define the balance required to maintain aligned network schedules as discussed in the interviews. Internal competition can be healthy but, if not planned well, channels may compete internally in a negative way and may lose viewers to external competition. The key here for every channel is to complement other channels' offerings and not duplicate efforts as explained by the Programme Producer at the Aljazeera Documentary Channel.

Media experts, in one of the focus group discussions, were asked a question about media and market research data usage and importance in the programme decision-making process. They confirmed that it is crucial for "**make or buy**" decisions as well as for "**placement decisions**". However, it was not clear exactly how this data is used and to what extent it is used accurately in programme placement process. Make or buy decisions are usually dictated by the nature and type of the channel and the allocated budget. However, it appears that decisions about what to buy or produce from the same type of offering are still being made without using analytical methods and techniques. It is very clear from the interviews that viewership analysis outputs are not used efficiently in the content planning and production process.

One of the focus group discussions concentrated on viewership data sources, quality and completeness and the way it is communicated with programmes and content producers. The group reported that a few research companies that dominate the market, such as Nielsen and Ipsos, have qualitative and quantitative data that television stations subscribe to and receive on a weekly/monthly basis to analyse the viewers' demographics, profiles, programme viewership, and competition analysis. The research department uses the data to report viewership behaviour, likes, dislikes, trends, etc. and recommends programme content options that might appeal to potential viewers. Planners afterwards utilise these reports in their programme decision-making process.

A question about automation and the use of technology in the planning and scheduling process revealed that some parts of the process are automated, especially the part when a programme schedule is final and ready to be inputted into a "**play-out**" software. One such application is called "**ScheduAll**[17]" that can schedule all resources allocated to a given project to maximise utilisation, efficiency and profitability as claimed by the software company. While such software packages do help broadcasters to perform

[17] http://www.scheduall.com/broadcast.html

better, some very important elements are still missing, such as optimisation and an intelligent decision-making tool for programme placement decisions.

Another problem discovered was the absence of scientific planning tools, sometimes leading to conflicts in the schedule itself which may cause cancellation and late schedule changes, affecting television stations negatively as stated by the Scheduling Manager at Aljazeera Arabic. A similar scenario can occur when television planners schedule for more than one channel in the television network. In some instances, there can be a conflict in the schedule with the other sister channels that leads to programme cancellation at a very late stage, causing financial losses and interruptions to the schedule, as described by the interviewee.

Furthermore, the availability of resources such as Studios, Anchors, Directors, Outside Broadcast (OB) Vans, etc. plays a major role in the planning and scheduling process. The lack of resources might hinder planners and limit a programme scheduler's ability to place a specific type of programme, especially a live programme.

The results of the first round of interviews and focus groups suggested that the current tools planners are using for planning are neither intelligent nor sophisticated enough to build programme schedules, due to the lack of a clear understanding of changes in viewership habits, as well as the ever-changing behaviour of the competition. At present, media schedulers and planners are using different tools and techniques such as Word, PowerPoint or Excel to plan and execute their programmes schedule. They also use different packages for airing scheduled programmes. However, no scientific evidence has been found which reports that they use advanced analytical tools, where a schedule is built around viewers' expectations in a scientific way.

In addition to the points mentioned above, the interview discussions with SMEs in the media and viewership research field supported the need for systematic and comprehensive decision-making tools in the programme planning and scheduling process. The feedback recorded from the interviews helped in building the foundation and the logic of the optimisation model developed in this research.

In summary, the following points were considered the main outputs of the interviews and focus group discussions with the SMEs:

- Programme planning and scheduling is a long and complicated process that takes into consideration different experts' opinions in television stations;
- Cost, content, and the airing time of programmes are very important elements for television planning cycles;
- The optimum mix of programme offerings depends on the television station's nature and strategy;
- Audience research data are used and are very important when making programme planning decisions;
- A manual process using Excel sheets, PowerPoint and other basic tools to build a programmes schedule is currently in use in many television stations;
- Programmes are classified and segmented according to their weight and grade (importance to the television station), and distributed in the schedule taking this important factor into consideration;
- Day parts and week parts are given special attention in scheduling decisions;
- Some specific time slots are more important than others in the programme schedule for different reasons and should be booked for specific pre-known programmes or advertisements;

- Different strategies are used currently in the programmes scheduling process, such as ***"Lead In"*** and the ***"Train Effect"***;
- The quality and accuracy of viewership research data is very important for successful television station planning and scheduling;
- Analytical tools are hardly used but could potentially be very useful in the planning and scheduling process.

In the following chapters of the thesis, an interactive computer optimisation model is presented and discussed in more detail, in an attempt to help the Media Industry to tackle its programme scheduling problems by making more sensible and informed decisions that are viewer-centric and cost efficient.

Furthermore, the second and third parts of the interviews discussions with SMEs will be presented and discussed. In those discussions, the optimisation model was presented and tested for different scenarios to seek SMEs' feedback on the usability and practicality of the interactive computer optimisation models.

Chapter 3

In the current chapter, the basic computer optimisation model is presented and discussed in more detail. The model's assumptions, inputs, outputs and limitations are also presented and explained. In addition, the programmes scheduling problem concept, logic and framework are presented and discussed. The mathematical formulation and the setup of the model in solver software are described with running tests by considering different scenarios are described and discussed.

3.1 Model Description:

As shown in Figure (2) below, the framework of the television programme planning and scheduling problem is demonstrated in a holistic diagram where all attributes and parameters of programmes and viewers are put together in one place to outline the research problem. The goal of this illustration is to establish a preliminary understanding of the research problem and to present the case visually so it can be tackled and solved appropriately.

A clear understanding of the problem will help in developing and formulating the optimisation model that is proposed to help media planners and practitioners to solve their real-life scheduling and planning problems.

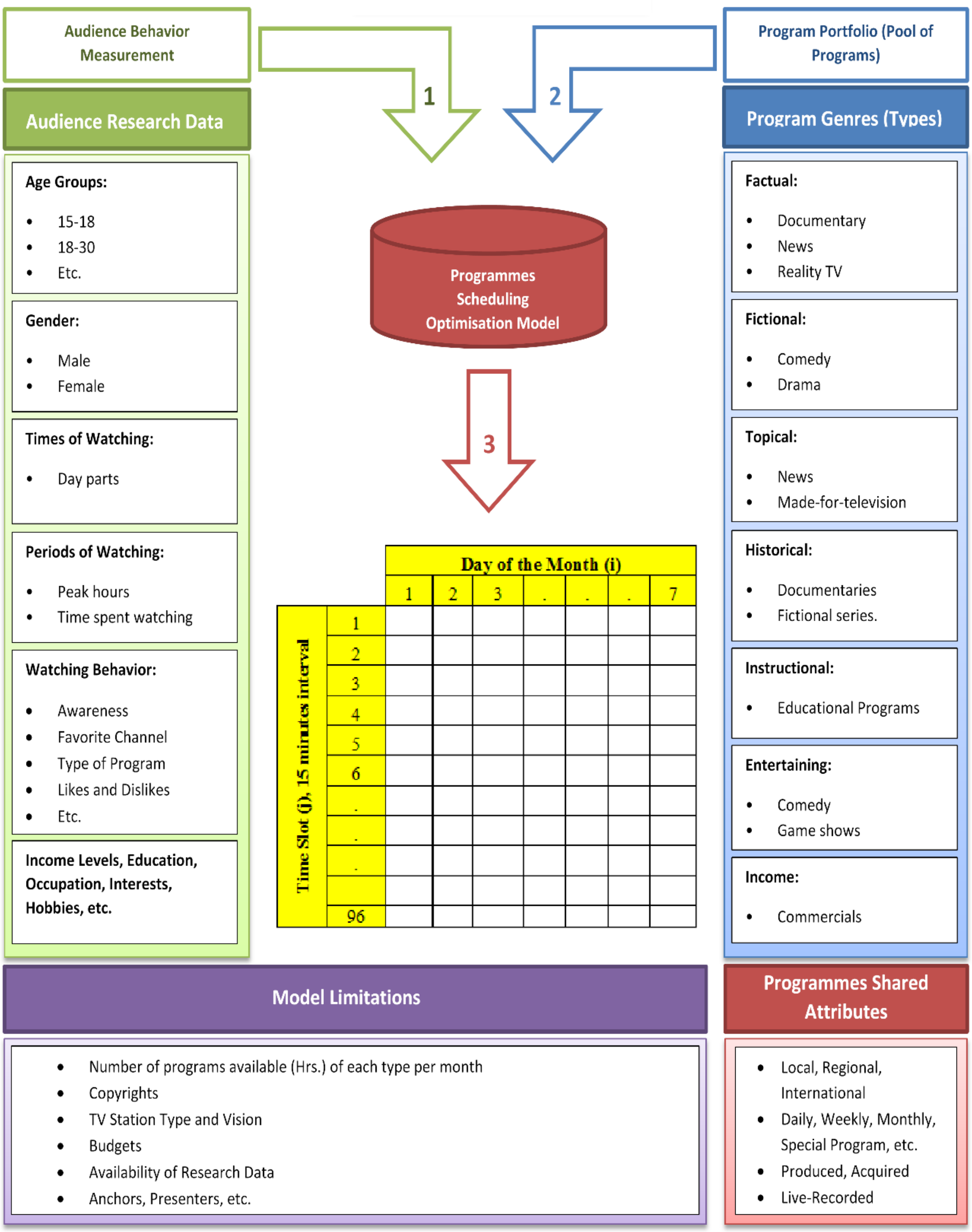


Figure (2): Programme Scheduling Problem Model

3.1.1 Model Inputs: Figure (2) shows, on the right-hand side (in step 2), a pool of programmes (**Programmes Portfolio**) where television broadcasters have a number of produced and/or procured television programme hours of different types: Factual, Fictional, Topical, Historical, Instructional, Entertainment, etc., to be scheduled and aired at a particular date and time.

As shown in the Figure (2), every programme has its own attributes. *Content Attributes*: local, regional and international; *Frequency Attributes*: daily, weekly, monthly and/or special programmes; *Ownership Attributes*: internally produced and/or procured from external resources, and *Live or Recorded*.

Different attributes of programmes should be considered seriously by programme planners when they build their programme schedules. It is very important to have a variety of scheduled hours of different attributes to be aired to attract viewers and keep them tuned in as long as possible. In this thesis, the ***Type*** and ***Quality*** of programmes are considered as the main attributes in formulating and solving the computer optimisation model.

The other important input to the model is the **(Audience Research Data)**, shown on the left-hand side (in step 1). Profiling audience and understanding viewership trends and habits by age group, gender, times of watching, periods of watching, etc. will help programme planners to put together a grid that potentially keeps viewers tuned to their screens.

The audience research provides data such as viewers' demographics, time and periods of watching, peak hours, viewership preferences, programme type preferences, income levels, education levels, occupation, interests, hobbies, etc. Audience measurement is a critical component in any television programme planning and execution. For the purpose of this research, a data set provided by Ipsos Research Group[18] was used. The data represent a full week of viewership per-channel in a sample country in the Middle East Region for March 2013.

Programme directors must consider all the parameters mentioned above to build their portfolio of programmes and to schedule them at the best date and time.

3.1.2 Model Outputs: As shown in Figure (2), in step 3, the **resulting output from programme scheduling process** is a list of programmes or programme types distributed over all the day parts and timeslots. This is known as the schedule of programmes (or Grid).

To produce a programme schedule, the research presented in this thesis suggests developing an intelligent decision-making tool to optimise the distribution of the pool of programmes, automatically utilising the research data as a baseline in making programme placement decisions. This intelligent decision-making tool should allow programme planners and directors to consider different programme attributes and other different variables, limitations and constraints in making scheduling decisions. The goal of the optimisation model is to maximise the viewership by utilising current and potential resources in an optimal way.

Further, as illustrated in Figure (2), there are several constraints and limitations that can be considered in programme scheduling decisions, such as the number of hours available in the pool for broadcasting television, the copyright status of each programme, the television station type and/or vision, programmes budget, audience

[18] Ipsos Group S.A. is a global market research and a consulting firm with worldwide headquarters in Paris, France. www.ipsos.com

research data availability, resources availability such as studios, anchors, presenters, etc.

In summary, the model in Figure (2) describes the framework of the automated intelligent decision-making tool that is developed in the thesis. The scheduling problem is solved by following three main steps:

- Step 1 is to build a reliable, up-to-date viewership database to be fed into the model.
- Step 2 is to build a portfolio of programmes that responds to audience expectations.
- Step 3 is to plug the outputs of step 1 and 2 into the intelligent decision-making tool to generate a programme schedule that potentially maximises viewership and utilises available resources in an optimal way, by considering all different variables and constraints.

In the following few pages, details are given of the mathematical model which has been developed to represent the basic computer optimisation problem in a logical and meaningful way. The objective function, constraints and variables are specified, and the problem is solved using sample data from industry.

3.2 Mathematical Programming Basic Model:

3.2.1 Model Assumptions:

For reasons of simplification, the following are the main assumptions made to build the initial basic computer optimisation model where the problem logic is created, concept viability is tested and the model is run.

- One television channel 24/7 that offers five main types of programmes (Entertainment, Economy, Science, Sport and Politics) of different qualities
- Three main qualities of programmes (A, B and C) which potentially attract 20%, 10% and 5% of available viewership respectively. This assumption is based on focus group discussion feedback where different scenarios were discussed; this concluded that three main qualities of programmes could be considered for this research with the viewership percentages mentioned above.
- Single feed television station
- One time zone
- One language
- One country
- Forecasted viewership ratings are available per programme type for total television viewership
- Each time slot takes one programme type/quality only (15 minutes total time each)

3.2.2 Input Parameters:

- Availability of resources (the number of hours of programmes of different types)
- Viewership data
- “Blocked” time slots, where the type and quality of programme are prespecified

- The maximum and minimum number of hours each day for each programme type and quality

3.2.3 Objective Function:

The model objective is to maximise the viewership of a television channel

$$\textbf{Maximise } z = \sum_{i=1}^{7} \sum_{j=1}^{96} \sum_{k=1}^{5} \sum_{x=1}^{3} \mathbf{Y}_{i,j,k,x} * \mathbf{C}_{i,j,k,x}$$

Where:

z The total objective value (the number of viewers)

i Day of the week 1 to 7

j Time slots 1 to 96 in day i

k Programme type 1 to 5 (the maximum number of available programmes under consideration to be assigned to time slots)

x The quality of the programme (1, 2 or 3)

$$Y_{i,j,k,x} \begin{cases} = 1 \text{ if programme type } k \text{ of quality } x \text{ is placed into time slot } j \text{ on day } i \\ 0 \text{ otherwise} \end{cases}$$

$C_{i,j,k,x}$ The contribution in number of viewers to z if programme type k of quality x is assigned to time slot j in day i

It is assumed that

$$\boldsymbol{C_{i,j,k,x} = P_{i,j,k} * F_x * Population}$$

where $F_1 = 0.2$, $F_2 = 0.1$ and $F_3 = 0.05$, and $P_{i,j,k}$ is the percentage of viewers "ratings" for a programme type k assigned to time slot i,j

3.2.4 Model Constraints:

$\sum_{i,j} \; Y_{i,j,k,x} \leq B_{k,x}$ $\qquad\forall \; k, x$ (1)

where $B_{k,x}$ is the number of hours available for programme type *k* and quality *x*

$L_{i,k,x} \;\leq\; \sum_{j} \; Y_{i,j,k,x} \;\leq\; U_{i,k,x}$ $\qquad\forall \; i, k, x$ (2)

where:

- $U_{i,k,x}$ is the maximum hours allowed per programme type *k* of quality *x* to be scheduled in a specific day *i*
- $L_{i,k,x}$ is the minimum hours allowed per programme type *k* of quality *x* to be scheduled in a specific day *i*

Blocking time slots: $Y_{i,j,k,x} = 1$ for some *k*, *x* (3)

where a programme type *k* of quality *x* must run in the slot (*i*,*j*)

$Y_{i,j,k,x} = 0$ for some *k*, *x* (4)

Where a programme k of quality x cannot run in slot (*i*,*j*)

One programme type/quality in each time slot:

$\sum_{x} \; \sum_{k} \; Y_{i,j,k,x} = 1 \quad \forall \;$ available (i, j) (5)

3.2.5 Model Discussion and Structure:

In formulating and solving the programme scheduling optimisation problem, an integer linear programming model has been developed that extends the approach of Horen (1980) and some other similar approaches by considering different variables and adding more complexities to the model. This problem can be regarded as a linear assignment problem where some programme types of different qualities are scheduled to be aired at specific time slots, with the objective of maximising overall viewership, subject to some constraints.

The objective function value, as shown previously in the formula, is equal to the contribution of each programme type/quality (C) multiplied by the value (Y). The value of Y is equal to 1 if a programme of type (k) and quality (x) is selected for a specific time slot (i,j); otherwise, Y will equal 0.

One important contribution of the model is taking into consideration the programme quality impact in optimising scheduling and placement decisions that might increase or decrease viewership numbers.

To investigate the relationship between programme quality and the impact on the number of viewers, a set of questions were asked in the focus group discussion sessions conducted for the purpose of this research. The goal was to measure and quantify the impact of programme quality on the number of viewers. The results confirmed the direct relationship between viewers' tendency to tune their television devices to a particular programme and the quality of that programme.

As discussed earlier in the thesis, the quality of a programme usually depends on the cost of production, popularity, guests (for talk shows for example), the technology used, etc. An "A" programme, for instance, is a programme that is very popular and rich in terms of content and value to viewers, for example, "***The Oprah Winfrey Show***[19]".

Previous research in this area has ignored the impact of programme quality on viewership preferences when scheduling programmes for a television station. The focus

---

[19] American talk show that aired nationally for 25 seasons from September 8, 1986 to May 25, 2011 in Chicago, Illinois. Produced and hosted by its namesake, Oprah Winfrey, it remains the highest-rated talk show in American television history according to Rose, Lacey (January 29, 2009). "America's Top-Earning Black Stars". Forbes. May 23, 2012.

group discussions confirmed viewers' tendency to stay tuned to a specific television channel to watch programmes based on its content, values, etc.

The percentages calculated after the analysis of those discussions are as follows: an "A" programme receives 20% of total viewership, "B" programme receives 10% of total viewership, and "C" programme receives 5% of total viewership. To confirm these percentages' accuracy, further research is required, but it seemed reasonable to use these percentages in the model for testing and validation purposes.

The model considers one full week 24/7 that contains 96 time slots per day. Each time slot is to be assigned one specific programme type and quality. Nevertheless, a longer schedule of a number of weeks or months is also possible if research data is available. Fortunately, and due to recent advancements in programming and computational capabilities, it is now possible to optimise combinatorial problems with a very large number of variables and constraints utilising currently available tools such as What's Best from Lindo, Frontline Solver, Gurobi Optimisation, etc., though the time it takes for the model to be solved depends on the complexity of the model.

In this research, Frontline Solver[20] software has been used in conjunction with the Gurobi Solver Engine, as it was found to be a very user-friendly and powerful optimisation engine when compared with other available tools. The Gurobi Solver Engine "plugs into" the Frontline Solver Platform for Excel that makes it flexible when formulating and solving problems.

Robert Bixby, Zonghao Gu, and Edward Rothberg, three key former members of the CPLEX[21] development team, have developed a high-performance solver designed for

[20] http://www.solver.com
[21] http://www.solver.com/gurobi-solver-engine

new multi-core processors: the Gurobi Solver. Their engine enables users to solve challenging linear programming (LP), quadratic programming (QP), quadratically constrained programming (QCP), mixed integer linear programming (MILP), mixed-integer quadratic programming (MIQP), and mixed integer quadratically constrained programming (MIQCP) problems.

The enormous computational capabilities of such optimisation tools were not available to scholars in the past. That, of course, prevented them from considering longer and more complicated schedules. The limited number of decision variables and constraints was a major concern in previous attempts to optimise programmes schedules. Therefore, programmes planning and scheduling decisions were limited by the number of variables and constraints allowed in the software.

Long schedule decisions are very important in planning for television channels since they take into consideration the seasonal and other viewership demand fluctuations, such as summer, winter, school terms, vacations, religious occasions, etc. Some television channels start the annual planning cycle at the beginning of autumn. They usually consider the current year basic schedule followed by the sessional television scheduling (Lupo 2014). This process is very similar to the programmes planning process in Aljazeera. The most important factor to consider in this process is the seasonal viewership ratings changes. Hence, it is important to feed into the model the ratings data that represent every season respectively and run the model accordingly. Thus, long schedule planning becomes possible by having the appropriate viewership data required to run the model.

In this thesis, a large number of variables and constraints are considered in formulating and solving the basic as well as the advanced interactive computer optimisation model that will be discussed in more detail in a later chapter of the thesis. The constraint number (1) presented in the mathematical model mentioned earlier represents the supply resource availability. It represents the number of programme hours available of each type *k* and quality *x* available for scheduling.

The basic model has been formulated and solved using a Microsoft Excel sheet and Frontline Solver (add-in) software, as a linear integer assignment-type 0-1 optimisation problem, where the variable $Y_{i,j,k,x} = 1$ if a programme of that type and quality is selected in that particular time slot on that particular day or 0 otherwise. Here *i* (*i* = 1..7) is the day of the week, *j* (*j* = 1..96) is the time-slot, *k* (*k* = 1..5) is the programme type (Entertainment, Economy, Science, Sports, Politics), and *x* (*x* = 1..3) is the programme quality (A, B or C). Thus, there are 10,080 0-1 decision variables. The value of the objective function is obtained by simply adding up applicable ratings for every time slot and every day.

Figure (3) below gives an illustration of the way that constraint number (1) is set up in Excel format. This is a key constraint where the model user can test and assess the programme hours' availability impact on the number of viewers.

Entertainment			Economy			Science			Sports			Politics		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
100	300	250	50	30	50	40	50	60	30	40	40	50	70	50
≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
80	211	30	50	30	14	40	29	14	30	40	14	50	20	20
	321			94			83			84			90	
Total Cumulative Duplicated Viewership (per week)														
Objective Function: Maximize Viewership											79,856,775			

Programme Types
Programme Qualities
Hours available for scheduling
Programmes scheduled by model

Figure (3): Constraint number (1): Resources Availability for Programme Hours

For example, a programme planner can increase/decrease the number of hours for a Politics programme of Quality "B", for instance, and re-run the model to test the impact on the potential number of viewers. The output in Figure (3) shows the hours available for scheduling (in yellow) and the hours that the model has chosen (in light blue), for each programme type and quality, that will optimise the television channel available resources and get the highest possible viewership. This is a very important and powerful testing tool to help television planners to perform their future planning and budgeting process. This will be discussed in more detail later in the thesis.

Constraint (2) represents the daily lower and upper bounds for each programme type and quality. This constraint gives programme planners a very powerful tool in putting upper and lower bounds on a type (genre) of the programme of a certain quality to be scheduled on a specific day of the week. Audience research shows that different days of a week have different viewership patterns for each type of programme. For instance, people tend to follow entertainment programmes at the weekend rather than watching political ones.

For this model, the programme planners' opinion and strong instinct and expertise in the field are not being ignored in the process of model formulation and solving. In fact, their input is vital in different phases of solving the optimisation problem as illustrated in different parts of the research. Figure (4) below is an illustration of how expert opinion is represented as a constraint in the basic model. As we can see, this constraint allows the planner to control the percentage of each programme type and quality for each day, for example, 30% Entertainment, 25% Economy, 15% Science and 30% Politics. It is possible to go further and specify some upper and lower bounds for a specific part/parts of each day, as shown in Figure (4) below.

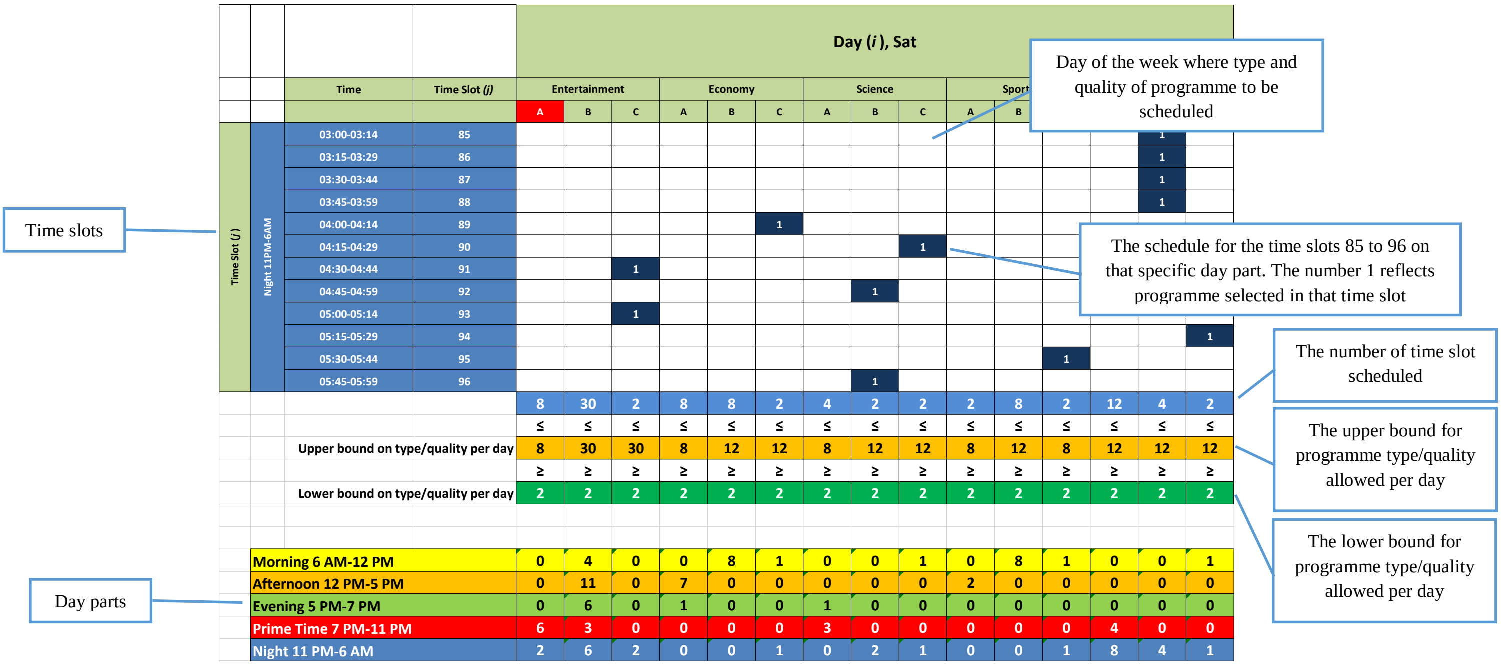


Figure (4): Upper and Lower Bounds on Programme Type/Quality Allowed Per Day

From the author's experience in the field, five day parts are normally specified as shown in Figure (4): Morning (6:00 am to 12:00 pm), Afternoon (12:00 pm to 5:00 pm), Evening (5:00 pm to 7:00 pm), Prime Time (7:00 pm to 11:00 pm) and Night (11:00 pm to 6:00 am). Viewers' lifestyles usually impact their viewership habits and are very important factors to consider when assigning a specific time for each day part; for example, *Prime-Time* start time, duration and end can be different in each country or geographical region. This will be tested and discussed in more detail in the advanced optimisation model chapter (Chapter 5) of the thesis.

Another important factor to consider in the model is the availability of programme hours per type/quality in the television station archives, in addition to the budget availability to buy or produce new programmes. This also will be considered and tested in the advanced model to measure the budget availability impact on the number of viewers.

Constraints number (3) and (4), as illustrated in Figure (5) below, allow media practitioners to schedule programme types/qualities by themselves before using the programmes schedule optimiser. This is a very important constraint as reported in the literature review and feedback from the SME interviews. This enables schedule planners to use their creativity and expertise to introduce new programme ideas and/or prevent the model from running a specific programme at a specific time slot (for example, preventing inappropriate content being scheduled times of day with high viewership among children (Lupo, 2014).

Many programmes planners do not want an automated system to interfere in their key programmes placement decisions. When the idea of automation and grid optimisation was discussed with programme directors and planners, they always insisted that they should be allowed to follow their strong instincts and to push and steer viewership demand the way they want to increase the viewership at peak times. While this is a reasonable argument, this may not apply to all parts of the day. The proposed optimisation model, therefore, aims to optimise the schedule around the prior scheduled editorial preferences of television experts.

The basic computer optimisation model also gives media experts and practitioners the comfort of changing the pre-scheduled programmes and measuring the impact on viewership before they even put the programme on air. Testing and simulating different programme combinations and scenarios is crucial in this industry.

Blocking time slots for previously known events or programmes gives media practitioners a very powerful tool in keeping viewers tuned to their favourite programmes in specific time slots, along with giving other programmes the chance to be scheduled in an optimum way. In Figure (5), time slots 56 through 61 in the Prime-

Time day part are blocked for Entertainment Programmes of Quality “A” and “B” respectively. In this scenario, the model will jump over those blocked time slots and keep them out of the placement decisions.

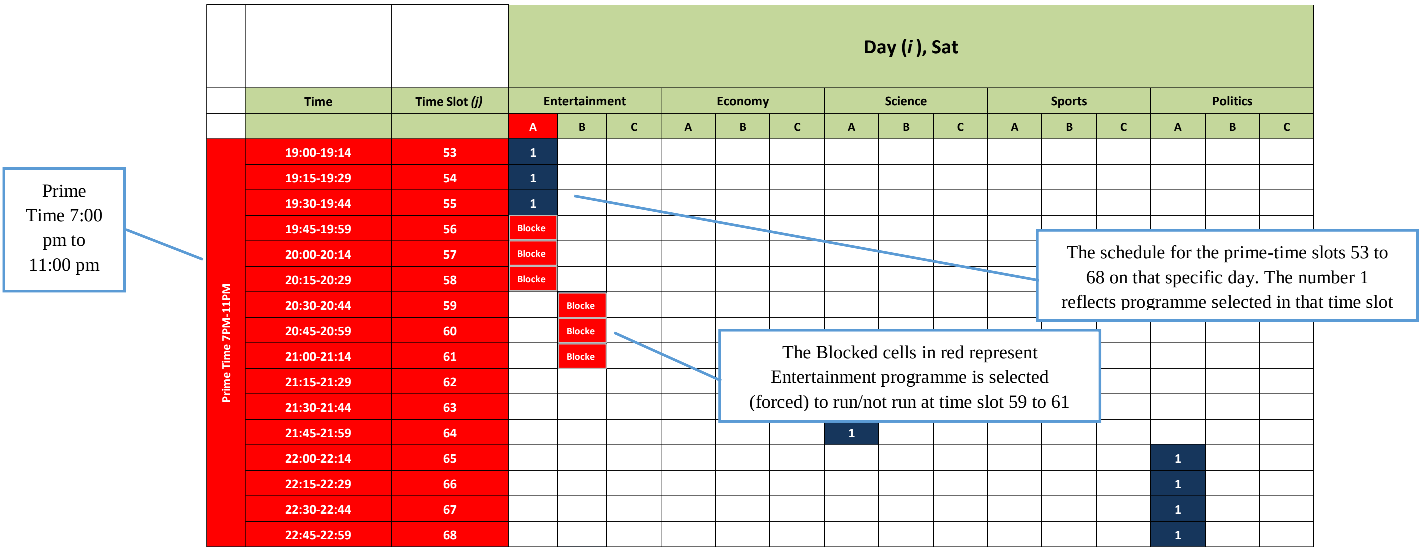


Figure (5): Blocked Time Slots for Specific Programmes/Events

Constraint number (5) forces the model to select exactly one programme in each time slot. This is very important as only one programme of type *k* and quality *x* can run at that specific 15 minutes’ time frame.

3.2.6 Push vs. Pull Scheduling Strategy:

The logic of the proposed programme scheduling model is built considering ***“the Push - Pull Strategy”.*** It is a very common strategy that originated in logistics and supply chain management (Hinkelman and Putzi 2005). Push strategy is used in several industries including the media and broadcasting industry (Peter and Donnelly 2002 and Dowling 2004).

The primary difference between push and pull strategies in business is the way customers are approached. In a push strategy, the idea is to produce products and then “push” them onto customers. However, in a pull strategy, the goal is to create a loyal following and attract customers to the products, thus creating demand in the market by establishing a position where a producer delivers products derived from customers' demand.

Historically, programmes editors and producers were used to produce and/or commission programmes based on their experience in the field and taking into consideration what the competition is doing. Their production then is "*Pushed*" out for potential viewers' consumption.

Later, as Audience Research Industry outputs became available and more reliable, the Push Strategy became even more popular as more rational and informed decisions were taken in the programmes planning and scheduling process. Quantitative and Qualitative Audience Research data were considered by programme planners to develop the portfolio of programmes. Then programmes were placed in the daily schedule for airing, in the hope that viewers would tune their television screens and stay tuned.

A Push Strategy takes into consideration viewership expectations in the programmes planning and scheduling decisions. However, more recently, the media environment has become much more competitive, and hundreds of thousands, if not millions, of programme hours, are available on multiple devices and platforms such as Cable, the Internet, Social Media, Television, Smart Phones, and Tablets. This has significantly fragmented viewers' behaviour and complicated the viewership decision.

This competitive environment has forced decision makers in the media industry to be much closer to viewers to respond to their needs more effectively. As a result, "*Push Strategy*" is becoming less effective in programme planning and scheduling.

Therefore, to enrich the proposed optimisation model, the “Pull System” approach was adopted. The main driver of this proposed scheduling methodology is the viewership behaviour and demand, as discussed later in the thesis.

The “Pull System” approach proposed requires a lot of computation and calculation. However, it is a very powerful tool, switching from a time-consuming manual model to an automated well-proven demand model where television planners offer viewers a programmes portfolio that meets or even exceeds their expectations.

As discussed earlier, the main input in the basic optimisation model is the viewership data per programme type (genre). This by itself is a huge challenge. Research companies such as Nielsen, Ipsos and others measure viewing habits by television channel and not by programme type. The proposed model logic is to distribute the available programme hours in the week grid while considering the total demand in the viewership market per programme type.

For the purpose of this research, a data set was provided by Ipsos Research Company[22] representing a full week of viewership ratings per channel in a sample country in the Middle East Region for March 2013. Long and manual process was required to come up with the required figures. A sample of these figures is shown below in Figure (6), where the ratings represent the viewership percentages on Saturday, by programme type, for the prime-time part of the day (slots j = 53 to 68). The full data set used for the model uses ratings over seven days, for all programme types and time slots.

---

[22] http://www.ipsos.com

	Time	Time Slot (*j*)	Ratings (Sat) per type of programme					Total TV
			Entertainment	Economy	Science	Sports	Politics	
Prime Time 7PM-11PM	19:00-19:14	53	25	6.6	6.5	4.3	3.8	52.62
	19:15-19:29	54	24.9	6.2	8.7	4.6	3.6	54.72
	19:30-19:44	55	22.9	5.2	6.7	3.8	3.7	48.62
	19:45-19:59	56	22.7	5.5	6.3	3.9	4.1	48.22
	20:00-20:14	57	20.9	16.4	18	4.4	8.1	73.92
	20:15-20:29	58	20	16.5	19.1	5.1	7.8	74.08
	20:30-20:44	59	21.2	16.3	19.7	5	8.2	76.23
	20:45-20:59	60	22.4	16.5	19.3	5	8.3	76.98
	21:00-21:14	61	18.2	8.3	17.9	5.3	8.6	65.18
	21:15-21:29	62	17.9	7.5	18.1	5.1	8.6	64.41
	21:30-21:44	63	21.5	10.4	17.3	5.8	8.4	72.4
	21:45-21:59	64	20.9	10.4	17.2	5.9	8.1	71.55
	22:00-22:14	65	20	10.1	8.8	5.9	10.8	66.21
	22:15-22:29	66	19.5	9.8	8.6	5.6	10.9	64.87
	22:30-22:44	67	19.7	9.7	8.1	4.8	10.9	62.82
	22:45-22:59	68	19.4	9.6	7.9	4.8	11.2	62.9

Figure (6): Sample of Viewership Ratings (per programme type)

To produce this data, a copy of the top ten television channels grids was collected for the week for which the viewership ratings had been reported by Ipsos. A detailed and comprehensive review of the top ten channels' offerings of different programme types throughout the week was completed to report the data by programme type rather than by television channel. Further details for the data preparation process is given in Chapter 4 of this thesis. For the purpose of this research, it has been assumed that a data forecasting model is available and is used to predict and forecast the future ratings, based on data resulting from the data preparations exercise described in Section 4.6 on page 122. The output from this forecasting model will then be used in the programme scheduling optimisation model.

As shown in Figure (6), so as not to overcomplicate the model during the model-building stage, just five main categories of programmes were initially used: Entertainment, Economy, Science, Sports and Politics. Other types of programmes are available as well, and the model has also been tested for a larger number of programme types and qualities scenarios as described in the following sections. The viewership ratings represent the total percentage of the population in that specific country who were watching television programmes of each type in every time slot on every day.

In Figure (7) below viewership ratings for a full day for each programme type are presented. The viewership ratings usually change during the day. For example, Morning (6:00 am – 12:00 pm) ratings are usually less than Afternoon (12:00 pm – 5:00 pm) ratings. Viewership, in general, peaks for all types of programmes in Prime Time (7:00 pm – 11:00 pm) as shown in the figure.

While prime time is important for all television stations, the other day parts, despite their lower ratings, are important as well; however, all previous research in this area has only taken into consideration prime time when scheduling programmes for television, rather than considering the full day's viewership ratings.

Also, the author's experience in the broadcast media field shows that different programme types can have their own prime times, rather than conforming to the overall prime time of the day. This means that the way that television channels schedule programmes need to change, though this argument needs to be confirmed by further research in this area.

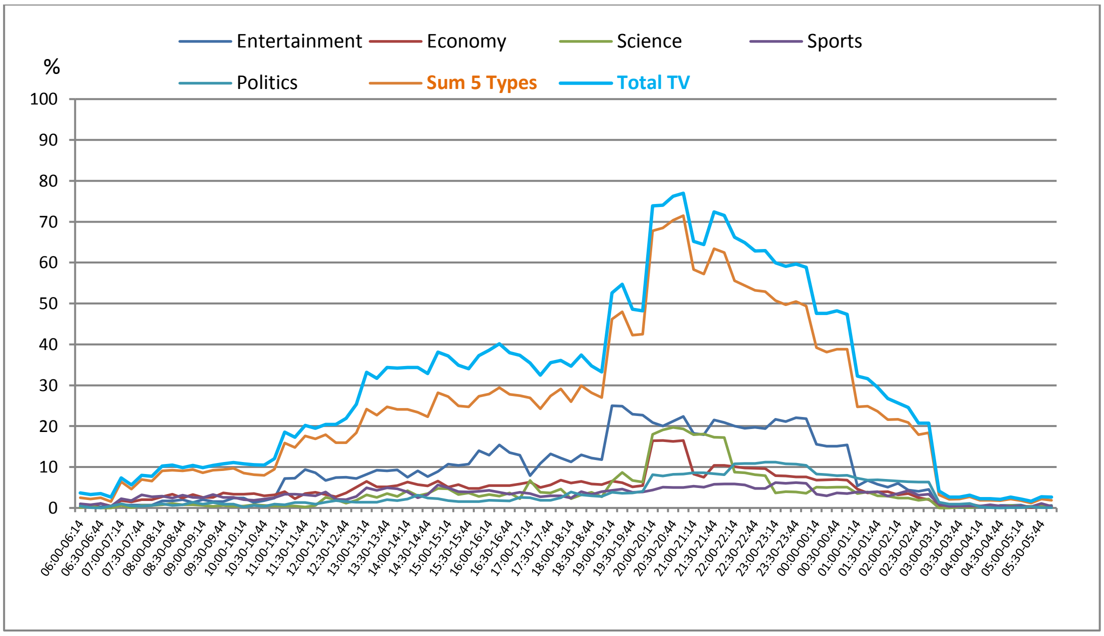


Figure (7): Viewership Ratings per Programme Genres for One Full Day (96 time slots)

The “Total TV” shown in blue in Figure (7) represents the total number of viewers that had their television screens on and were watching television out of the total population in the sample country. The “Sum of 5 Types” shown in orange is the sum of the main five types considered in the proposed computer model. The gap between Total TV and the Sum of 5 Types is the number of viewers that are watching some other types of programmes. All television stations are competing for a share of that total available viewership demand. However, only good content that is scheduled and promoted correctly can, potentially, increase a television station’s share of total viewership.

Further research is required to analyse viewership patterns during different times of the day and week. This is expected to confirm the importance of understanding the difference between overall viewership patterns during the day and the patterns for each type of programme and will help the model to produce schedules that respond to actual viewership demand.

Of course, airing programmes, of different types, at the optimum time slots scheduled by the model will NOT necessarily guarantee optimum viewership. Other functions within media organisations such as Sales, Marketing, Distribution, etc. need to play key roles in making that happen. Viewers are willing to tune their television sets when they are aware of these programmes offerings ahead of time. They usually expect to watch television programmes at specific times that were communicated with them earlier by media platforms. Thus, all functions within media organisations need to work together in harmony to bring television programmes that can attract viewers to stay tuned as long as possible.

3.2.7 Running the Basic Model:

As discussed earlier, Frontline Solver Gurobi optimisation engine was used to solve the basic computer optimisation problem. Several optimisation software packages were compared, and it was concluded that this tool is the most appropriate for this research, being very user-friendly and powerful. The front face tool to set up and program the research scheduling problem uses a simple Excel Sheet format as discussed earlier in this chapter. However, it also requires an experienced person to program the formulae in Excel, builds the logic of the model and adds/edit/eliminate the objective function, decision variables and constraints in the software. Hence, the programme planner/scheduler will not be able to use the tool by him/herself without help and support from an expert in Excel and Operational Research.

The licence comes with different options for the number of variables and constraints it can solve. It also comes with different options of Solver engines to choose from. The student licence was acquired which can solve an unlimited number of variables and constraints and uses the Gurobi engine. The Excel sheet contains day parts, time slots, weekdays, programme types, programme qualities, viewership ratings, the objective function, decision variables and the model constraints.

To illustrate and pilot the model functionality and to test the proposed placement strategy according to the push/pull scheduling theory, a real case scenario for a sample television channel was tested for a one-week programme grid, using the computer model, thus calculating the "duplicated viewership" figures for the full week in a sample country "X".

The term "Duplicated Viewership" allows for viewers who are reached more than once by the same television channel on the same day. For example, a viewer may watch the television channel during the morning, then leave the channel to come back later in the afternoon to watch another programme on the same channel and then leave again to come back yet again during peak time to watch another programme. Such a viewer contributes to the Duplicated Viewership figures for every 15-minute slot during which he or she is watching the channel; this may be as many as twenty times or more during a single day. Henceforth the simple term "viewership" will be used rather than "duplicated viewership".

The current total viewership of the programme schedule for the sample channel, according to the model calculation, reached about 51 million viewers. The television channel used to pilot the basic optimisation model offers Entertainment, Sports, News, Politics and other related content. The proposed computer model used the main five programme types as discussed earlier.

To run the model, Windows 8.1 software was used, installed on a laptop computer with Intel Core i7 (2.6 GHz) and 8 GB RAM memory. By running and solving the basic model optimisation problem, the resulting schedule potentially increased the viewership by 58%. The model has rescheduled the current programme portfolio of the sample channel differently resulting in a potential increase in viewership from 51 million reaching up to 80 million viewers. Table (1) below shows the Solver running times.

Problem setup time	1.01 seconds
Engine solve time	0.09 seconds
Solve time	4.34 seconds

Table 1: Basic Model Solver Running Times (5 Types/3 Qualities)

The number calculated here (80 million) is the summation over all time slots of the number of viewers in each time slot. It is not the actual number of viewers, because of duplication, as discussed earlier; however, as the objective is to maximise the overall viewership across the week, it seems sensible to use this figure as the objective function to be maximised.

Reasons for the potential increase in viewership are described below:

- Rescheduling existing programmes to another time slot where they potentially get higher audience interest;
- Introducing upper and lower bounds on types of programmes aired per day so that the channel offerings are kept more balanced and diverse;
- Introducing more options of programme qualities that can be distributed to fill air time and keep it balanced and diversified throughout the week;
- Introducing new types of programmes that have high demand in the market as suggested by ratings that will bring new people to their screens.

The proposed model will not necessarily guarantee viewership increases, but it will show the potential and the lost opportunities to other television channels because of not offering the required portfolio at the right times.

The model outputs regarding schedule and number of viewers can vary based on the upper and lower bounds and limitations introduced. It will also vary based on the hours of programmes available per type and quality to be scheduled. “What-if” analysis will help programme experts measure the impact on their financial and budget plans before actual production. Viewership increase is the ultimate target for every media organisation since it automatically increases the revenues by increasing the volume of commercials, advertising sales and programme sponsorships as well as other revenue streams. The price for advertising is usually based on the number of viewers reached, as well as varying by day and by the time of day.

3.2.8 Model Sensitivity & Parameter Analysis:

The availability of resources, as shown in yellow colour (see Figure (3) on page 77), may have a positive or negative impact on total viewership numbers. The current figures represent a constant number for each programme type/quality that is available to be scheduled. Hence, any increase or decrease in these numbers may have an impact on the optimum schedule placement decisions.

In this section, the parameter analysis function in Frontline Solver is used to report the sensitivity of changing the availability of resources on the optimum solution by running multiple optimisations. To set up this function, the optimisation parameter (PsiOptParam) in Frontline Solver was used. This parameter is entered in the resource availability constraint cell in the Excel sheet. To give an example, the number of available hours of Entertainment programme of quality A is changed from 100 hours to the “PsiOptParam(60,100)” parameter; here the number 60 represents the lower bound and the number 100 represents the upper bound allowed for that specific programme type/quality.

The upper and lower bounds can be different for every programme type/quality and should be decided by the programme scheduler. This function will force the optimisation engine to use different bounds for Entertainment programmes in each run.

This parameter was set up in the model for all types/qualities of programmes, and the solver optimisation was programmed to run multiple times (in this case 11 runs were chosen for testing purposes). By running the model, we get the figures shown in Table (2) below.

Run	Entertainment			Economy			Science			Sports			Politics			Objective Function	Viewership Increase
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C		
1	60	60	60	56	60	15	56	46	14	56	55	14	60	40	20	73358910	44%
2	65	65	65	56	65	14	56	40	14	56	52	14	65	25	20	74716695	47%
3	70	70	53	56	70	14	56	38	14	56	49	14	70	22	20	75936375	49%
4	75	75	44	56	75	14	56	33	14	56	47	14	75	18	20	77065830	51%
5	80	80	38	56	70	14	56	31	14	56	46	14	80	17	20	78118920	53%
6	80	85	32	56	68	14	56	31	14	56	46	14	84	16	20	78374970	54%
7	80	90	29	56	69	14	56	31	14	56	42	14	84	17	20	78602130	54%
8	80	95	27	56	66	14	56	31	14	56	43	14	84	16	20	78816960	55%
9	80	100	24	56	65	14	56	31	14	56	42	14	84	16	20	79021620	55%
10	80	105	22	56	66	14	56	28	14	56	40	14	84	17	20	79219620	55%
11	80	110	19	56	65	14	56	28	14	56	40	14	84	16	20	79407630	56%

Table (2): Basic Model Parameter Sensitivity Analysis

The first run of the multiple optimisations has selected a number of hours to be scheduled from every programme type/quality (as shown in the table above in green font). That particular selection yields higher viewership of 44% than the original Channel 1 "as is" schedule. Moreover, every hour's selection in the following model runs reflects the percentage increase/decrease impact on the total viewership. This is illustrated in Chart (1) below.

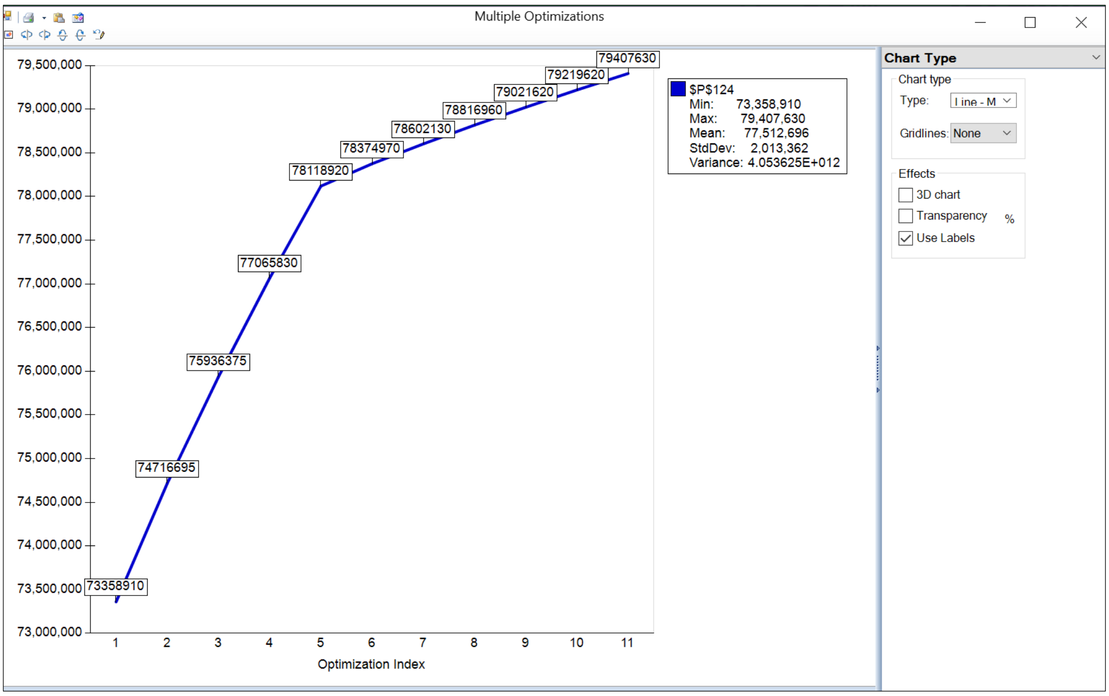


Chart (1): Basic Model Parameter Sensitivity Analysis

As shown above, the overall improvement in viewership as the bounds change is significant, ranging from 44% to 56% depending on the combination of bounds for different programmes types/qualities selected.

3.2.9 Basic Model Scalability:

As the model should be sufficiently general that it can work for different television channels, the scalability of the model was tested to handle more programme types, qualities and longer schedules. Different scenarios and problem setups were used and tested. Hypothetical television programme schedules and simulated viewership data were used to solve these scenarios.

3.2.9.1 Basic Model with More Programme Types:

As shown in Figure (8) below, two more programmes types were added to the model (Kids and History). The figure shows a one day sample (Saturday), but the testing was still carried out for a full week.

Day (*i*), Sat																				
Entertainment			Economy			Science			Sports			Kids			History			Politics		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C

Figure (8): Sample Basic Model with 7 Programme Types and 3 Qualities

This new hypothetical scenario was formulated and solved in Frontline Solver for j =1 to 96 time slots, i = 1 to 7 days, k = 1 to 7 programme types (Entertainment, Economy, Science, Sports, Politics, Kids and History), and x = 1 to 3 programme qualities (A, B, C). The number of binary decision variables was thus 96 × 7 × 7 × 3 = 14,112. There are 28,224 upper or lower bounds on hours availability/allowance per programme type and 987 other constraints. The objective function to be maximised is still total viewership.

The viewership recorded before running the model was about 46 million duplicated viewers in that hypothetical country for that specific week. All other model assumptions remain the same. By running the model, the potential viewership increased up to 74.9 million, which is approximately a 63% potential increase. Table (3) below shows Solver running times.

Problem setup time	1.25 seconds
Engine solve time	0.16 seconds
Solve time	5.48 seconds

Table (3): Basic Model Solver Running Times (7 Types/3 Qualities)

3.2.9.2 Basic Model with Fewer Programme Types and More Qualities:

For the next experimental run, as shown in Figure (9) below, four types of programmes were identified, and five qualities were introduced: A, B, C, D, and E. The figure represents a one day sample (Saturday). It was assumed that quality measures A, B, C, D and E could potentially attract 20%, 15%, 10%, 5% and 2.5% of available viewership respectively.

Day (*i*), Saturday																			
Type I					Type II					Type III					Type IV				
A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E

Figure (9): Sample Basic Model with 4 Programme Types and 5 Qualities

Here the number of decision binary variables is 96 × 7 × 4 × 5 = 13,440. There are 26,880 upper or lower bounds on hours availability/allowance per programme type and 972 other constraints. The value of the objective function is obtained by simply adding up applicable ratings for every time slot and every day.

The viewership observed before running the model was about 57 million duplicated viewers in that hypothetical country for that specific week. All other model assumptions remained the same. By running the model, the potential viewership increased up to 78.9 million, which is approximately a 38% potential increase. Table (4) below shows Solver running times.

Problem setup time	1.26 seconds
Engine solve time	0.16 seconds
Solve time	8.85 seconds

Table (4): Basic Model Solver Running Times (4 Types/5 Qualities)

3.2.9.3 Basic Model for a Long Period:

For the next experimental run, as shown in Figure (10) below, a longer time frame of three weeks was considered, with five types of programmes and three qualities. The figure shows the availability per week for programme type/quality bound shown in yellow colour. It also shows the current programme schedule hours for that hypothetical television channel shown in light blue.

	Entertainment			Economy			Science			Sports			Politics		
Week 1	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	100	300	250	60	30	50	40	50	60	30	40	40	50	70	50
	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	77	312	198	0	0	0	0	0	0	21	0	0	24	40	0
	587			0			0			21			64		
	Entertainment			Economy			Science			Sports			Politics		
Week 2	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	100	300	250	60	30	50	40	50	60	30	40	40	50	70	50
	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	77	312	198	0	0	0	0	0	0	21	0	0	24	40	0
	587			0			0			21			64		
												0			
	Entertainment			Economy			Science			Sports			Politics		
Week 3	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	100	300	250	60	30	50	40	50	60	30	40	40	50	70	50
	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	77	312	198	0	0	0	0	0	0	21	0	0	24	40	0
	587			0			0			21			64		
	Total Average Cumulative Duplicated Viewership (per week)														
	Objective Function: Maximize Viewership												51,201,870		

Figure (10): Basic Model of Three Weeks with 5 Programme Types and 3 Qualities (AS IS)

Here the number of decision binary variables is 96 × 21 × 5 × 3 = 30,240. There are 60,480 upper or lower bounds on hours availability/allowance per programme type and 2691 other constraints.

The average viewership recorded per week before running the model was about 51 million duplicated viewers in that hypothetical country for that specific week. All other model assumptions remained the same. By running the model, the potential viewership increased up to 80.6 million, which is approximately a 57% potential increase. Table (5) below shows Solver running times.

Problem setup time	4.41 seconds
Engine solve time	0.34 seconds
Solve time	14.79 seconds

Table (5): Basic Model Solver Running Times for 3 Weeks (5 Types/3 Qualities)

The small increases in running times show that there is no computational barrier to producing schedules as long as may be required.

Figure (11) below illustrates the "TO BE" schedule after running the three weeks' model. Its shows the television programmes hours per type/quality selected by the model to run for every week.

Week 1	Entertainment			Economy			Science			Sports			Politics		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	100	300	250	60	30	50	40	50	60	30	40	40	50	70	50
	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	80	208	30	56	30	14	40	26	14	30	40	14	50	20	20
	318			100			80			84			90		

Week 2	Entertainment			Economy			Science			Sports			Politics		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	100	300	250	60	30	50	40	50	60	30	40	40	50	70	50
	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	80	215	24	56	30	14	40	29	14	30	40	14	50	16	20
	319			100			83			84			86		
												0			

Week 3	Entertainment			Economy			Science			Sports			Politics		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	100	300	250	60	30	50	40	50	60	30	40	40	50	70	50
	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	80	207	29	56	30	14	40	31	14	30	40	14	50	17	20
	316			100			85			84			87		

Total Average Cumulative Duplicated Viewership (per week)	
Objective Function: Maximize Viewership	80,601,315

Figure (11): Basic Model of Three Weeks with 5 Programme Types and 3 Qualities (TO BE)

To summarise: in this section, several scenarios with different numbers of programme types and qualities, as well as longer time periods, were considered and tested using the developed basic model for each scenario, using a hypothetical television schedule and simulated data sets. All model scenarios ran efficiently and gave new optimal schedules with increased potential viewership.

3.2.10 Challenges of the Basic Model:

The basic computer model has succeeded in distributing programmes efficiently in the week schedule and managed, theoretically, to increase overall viewership. However, when this work was presented back to media practitioners, ensuing discussions disclosed more challenges and more areas to consider for the computer model to be more realistic and comprehensive at the same time.

The model was presented in its initial basic working condition to the Director General of Aljazeera Media Network. In this session, the DG showed much interest in the model and was excited by the potential increase that can be achieved by implementing different scheduling strategies such as Pull – Push Strategy.

Initially, he raised a point that some programmes cannot be changed as this might cause huge loss to the television station in his opinion. He also stated that some famous programme presenters might disagree with the automation and insist on keeping their programmes at the original airing times. To respond to the DG's concerns, the "Push - Pull" system taken into consideration when building the computer model was discussed with him; this will ensure that popular programmes can be fixed in the schedule so that the optimisation model cannot move them around.

The potential for "what if" analyses that can be performed before moving any programme, was also discussed; thus, an expert can see the potential positive or negative impact of the viewership that might encourage programme decision makers to consider whether or not to move a popular programme.

After seeing several scenarios, the DG requested to share this model with a larger pool audience to collect their inputs, and he recommended that the model should be put into piloting mode within the network. Unfortunately, the model was not ready yet to be piloted or implemented in its current state. However, the model was presented and discussed with some of the main key decision makers at Aljazeera Media Network.

The outputs of these sessions were very useful as they highlighted more points that required focus and attention to improve the model and get it ready for implementation. The Director of Programmes was impressed by the outputs and discussed the possibility of including cost and budget planning if possible in this model. He said that "it will be good if we can plan our budget allocation while scheduling programmes".

Another area of improvement required in the model was the ability to schedule one complete programme at a time rather than scheduling one-time slot. As shown in Figure (12) below, the model outputs were unrealistic in some placement decisions. Here the model's decision was to place Sports C in time slot 1, Science C in time slot 2, Economy C in time slot 3 and Politics C in time slot 4. This assumes that all of these programmes will have an equal length of 15 minutes each. As discussed earlier, this was one of the model assumptions made to simplify the basic model formulation and solving. However, this is not a practical assumption if the model is to be implemented in real life.

		Day (*i*), Sat														
Time	Time Slot (*j*)	Entertainment			Economy			Science			Sports					
		A	B	C	A	B	C	A	B	C	A	B	C	A		
06:00-06:14	1												1			
06:15-06:29	2									1						
06:30-06:44	3						1									
06:45-06:59	4															1
07:00-07:14	5											1				
07:15-07:29	6											1				
07:30-07:44	7											1				
07:45-07:59	8											1				
08:00-08:14	9											1				
08:15-08:29	10					1										
08:30-08:44	11											1				
08:45-08:59	12					1										
09:00-09:14	13											1				
09:15-09:29	14											1				

1 means Sports programme of quality C is scheduled in time slot 1

1 means Science programme of quality C is scheduled in time slot 1

Figure (12): Sample of Saturday the Schedule after running toe model (6:00 am to 10:00 am)

As reflected in the discussions with Aljazeera Media Network team, the ability to schedule longer than one week of time is essential, and they wanted to see the model placing programmes for more than a week – this can be done as shown in the previous Section, but at the time it was not possible to show this to the Network team. Another main challenge in running the computer model and getting realistic placement decisions was having the accurate forecast viewership rating for different programmes types per time slot/day.

In the remaining parts of this thesis the Audience Research Industry will be discussed, followed by descriptions of how the model was transformed into the advanced programmes scheduling optimisation model, designed to be more comprehensive and realistic in solving scheduling problems.

Chapter 4

The aim of this chapter is to give a clear understanding of the audience research industry and the use of data in the programme planning and scheduling process. Topics discussed in detail include data collection tools and techniques; the advantages and disadvantages of each tool; challenges to the new media environment; understanding ratings and audience behaviour; and data prediction. In addition, the need for viewership ratings in the broadcasting industry is described, and an organisational model of a sample media organisation is illustrated, to explain the different business operations and the business dynamics of the television industry.

4.1 Audience Research Industry:

Webster *et al.* (2014) in their book (Rating Analysis) have identified several types of audience research that are available to measure viewership: Applied vs. Theoretical, Quantitative vs. Qualitative, Micro vs. Macro, Syndicated vs. Custom, and Rating Research. As a programme schedule relies heavily on viewership ratings, this thesis will concentrate mainly on "Rating Research", though other types of audience research are also discussed.

A "Rating" is defined as a percentage of the entire population that sees or hears something. Historically, Rating Research had begun in the 1930s in the United States for radio market analysis where researchers started reporting programme ratings. Later, in the 1950s, rating analysis moved to the television industry, and it became the primary source of audience research as we know it today (Webster *et al.* 2014).

Rating research is always quantitative, describing a population engaged in viewing, listening, interacting, etc. It provides very important information as it gives broadcasters, media planners and other decision makers a very powerful tool to make informed decisions about their industries. Important questions here are: Where does the data come from? How is data collected and reported? How accurate is this data? How is this data used?

Different techniques are used to gather and analyse data, as described below:

Telephone Interviews: this is one of the traditional and most powerful tools to survey people's opinions about products and/or services. In the very early stages, it was an unconventional tool for conducting survey research. At the time, research companies used it to gather information about advertisements' effectiveness. Telephone Interview techniques and methodologies have progressed over time and have become very common in today's audience research industry. Recent advancements in today's technologies have established structured interview techniques such as Computer-Assisted Telephone Interviews (CATI)[23] in which the interviews follow a script provided by a software application that allows for timely and accurate data. Later, Automated Computer Telephone Interviewing (ACTI) was introduced. An ACTI system is a computer-based system that asks respondents a series of questions and stores answers. It follows a scripted logic and branches questions according to different answers (Mytton *et al.* 2016). Telephone interviews provide fast and inexpensive data but have some limitations, such as memory problems and a high margin of error. Despite these limitations, telephone interviews remain the most commonly used low-cost tool to date.

Face to Face interviews: these were used for data collection and considered very accurate in collecting audience data and in capturing socio-psychological and

[23] https://en.wikipedia.org/wiki/Computer-assisted_telephone_interviewing

behavioural information (Webster *et al.* 2014). As very few people owned telephones in the past, this method was very popular for data collection. However, over time, face to face interviews became very expensive, and traditional questionnaires based on recall have a hard time following media use in a highly fragmented digital media environment.

Diaries: this is a data collection tool that provides a grid from time to time during the day, divided into smaller time segments, usually 15 minutes, asking respondents to list their consumption behaviour of different media outlets throughout a specific time frame (a week or so). The diaries form a very important, relatively inexpensive, tool in capturing lead-in or lead-out programmes (Webster *et al.* 2014). They were commonly used along with telephone interviews to reach more people than could be reached by telephones in the past. In today's world, diaries are still in use to collect television viewership data around the globe, especially in those countries where people meters (see below) are very expensive and/or not permitted. Diaries are convenient tools to collect detailed information and measure out of home media use and can be completed at respondents' convenience. However, the time it takes to collect and analyse diaries can be seen as a disadvantage; also the number of respondents' can often be limited.

People Meters: a people meter is a research tool that is used to measure the viewing habits of television and cable audiences. It is a simultaneous, permanent and instant recording of what people see on television screens. It was initially used to measure radio listening behaviour, but it progressed dramatically over the recent years and became a very powerful tool for audience research around the globe (Buzzard 2012).

People Meters are used in different shapes and forms. Generally, it is a box that is connected to a television device accompanied by remote control units for each family member in a sample household. Figure (13) below shows some samples of the people meter box.

Figure (13): Sample People Meter Boxes

The box sends its data electronically to the research company server where data are combined for further analysis. In developed regions such as the USA and Europe, the use of people meters is common and popular. However, in other developing regions, such as Africa and the Middle East for instance, where satellite and cable penetration is still lagging behind, it is very hard to apply and use people meters to measure audience behaviours. While some research companies in the MENA region, for example in the UAE and Egypt, have used people meters to monitor viewership, their use is limited to major cities such as Dubai and Cairo. Instead, telephone interviews and diaries are more popular and cost effective in those countries, giving more coverage at much lower cost.

Recently, in an effort to improve accuracy and coverage, new systems have been devised such as Portable People Meter (PPM) and Picture Matching systems that are still in testing mode, in an attempt to progress in this industry. A PPM is a portable electronic device that is attached to a belt or purse to gather data on radio audience behaviour (Napoli 2010).

Recent changes in the media environment such as the increasing number of media outlets, unconventional systems and platforms like Video on Demand (VOD), and New

Media platforms such as Smartphones and Tablets have given viewers more control over their viewing habits. Hence, these changes have complicated the data gathering process and introduced new challenges to the media environment.

The previously listed tools and techniques are currently being used in different formats and combinations. Countries around the globe use tools that are accessible and economically viable for their current and future needs of viewership data. More importantly, it appears that no single tool is recommended over another. In this research, for instance, a combination of different data sources such as a CATI interviewing system along with Face to Face interviews and focus groups are used to understand and react to viewership behaviours.

4.2 Challenges to the New Media Environment:

The New Media environment has pushed the audience research business to adapt and to change the tools and methodologies of measurement. The ever-changing and an increasing number of media outlets posed a major challenge that has fragmented audiences into smaller groups that make it extremely hard to measure their media consumption habits. Another major challenge to audience research was the audience themselves getting more control over their media outlets and consumption habits such as Video on Demand (VOD), Internet and Smart Devices.

It makes perfect sense to measure each viewer consumption behaviour on different media platforms. However, unfortunately, most companies working in this area are specialised in one or more types of audience research. For example, one type of company audience research can be perfect for the television industry but not for New Media. Another can be good for radio but not for print. Hence, to get a comprehensive understanding of viewers′ moves between different media outlets and platforms requires enormous amounts of data from different research companies and a major effort in the extrapolation of data to plan properly for media offerings.

Two main strategies are used to measure audience behaviour. **User-centric** measurement strategy is where information is collected from users who agree to answer questions, fill out diaries or accept meters. Then the data is used to make inferences about the larger population. This is a very good approach as people are contributing willingly to provide information about themselves. However, a disadvantage of this approach is the sampling itself, as it becomes challenging to select a sample that represents all the population that is required to be measured. Another challenge is the huge cost associated with a large sample size needed in order to avoid or minimise errors.

Another measurement strategy, in common use recently, is called the **Server-centric** strategy. This strategy avoids the sample size problems and simply measures all the population automatically and instantly. This is the case for digital media platforms as servers record every download, every streaming and every advertisement that is served. A major drawback of this strategy is that not all media consumers have access to digital media outlets. The use of this strategy becomes hard for measurements in developing countries. Another drawback of this strategy is not being able to know viewers' characteristics, which are very important in programme or content building decisions.

Researchers have developed ways to minimise the weaknesses of different data collection strategies and have developed different methodologies to combine the data to make it useful for the media industry.

In this thesis, a novel way to integrate and combine viewership rating data is presented to make it ready to be used in the programme scheduling model. This potentially will help media practitioners in the distribution of programme hours in an optimum way across weeks, days and hours.

Audience ratings are commonly dominated by a few firms in the market such as Nilsen and Ipsos. The reason behind this is the high cost of investment required to have a sustainable audience research operation that covers most of the market. It takes huge initial investment for the machinery, meters and software required to run such an operation. To regulate research methodologies and outcomes, joint industry committees are established for this purpose. In the United Kingdom, for instance, the BBC and other companies have created a non-profit entity called Broadcasters Audience Research Board (BARB[24]) for this purpose.

4.3 Understanding Ratings and Audience Behaviour:

Audience research provides a wealth of data in different formats that are all used in trying to understand audience behaviour. Simply, data is a record taken from recording people's media choices. The data provides important information about viewers' demographics such as Gender, Age, Education, Income levels, etc. It also provides information about viewership habits and trends, but it does not provide information such as the reasons of certain media exposure (Webster *et al.* 2014). This is where social media now is taking place in bridging this gap. In this research, interviews and focus group discussions, along with sample television grid and viewership ratings, were used to understand audience behaviour patterns regarding what is viewed and why it is viewed.

Mathematically, a Rating (Napoli 2011) is the number of households tuned to a channel calculated as a percentage of total television households. Other important measures usually used are the "HUTs" (Households Using Television) and "Share". The HUT ratio is calculated by dividing the number of households using television over the total television households (Webster *et al.* 2014). Share is calculated then by dividing the number of households tuned to the channel by the number of households using television.

---

[24] http://www.barb.co.uk/

An illustration of how these different measures are used in the industry is shown in the next few pages. Table (6) below shows a sample of the viewership data for Channel 1 compared to Total TV in the peak time between 6:00 pm and 10:00 pm. It also shows at the bottom the daily reach, highest ratings and total ratings.

Time of Watching	Channel 1	Total TV
18:00-18:14	1.17%	36.02%
18:15-18:29	0.91%	34.89%
18:30-18:44	1.11%	34.70%
18:45-18:59	0.92%	35.71%
19:00-19:14	1.02%	38.86%
19:15-19:29	1.12%	38.99%
19:30-19:44	1.07%	39.01%
19:45-19:59	1.21%	38.21%
20:00-20:14	1.47%	48.84%
20:15-20:29	1.29%	48.69%
20:30-20:44	1.47%	49.01%
20:45-20:59	1.35%	48.65%
21:00-21:14	2.23%	57.93%
21:15-21:29	2.06%	56.79%
21:30-21:44	2.08%	63.73%
21:45-21:59	2.06%	65.25%
Daily Reach	13.66%	95.50%
Highest Ratings	2.67%	65.25%
Total Ratings	83.83	2540.22

Table (6): TV Viewership Table - Survey: KSA TLM JAN 2012[25]

Figure (14) below shows Channel 1 ratings throughout one full day (96 time slots) in the Kingdom of Saudi Arabia (KSA) in June 2012[26]. The data chart is very important in understanding the viewer behaviour for Channel 1 (blue line) and the times of

[25] Ipsos TLM KSA data Jan-2012
[26] Ipsos TLM KSA data Jan-2012

watching. When compared to other channels ratings, for instance, media planners can make informed decisions about programmes and advertisement placements. They can also understand the market trends and plan for content production that meets viewership expectations. The red line in Figure (14) reflects total television viewership, i.e. the total number of viewers that can be attracted by several channels. It thus reflects the maximum available viewers on that specific day. Total viewership can also be extended further by tapping into the total number of media consumers that might be on different media outlets such as new media.

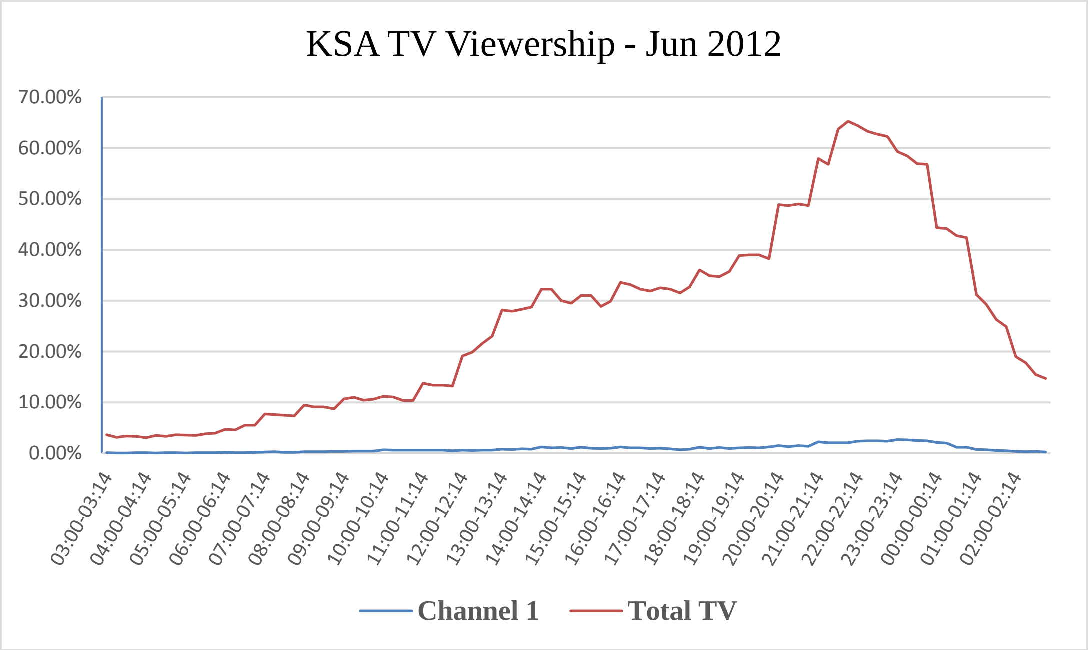


Figure (14): KSA Television Viewership (Jun 2012)

Table (7) below shows the demographics data for television channels 1, 2 and 3 in Egypt in December 2008. The data provide very useful information on viewers' profiles such as Sex, Age Group, Geographical Distribution, Family Size, Income Levels, Education Levels, etc. This type of data provides very important information about media consumers and gives media planners and television schedulers a better understanding of their audience viewership habits. This will make content building and scheduling decisions much easier.

		TV Channel 1	TV Channel 2	TV Channel 3
Total Sample		**100**	**100**	**100**
Sex	M	66	65	55
	F	34	35	45
Age Groups	15-19	11	23	15
	20-24	11	10	21
	25-34	15	7	10
	35-44	20	29	37
	45 Yrs	43	31	17
Male	15-19	11	19	24
	25-34	9	5	2
	35-44	14	20	20
	45 Yrs	33	21	9
Female	15-19	11	14	12
	25-34	6	2	8
	35-44	6	9	17
	45 Yrs	10	10	8
Location	Cairo	36	38	42
	Coastal	17	17	18
	Delta	24	25	21
	Lower Egypt	17	16	14
	Upper Egypt	6	3	5
Marital Status	Single	30	39	35
	Married	70	61	65
Children at Home	Less than 2 Years	9	8	10
	2-6 Years	20	15	23
	7-14 Years	42	43	39
Family Size	Up to 2	19	6	22
	3 - 4	43	55	46
	5 and Over	38	40	31
Monthly House Hold Income	Up to 300	5	4	0
	301-500	15	4	22
	501-800	23	34	19

	Over 800	51	48	53
Occupation	Unspecified	7	10	6
	Management	16	9	15
	Employee	33	43	21
	House Wife	18	12	25
	Do not work	34	35	39
Education	Below Primary	20	25	8
	Below Secondary	28	36	32
	Below University	28	23	29
	University and Above	25	16	32

Table (7): Television Channel Profile in Egypt (Continuous TV Rating Survey - Dec 2008)[27]

Data interpretation and viewership projections are very useful in providing an estimate of the real population from the sample data. To calculate the projected audience for a specific time slot, the ratio is simply multiplied by the total population size. We give an example using the data in Table 1 to calculate the projected audience for Channel 1 in KSA in the time slot shown below.

Time Slot	Channel 1	Total TV
18:00-18:14	1.17%	36.02%

Channel 1 Projected Audience = 1.17% * KSA Population (22,000,000) = 257,400

Total TV Projected Audience = 36.02% * KSA Population (22,000,000) = 7,924,400

About 8 million viewers in KSA were watching television, of whom 257,400 were watching Channel 1 from 18:00 to 18:15. This implies that whatever was being shown on Channel 1 at that time had attracted that number of viewers. Hence, there is a potential to increase that number by conducting an analysis of the viewership and

[27] Ipsos TV Ratings Survey – Dec 2008

content on other competitive channels, to see if better and/or different content can be profitably offered at that time.

The estimated number of viewers is also very important in commercial terms where television officials can offer advertising spots before, within and/or after that time slot. This will secure the advertiser an estimated 257,400 viewers at that time in the example shown above. Further analysis of that number is required to understand who was watching, in what location of KSA, how old is he/she, what is his/her education, income levels, etc. This analysis gives a wealth of information to broadcast media and advertising industry that can be used effectively to plan, produce/procure and schedule programmes appropriately so as to get the optimum number of viewers and place the commercial advertisements where and when they will potentially have a high impact on viewers' minds.

In Audience Research, it is important to understand viewers' interests and choices to understand and possibly predict their viewing behaviour. Media planners and television schedulers usually link people's choices to their programme types likes and dislikes. They usually build their content mix by assuming viewership behaviour and anticipating people's preferences based on their content consumption behaviour in the past. In earlier Chapters of this thesis, the impact of lead-in and the tent-pull scheduling strategies and the importance of the time and content type in scheduling television programmes were discussed and explained in detail. As the literature review reported, some scholars believe that audiences are fragmented around their attitudes and beliefs. Hence, they watch and do not watch according to their pre-selected criteria (Webster *et al.* 2014). This means that people tend to see what they wanted to see and avoid what they do not want to see. Therefore, it is very important for programme planners to understand not only numbers and ratings but also the reasoning behind what constructed these numbers.

Furthermore, in light of the data presented in Table 2, the model can be extended and used to maximise particular groups/segments of the population. As discussed in Chapter 3, the data used in the model represents all viewer demographics in order to schedule programmes according to their viewership habits. However, it is possible as well to produce viewership ratings per programme type and population segment/gender/occupation for example and re-run the model to maximise one segment or more of the targeted audience.

4.4 Data Prediction:

As discussed in the previous pages, Ratings and Shares are the most commonly used ratios to project audience and viewership at the time of measurement. However, it is obvious that future ratings and shares might be slightly or dramatically different due to a huge number of ever-changing factors, for example, the number of Television Channels, Content Offerings, Sessional Trends, etc. Therefore, future ratios prediction is relatively mathematically easy. However, it requires much historical data, experts in the field who understand viewers' behaviour and the potential trends in viewing habits.

From the author's experience in the field, forecasts are generated not only by a mathematical model; there is a lot more to it than that. Currently, some prediction software and formulas are available in the market to forecast future ratings. These are usually referred to as "pre-buy" analysis tools. Data prediction is crucial to this industry as billions of advertising dollars are spent guided by this prediction, hoping to attract the forecast number of viewers.

Different attempts in modelling and predicting ratings have been mentioned in the literature review of this thesis. For simplification reasons and due to the reason that this research focus is on using data appropriately rather than building prediction models, the research assumes the availability of reliable future forecast data that can be utilised for the purpose of building and solving the proposed computer models.

4.5 Broadcast Media and the need for Audience Ratings:

Broadcast Media Organisations transmit their content offerings via different platforms such as Television Channels, Satellite and Cable Companies, IPTV, Radio Stations, Websites, Social Media, etc. To do so, thousands of people work together in harmony to support these organisations to deliver their content for people to view, read or listen to. In this part of this thesis, a brief understanding of media organisations' organisational structure is presented and discussed, so that the way they produce and broadcast media content can be well understood. This will also help to convey a better understanding of Audience data and its use in those different functions and operations.

Generally speaking, Media Organisations are structured differently from one another. However, they usually comprise two main arms: **Core Business** and **Support Services**. Core Business is usually the factory and the brain behind getting the picture on the screen while the Support Functions provide legal, operational and administrative support to make that possible. Content on screen, such as television programmes, for instance, is a piece of text (script) written on paper that travels throughout a large process of production until it finds its way to the screen. Every Core or Support function within the organisation participates and adds value in some part or parts of this journey.

Figure (15) shown below illustrates one sample of a business model and different functions and operations of the broadcast media organisation.

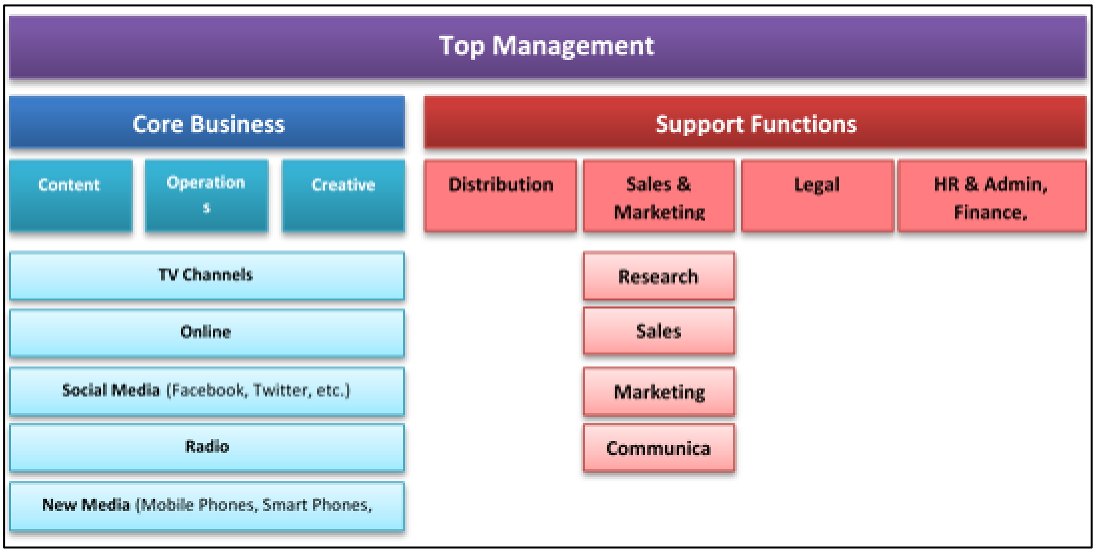


Figure (15): Broadcasting Media Functional Organisation Structure

Core Business: this function usually contains several sub-functions such as Content / Editorial (Programs) Division, Studio Operations Division and Creative Division. Each one of these divisions works separately but very collaboratively because the end product has all of these components embedded together.

For example, a television programme starts with a script that is drafted very carefully to be produced by producers and directors to tell a story or to deliver value for viewers. To do so, a lot of equipment is required such as cameras, lighting, editing suites, etc. Not only is equipment required, but also studios are needed where the shooting and recording usually take place. Presenters and/or actors are needed as well. All of the elements mentioned above should be put together on the screen with proper creative graphics to make a final product that is ready to be broadcast and consumed. That is, of course, an oversimplification of the production and programmes value chain journey, but it shows the importance and the interdependencies that exist between different functions within the Core Business units.

The ***Programming*** role was described in detail earlier in this thesis. However, the programmes division is the heart of every media organisation where the business and value are generated. The role of ***Broadcast Operations*** is to allow the editorial teams to operate properly and to provide them with the technical requirements for the production such as directing, cameras and lighting, studio operations, studio graphics, studio sound, audio mixing, makeup and satellite/facilities planning and coordination. The ***Creative Function*** is responsible for creating screen art production, broadcast graphics, visuals for the screen, interactive, on-air graphics and promotions. This is a very important function where the final look and feel of the television screen takes place and makes the programme content more appealing to viewers.

In summary, editorial ideas require appropriate tools, techniques and equipment to make the final product. A Core Business function with the support of all other Support Functions will make a final package that is consumable and ready to be distributed over different platforms.

Support Services: As the name suggests, Support Services such as Finance, Procurement, Human Resources, Distribution, Technology, Sales and Marketing, Legal, etc. are formed to support Core Business to operate smoothly and to provide them, for instance, with proper legal and organisational structures, IT support and broadcast technology, human resources services, administrative support, etc.

For example, a budget is required to produce/procure a programme. The budget allocation is based on rational and complicated decisions after studying cost/benefit scenarios for a certain programme. To do so, a detailed market analysis is required to understand the need for such a programme and what other players in the Media Industry are offering.

When budget decisions are made, finance people should come with the financial resources at the right time. All Support Functions, each working separately but collaboratively, are required to come up with the best process of hiring and moving people, resources, and technology to support the Core Business in producing/procuring (commissioning) this particular programme. Afterwards, when the production is completed, the programme is now ready to be aired. Now the questions come: What is the right date and time to first run/repeat this program? What are the different variables to be considered when making that decision? What is the potential return on investment?

As briefly discussed above, it is very important to understand the value chain of the Media and Broadcasting business and to analyse the impact of each function over the other in order to understand the harmony of each and to produce and/or to procure the proper content of a high quality to be transmitted via multiple platforms.

The ***Signal Distribution*** function is a Support Service operation that is responsible for designing and implementing the distribution strategy via multiple platforms. The goal is to maximise the exposure of the Media Organisation's offerings through conventional and unconventional mediums. That allows also generating licensing and subscriber-related revenue to the Media Organisation. This function is very important since it establishes the media agreements where the content can be consumed. Hence, content can be the same, but it needs to be customised to fit the platform of delivery. The following are the most popular platforms for media content:

- Satellite, Cable, Terrestrial, IPTV

- Online, Broadband, DTT, OTT
- Radio and Newspapers
- Mobile phones and Smart devices such as IPad, iPhone, and Android operated devices.

Coordination and collaboration is a must between several Support Functions, especially the distribution and marketing functions. For example, what happens if the organisation produces/procures the best programme ever but the television channel was distributed poorly in the region? That will limit the success of the programme and, hence, will result in limited viewership. Another scenario to consider is where the television channel is distributed properly within a specific region and on several platforms but, because of a lack of good marketing strategy, the situation can also end with lower viewership.

Signal Distribution is a core function within the Support Services functions because it creates the opportunity to reach out and establish the distribution channels and platforms, after which it is the responsibility of both marketing and content builders to offer and promote content for viewership consumption. A proper utilisation of this function will help in better utilisation of all promotional opportunities as well. ***Commercial Distribution*** opportunities are very important as well to gain maximum revenue and exposure for the Media Organisation in places such as Hotels and Resorts, Public Spaces, etc.

An important other Support Function is the ***legal*** function. For instance, content producers usually sell the broadcasting rights to broadcasters on specific platforms, with specific time limits and in specific regions and territories. That means that every programme procured and/or produced has its legal terms that allow the broadcaster to air it and repeat it for some times only in a specific region or territory, e.g. World Cup or European League rights in a specific continent.

Hence, it is very important that every Media Organisation keeps all its programme rights aligned with its distribution strategy and keeps a track record of those rights, in order that everything is managed properly. Otherwise, it might cause the Media Organisation to go through legal complications and liabilities. This is a genuine risk that requires intelligent tracking systems and powerful management tools that help programme directors and planners to control and manage their portfolio of programmes effectively and to avoid penalties and legal snags. There are software packages to manage programme copyrights that are commonly used in this industry.

Marketing[28], by definition, is the process of communicating the value of a product or service to customers. Marketing is the link between the viewer's needs and Media Organisations. Marketing satisfies these needs and wants through building long term relationships with viewers. It is clear from the definition that the "Marketing" role is very crucial to the success of any Media Organisation. Marketing management is a science of capturing market insights, reaching to customers, creating awareness, building strong brands, delivering values and developing marketing strategies. It is very important to choose the right markets via proper market research, analysis and market segmentation. Understanding competition, consumption habits and viewership behaviour gives the organisation competitive advantages to build editorial content and programmes portfolio and to air it when people are ready to consume it. As a critical function of marketing, ***Audience Research*** is responsible for capturing audience behaviour and analysing trends in the Media Industry. The research recommends

[28] http://en.wikipedia.org/wiki/Marketing

different market opportunities that complement the organisation's offerings regarding the development of new segments or expanding within the same segment. Research helps in determining relevant opportunities to raise audience awareness and to build brand loyalty within key markets and target audiences.

Audience Research helps in:

- Understanding the consumption habits, usage and attitudes (interest in different types of editorial content, time spent viewing, tone, preferred programmes layouts, etc.) for each platform.
- Assessing viewers/users, media needs and identifying gaps, identifying topics of interest, preferred genres, formats of content delivered, etc.
- Profiling of viewers/users and identifying priority segmentation of potential viewers/users across each platform,
- Understanding of the status, size and strength of carriers (for each platform).
- Understanding of the competitive landscape and identifying potential competitors.

All of the above will allow marketing experts to project market trends and opportunities and to identify risks and gives the editorial people the right media and market data and analysis they need to build their current and future programming plans.

Sales are when the product is turned into monetary value. In media organisations, sales can take many forms such as advertisements sales and subscriptions, or it can be selling the content itself through licensing, DVD sales, CD sales, etc.

The ultimate goal of the presence of Media Organisations is to make profits. With that in mind, all a company's resources, plans and strategies should be aligned towards common goals. In a Media Organisation, the goal is usually to maximise viewership and market share. That will lead to more business, revenues and profits respectively.

Now it is important to ask these questions: How do all of the above discussions relate to building the optimal programmes portfolio? How should all functions come together to build the perfect programme schedule (Grid)? In concept, the answer to this question is very simple. To build the perfect programmes and content offerings, organisations need to understand both competition and consumers at the same time. To build an optimum grid, organisations need to schedule their programmes taking into consideration consumers and competition. However, what is the perfect mix? Many Organisations are working to answer this question. Many Organisations are struggling to find the best programme mix that maximises viewership, minimises costs and generates more profits.

In summary, Media Organisations can have different operational models and organisational structures, but they share many similarities in the way they conduct their day to day operations. As discussed earlier, Audience Research is very important for the Media Industry as it helps in making short and long-term investment decisions, content producing/procuring decisions, scheduling decisions, sales and distribution decisions, etc. A bad choice of a programme from an investment perspective or scheduling perspective can cost millions of dollars. The huge number of hours available for broadcasting puts a very strong pressure on all Media Organisations to perform better.

4.6 Audience Ratings and Grid Building:

In the Model Discussion Chapter earlier in the thesis, the basic optimisation model to schedule programmes optimally for television is presented and discussed. A sample set of ratings from industry is used to feed the model that is built for this purpose. One major challenge was getting the data in the format required for the optimisation model to run. In the second phase of this work, an attempt to improve data extrapolation is presented and discussed to produce more accurate and reliable data for the model to produce better quality outputs. In Figure (6) on page 84, a sample of the viewership ratings, per programme type, is shown. This data was used to build an improved schedule of programmes that maximises potential viewership for a Television Channel in the Middle East.

As shown in Figure (6), five main programme categories are used: Entertainment, Economy, Science, Sports and Politics. The total viewership ratings represent the total percentage of people in that country who were watching television in that specific time slot. The ratings were extrapolated using a very lengthy and manual process as we will see below.

Table (8) below shows part of Channel 1 grid that was aired in March 2013[29]. The grid from Saturday to Wednesday reflects a schedule of programmes of different types such as Entertainment, Politics, etc. that consumes four consecutive time slots. For Thursday and Friday (the weekend in the Middle East) programmes vary in length and can take more than four time slots. From the author's experience, those programme types are usually different from the ones aired in regular weekdays. As discussed in Chapter 2, the interview responses reflected that building the grid is still a manual process building

[29] Ipsos 2013

on experience, viewership ratings and a comparison with the main competition's offerings.

The option of changing programme schedule and airing time and the potential impact on its rating in SMEs' opinions was discussed earlier. The results reflected the uncertainty of knowing the impact on ratings!

	SAT	SUN	MON	TUE	WED	THU	FRI
15:00	**HIBR AL OYOUN**	**HIBR AL OYOUN**	**HIBR AL OYOUN**	**HIBR AL OYOUN**	**HIBR AL OYOUN**	**KHAWATER (8)**	**SHAYE FI SADRY**
15:15							
15:30						AL MASAGEEL (2)	**CLASSIC ARABIC MOVIE**
15:45	**Gulf/ حبر العيون**	**Gulf/ حبر العيون**	**Gulf/ حبر العيون**	**Gulf/ حبر العيون**	**Gulf/ حبر العيون**	KALAM NAWAEM	
16:00	**ANTA QALBI**	**ANTA QALBI**	**ANTA QALBI**	**ANTA QALBI**	**ANTA QALBI**		
16:15							
16:30							
16:45	**Turkish/ أنت قلبي**	**Turkish/ أنت قلبي**	**Turkish/ أنت قلبي**	**Turkish/ أنت قلبي**	**Turkish/ أنت قلبي**		
17:00	**AL MONTAQEM EP 86**	**AL MONTAQEM EP 87**	**AL MONTAQEM EP 88**	**AL MONTAQEM EP 89**	**AL MONTAQEM EP 90**		AL FALTA (2) ® Ep 27
17:15						ARAB IDOL (2)	
17:30							Mothakarat 3a'eliya Jedan ® Ep 11
17:45	**Egyptian/ المنتقم**	**Egyptian/ المنتقم**	**Egyptian/ المنتقم**	**Egyptian/ المنتقم**	**Egyptian/ المنتقم**		
18:00	**FERKAT NAJY ATALLAH**	**FERKAT NAJY ATALLAH**	**FERKAT NAJY ATALLAH**	**FERKAT NAJY ATALLAH**	**FERKAT NAJY ATALLAH**		Jaltham w Metha
18:15							
18:30							
18:45	**Egyptian/ فرقة ناجي عطالله**	**Egyptian/ فرقة ناجي عطالله**	**Egyptian/ فرقة ناجي عطالله**	**Egyptian/ فرقة ناجي عطالله**	**Egyptian/ فرقة ناجي عطالله**		Stars on Vacation (2)
19:00	**FATIMA (2)**	**FATIMA (2)**	**FATIMA (2)**	**FATIMA (2)**	**FATIMA (2)**	**Style**	
19:15							
19:30							
19:45	**Turkish/ (2) فاطمة**	**Turkish/ (2) فاطمة**	**Turkish/ (2) فاطمة**	**Turkish/ (2) فاطمة**	**Turkish/ (2) فاطمة**	ستايل	
20:00	**AL THAMINAH - LIVE -**					**Joelle Ep 84**	**Green Apple**
20:15							
20:30							
20:45							

Table (8) March 2013 Grid of Channel 1

The ratings for that specific sample Channel 1 are presented in Table (9) below. The ratings represent the share of Channel 1 from total television viewership. They are different for each time segment as shown in the table. By analysing viewer ratings in every time slot and comparing them with the grid shown in Table (8), we can come up with the number of people that are watching a specific programme as well as the time of watching on Channel 1.

Moreover, to analyse other channels' programme offerings and compare the different types of the programmes aired on those channels, we need to collect and compare all their programme schedules and perform the same analysis for every channel.

	Total TV	Channel 1
15:00-15:14	35.9	8.83
15:15-15:29	34.3	8.93
15:30-15:44	34.0	9.61
15:45-15:59	34.4	9.79
16:00-16:14	36.8	9.81
16:15-16:29	35.1	10.16
16:30-16:44	34.8	10.15
16:45-16:59	35.0	11.12
17:00-17:14	35.9	8.66
17:15-17:29	36.0	9.41
17:30-17:44	36.5	8.65
17:45-17:59	37.9	9.29
18:00-18:14	38.2	8.78
18:15-18:29	38.2	9.63
18:30-18:44	38.1	8.62
18:45-18:59	37.0	8.60
19:00-19:14	48.4	16.94
19:15-19:29	48.2	16.69
19:30-19:44	46.3	16.81
19:45-19:59	45.9	16.94
20:00-20:14	66.2	14.74
20:15-20:29	66.1	14.62
20:30-20:44	66.9	14.55
20:45-20:59	66.6	14.45

Table (9): TV Viewership Table - Survey: KSA TLM Mar 2013[30]

[30] Ipsos TLM KSA data Mar-2013

As discussed earlier in Chapter 2 of the thesis, a data set was provided by Ipsos Research Company representing a full week of viewership ratings per channel in a sample country in the Middle East Region for March 2013. A long and manual process was required to come up with the required figures. The full data set used for the model uses ratings over seven days, for all programme types and time slots.

To produce this data, a copy of the top ten television channels grids was collected for the week for which the viewership ratings had been reported by Ipsos. A detailed and comprehensive review of the top ten channels' offerings of different programme types throughout the week was completed to report the data by programme type rather than by television channel. A similar exercise was completed for all top ten channels to come up with the data set used for the model. The optimisation model will require the complete set of data that reports viewership ratings of the full weekday parts (that is 5 programme types × 7 days × 96 time slots = 3360 data points).

For the purpose of this research, it has been assumed that a data forecasting model is available and used to predict and forecast the future ratings, based on data resulting from the previous step described above. The output from this forecasting model will then be used in the optimisation model.

4.7 Limitations:

Audience Research is a very complicated process and can be very costly if we wish to increase data reliability and accuracy. As it is an expensive industry, only a few players dominate the audience research market. Every region around the globe has its uniqueness and maturity levels when it comes to Media and Market Research industries. In some developed countries such as USA, Canada and EU Countries, the maturity levels of those industries are considerably higher than in some other developing countries such as countries in the Middle East and Africa for instance.

The advanced media environment and the huge number of media outlets on different broadcasting platforms encourage research companies to invest more and to provide higher quality data at lower cost. People Meter measurement becomes very affordable in those developed countries as the buying power is much higher than other less technologically advanced developing countries, where the Audience Research Industry is still in the infancy phase and requires huge capital investment to compete and provide more accurate and reliable data.

In the Middle East and GCC regions, where this research was conducted, the Media Industry is slightly more mature than in other countries in the region. A considerable number of Media Organisations are producing and airing editorial content that is competitive locally and even globally especially in the recent political situation and the Arab Spring in the Middle East. The limitation of data availability and accuracy varies from country to country and it is becoming more difficult to keep up with the recent advancement in the Media Industry.

The discussions in the previous chapters have concentrated on the importance of the programme scheduling problem and the viewership data usage in building an optimum programme schedule that can attract a maximum number of viewers under given constraints. The following chapters will discuss the advanced model and the research contribution to academia and real practice.

Chapter 5

In the current chapter, the advanced computer optimisation model is presented and discussed in more detail. Different scenarios and problem setups are used and tested. Hypothetical television programme schedules and simulated viewership data are used to solve these scenarios.

5.1 Television Programme Scheduling Advanced Model:

As discussed earlier in Chapter 3, the basic computer model requires some improvements to make it solve realistic scenarios and give optimised schedules that maximise viewership within certain limitations.

In the advanced computer optimisation model, most of the initial assumptions of the basic model remain the same. However, some more assumptions and constraints were introduced as well. In this chapter, the model functionality is discussed in more detail, and a comprehensive overview of the model in action is provided.

5.1.1 New Additions to the Basic Computer Optimisation Model:

The following parameters have been introduced to the basic computer model:

- Availability of Budget to produce and/or procure different new programmes,
- The number of programme hours, of each type that is allowed per day,
- The number of programme hours, of each type that is allowed per day part,
- The cost per minute of procuring and/or producing a programme type/quality,

The following constraints have been added to the model:

1. Budget availability constraint.

$$\sum_{k,x} \mathbf{S}_{k,x} \leq \boldsymbol{M}$$

Where $\mathbf{S}_{k,x} = \boldsymbol{v}_{k,x} * \sum_{i,j} \mathbf{Y}_{i,j,k,x}$

$S_{k,x}$ = The cost of programme hours that are scheduled from different types *k* of quality *x*,

$v_{k,x}$ = The cost per 15 minutes of programme type *k* of quality *x*,

M = the budget available to buy and/or produce programmes to be scheduled

2. Upper and Lower bounds on programme type *k* and quality *x* allowed to be scheduled in each day part *d*, at time of the day *t*

$$L'_{i,d,k,x} \leq \sum_{j=t_d}^{t_{d+1}-1} \mathrm{Y}_{i,j,k,x} \leq U'_{i,d,k,x} \quad \forall \quad d = 1 \text{ to } 5$$

Where

- $L_{i,k,x} = \sum_{d=1}^{5} L'_{i,d,k,x}$
- $U_{i,k,x} = \sum_{d=1}^{5} U'_{i,d,k,x}$
- $t_1 = 1$
- $t_2 = 25$
- $t_3 = 45$
- $t_4 = 53$
- $t_5 = 69$
- $t_6 = 97$

New budgetary and cost constraints have also been added to allow television officials and media practitioners to consider the availability and efficiency of their financial resources when they make scheduling and investment decisions while maximising the viewership as their main objective.

Upper and Lower bounds on day parts are proposed and activated in the advanced computer optimisation model to allow fair and balanced programme type distribution between day parts. As can be seen in constraint (2) presented above, the media planners usually wish to set a minimum and a maximum number of hours for each type of programme in every day part. Previously, in the basic computer optimisation model, the optimisation engine placed, freely, any type of programme of any quality in any day part as long as it increases the overall viewership.

As Figure (16) below suggests, every programme type will have a different cost per minute of production and/or procurement. For example, the cost to produce/procure one minute of Entertainment programme of quality "A" is shown as $950. The costs for different programmes per minute shown in Figure (16) represent the average cost in the industry for such programmes. The costs, in reality, can be slightly higher or lower per programme. However, from the author's experience in the field, Figure (16) gives an approximate representation of the real numbers needed to run the optimisation model. In running the interactive model, changes to the cost per minute will mean higher or lower supply or demand on that particular type of programme. The decision to invest in that programme will depend on the viewership impact. So if the cost went up, television officials can measure the impact of that increase on the viewership expectation and make the right investment decision as early as possible in the planning horizon.

"What if" scenarios can be very helpful to decide on the best mix of programmes portfolio that is viable financially and can achieve the maximum number of viewers at the same time. This constraint also can be used by setting a cap or an upper bound on the total budget available for investment in all different programme types/qualities. The advanced computer optimisation model runs and places programmes accordingly to maximise viewership taking into consideration all other variables and constraints.

Programmes Type/Quality		Cost per Minute ($)	(v) Cost Per 15 Minute ($)	Programme Hours Scheduled	Programme Cost ($)
Entertainment	A	950	14,250	80	1,140,000
	B	750	11,250	193	2,171,250
	C	450	6,750	20	135,000
Economy	A	650	9,750	56	546,000
	B	595	8,925	30	267,750
	C	375	5,625	18	101,250
Science	A	765	11,475	40	459,000
	B	650	9,750	14	136,500
	C	250	3,750	60	225,000
Sports	A	850	12,750	30	382,500
	B	750	11,250	16	180,000
	C	400	6,000	17	102,000
Politics	A	950	14,250	64	912,000
	B	650	9,750	14	136,500
	C	350	5,250	20	105,000
					6,999,750
Available Budget for All Programmes					7,000,000

Figure (16): Cost of Programmes Constraints for Optimising the Grid

In Figure (17) the upper and lower bound constraints for a sample day (Saturday) are shown for every day part. A programme planner can increase and/or decrease those limits and test the impact on viewership instantly by running the model several times before he/she decides on the right mix of programmes to be scheduled optimally, as described in Chapter 3 (the push system). Furthermore, it is advisable that the model is run first with relaxed upper and lower bounds for all constraints to discover the maximum potential of the programme assignment decisions before narrowing down the maximum and minimum limits so that the effects of these limits can be clearly seen.

After adding all the additional elements to the basic computer model, two steps instant logical decision-making approach is used to finalise the weekly schedule as described in the following few pages.

	Day (*i*), Saturday														
	Entertainment			Economy			Science			Sports			Politics		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Morning 6 AM-12 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	3	1	0	7	3	0	1	1	2	3	3	0	0	0
	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Afternoon 12 PM-5 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	13	1	6	0	0	0	0	0	0	0	0	0	0	0
	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Evening 5 PM-7 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	5	0	2	0	0	1	0	0	0	0	0	0	0	0
	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Prime Time 7 PM-11 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	3	0	0	0	0	3	0	0	0	0	0	4	0	0
	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Night 11 PM-6 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	6	0	0	0	0	0	1	7	0	0	0	8	2	2
	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13

Lower bound on type/quality allowed in morning day part

Type/quality selected by the model in morning day part

U bound on type/quality allowed in morning day part

Figure (17): Upper and Lower Bounds on Programme Type for each Day Part on Saturday

5.1.2 Conditional Formatting Logic Introduced to the Model:

The initial assumption of a programme taking only one-time slot was not realistic, as was concluded after discussions with media practitioners. Media industry research and the analysis of different types of programme lengths revealed that, in current practice, most programmes usually take 3-4 time slots of 15 minutes each. Other programmes such as live shows, concerts, sports, etc. might take more or fewer time slots. In the advanced, improved computer model, the scheduler may want to specify that a programme will take 3 or 4 (or perhaps more or less) consecutive time slots, and this can be changed later by the scheduler using the model interactively.

For this purpose, a conditional formatting logic was introduced to the advanced model, linking the optimization outputs in the advanced model to a new Excel sheet in the same Excel file that reads the optimal outputs and forces the condition of running the same programme type and quality for selected time slots as required by the end user.

To illustrate the logical formatting in the model, Figure (18) below shows the optimised programme placement decisions for a sample day (Saturday from 6:00 am to 9:00 am) that maximise viewership while considering all model constraints and resource availabilities. As shown in Figure (18), the model selected a variety of different programmes of different types/qualities to run on Saturday morning. The end user can proceed with this placement decision if he/she is satisfied with the model selection, but may wish to specify that programmes should last for more than one time slot.

		Day (*i*), Sat														
Time	Time Slot (*j*)	Entertainment			Economy			Science			Sports			Politics		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
06:00-06:14	1												1			
06:15-06:29	2									1						
06:30-06:44	3						1									
06:45-06:59	4															1
07:00-07:14	5												1			
07:15-07:29	6												1			
07:30-07:44	7										1					
07:45-07:59	8											1				
08:00-08:14	9											1				
08:15-08:29	10					1										
08:30-08:44	11											1				
08:45-08:59	12					1										

Figure (18): Optimised Schedule on Saturday (6:00 am to 9:00 am)

In this example, the user could specify, using simple Excel commands, that the full rows corresponding to the second, third and fourth time slots should be the same as the first row; similarly that the sixth, seventh and eighth rows should be the same as the fifth row and the tenth, eleventh and twelfth rows should be the same as the ninth row. In this specific scenario, the end user has decided that each programme should last for one hour. Of course, this could be done differently, resulting in programmes of 30 or 45 minutes, for example. This results in a new Excel sheet as shown in Figure (19).

		Day (i), Sat														
Time	Time Slot (j)	Entertainment			Economy			Science			Sports			Politics		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
06:00-06:14	1												1			
06:15-06:29	2												1			
06:30-06:44	3												1			
06:45-06:59	4												1			
07:00-07:14	5												1			
07:15-07:29	6												1			
07:30-07:44	7												1			
07:45-07:59	8												1			
08:00-08:14	9											1				
08:15-08:29	10											1				
08:30-08:44	11											1				
08:45-08:59	12											1				

Figure (19): Logical Formatted Schedule on Saturday (6:00 am to 9:00 am)

The way this selection is placed in the Excel sheet is shown below:

$Y'_{i,1,k,x} = Y_{i,1,k,x}$ The placement decision in the logical formatted Excel sheet is equal to the placement decision in the optimised Excel sheet for time slot 1.

- Logical Condition (1): $Y'_{i,2,k,x}$ = IF ($Y'_{i,1,k,x}$, 1, 0), This condition implies that if programme of type *k* of quality *x* is placed in day *i* on time slot 1, then the following time slot 2 is equal to 1, otherwise it is equal to 0.
- Similarly, the Logical Condition (2): $Y'_{i,3,k,x}$ = IF ($Y'_{i,2,k,x}$, 1, 0), if programme of type *k* and quality *x* is placed in day *i* on time slot 2, then the following time slot 3 should be equal to 1, otherwise it is equal to 0.
- Other conditions are added similarly to the above examples.

The Excel sheet 2, (an example shown in Figure (19) above), should be formulated by the end user to reflect his/her preferences of programme lengths to be scheduled in the final grid. The resulting schedule should look like the example given above in Figure

(19) where the conditional formatting logic has placed programmes according to the lengths chosen by end user. The archives and actual programmes library in the television station will help decision makers in the decision of length of programmes required for each type/quality.

In this specific example, as shown in Figure (19a) below, the optimised grid selected by Frontline Solver is shown in Column (1) and the logical formatted schedule that is driven from the Frontline Solver outputs is shown in Column (2). The schedule, in this case, is more realistic and practical; here the user has decided that programmes of an hour's duration are required for these slots, with the result that a Sports programme of quality (C) is placed in time slots 1 to 8 and a Sports programme of quality (B) in time slots 9 to 12. The potential impact on viewership numbers, and the fact that the new schedule may now break some constraints, will be discussed later in this chapter.

		Day (*i*), Sat	
Time	**Time Slot (*j*)**	**Column (1)** **Optimised Schedule (Excel Sheet 1)**	**Column (2)** **Logical Formatted Schedule (Excel Sheet 2)**
06:00-06:14	1	**Sports C**	**Sports C**
06:15-06:29	2	**Science C**	**Sports C**
06:30-06:44	3	**Economy C**	**Sports C**
06:45-06:59	4	**Politics C**	**Sports C**
07:00-07:14	5	**Sports C**	**Sports C**
07:15-07:29	6	**Sports C**	**Sports C**
07:30-07:44	7	**Science A**	**Sports C**
07:45-07:59	8	**Sports B**	**Sports C**
08:00-08:14	9	**Sports B**	**Sports B**
08:15-08:29	10	**Economy B**	**Sports B**
08:30-08:44	11	**Sports B**	**Sports B**
08:45-08:59	12	**Economy B**	**Sports B**

Figure (19a): Optimised Schedule vs Logical Formatted Schedule on Saturday (6:00 am to 9:00 am)

In summary, as described above, the advanced model logic is divided into two phases; one is to run the model to produce an optimised schedule and the other is to use the outputs of the first phase in the same software to produce a realistic schedule that is interactive and responds to end user preferences. The model functionality will be discussed in more details in the following sections of this Chapter.

5.2 Running the Advanced Computer Optimisation Model:

In this part of the thesis, the advanced model is formulated and solved considering the added complexities to make it more realistic. All parameters of the optimisation model are set to the original state where the sample channel schedule is inputted into the decision variables cells in Excel in the front-face part of Frontline Solver. Also, all constraints, as well as the objective function, are formulated/programmed in the solver options part of the software (Please refer to Appendix 4 for the model formatting/formulas in Frontline Solver). All previously prepared viewership ratings, per programme type, as well as other formulas and ratio assumptions, are entered into the Excel sheet.

To overcome the main challenges that were preventing the basic model from giving a realistic schedule, a logical formatting Excel sheet was added to the Excel book (Excel Sheet 2). As discussed earlier, the new Excel sheet will read the optimal outputs from the original optimised schedule Excel Sheet (1) and, by means of logic and conditional formatting, will generate a realistic schedule, avoiding the problem of programmes lasting only 15 minutes.

The optimal schedule generated from running the advanced model in Excel Sheet (1) is used as the initial schedule. Then, in the Excel Sheet (2) with the added conditional formatting formulas, the final grid starts taking its final shape, and the resulting schedule is much more realistic and almost ready for the final actual programmes placement decisions to be made by end users.

The new Excel Sheet (2) can help end users in making programme assignment decisions such as:

- Booking more than one-time slot for a programme that was selected by the optimum schedule in Excel Sheet (1).
- Repeating and/or rerunning the same programme type/quality *in the same day* but in a different time,
- Repeating and/or rerunning the same programme type/quality *in another day* but at the same time of the day or a different time,

In many cases, the number of consecutive time slots for programmes will be three or four (thus 45 or 60 minutes), but this may vary by type of programme, time of day, day of the week, etc. These decisions are up to the scheduler who is using the model, who may want to try out several different scenarios.

Decisions may also be made, for example, to repeat the same type/quality of the programme in different parts of the same day, or for the same time on succeeding days of the week.

For example, as shown in Figure (19a) above, the rational placement decision in time slots 1 to 8 was to schedule a Sports (C) programme. If this particular programme is a one-run time programme and cannot be repeated on the same day, then no action is required. However, if the programme can run more than one time per day, then the end user can choose to repeat the same programme one or more times at the same day. This can be easily formatted in Excel Sheet (2) as discussed in the previous section. This is often the general practice of scheduling programmes in media in order to fill all day time slots with repeats and reruns.

Thus, decisions have been passed to the programme planner in order to give him/her the flexibility to select the number of time slots that should be booked for every programme type and quality. In current practice, as mentioned earlier, most (but not all) of the programmes during regular week days take three or four consecutive time slots. At weekends, there may be more programmes which take more or fewer time slots. This Excel Sheet (2) will allow the schedule planner to try different combinations and measure the impact of each option on the total cost of programmes and viewership.

In Figure (20) below, a sample of the model is illustrated to demonstrate the scheduling optimiser capabilities before and after running the model. As can be seen from the figure, the sample channel that was selected to pilot the model was broadcasting mainly Entertainment programmes of different qualities throughout this day part. Due to the huge size of the full week/all day parts model, only one day part (Saturday night from 11:00 pm to 6:00 am) is shown in Figure (20). The number (1) in a blue cell represents that a programme was running in that specific time slot. Blank cells mean that no programme was scheduled in that time slot.

			Day (*i*), Sat														
	Time	Time Slot (*j*)	Entertainment			Economy			Science			Sports			Politics		
			A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Night 11PM-6AM	23:00-23:14	69		1													
	23:15-23:29	70		1													
	23:30-23:44	71			1												
	23:45-23:59	72			1												
	00:00-00:14	73			1												
	00:15-00:29	74		1													
	00:30-00:44	75		1													
	00:45-00:59	76		1													
	01:00-01:14	77		1													
	01:15-01:29	78										1					
	01:30-01:44	79										1					
	01:45-01:59	80										1					
	02:00-02:14	81		1													
	02:15-02:29	82		1													
	02:30-02:44	83		1													
	02:45-02:59	84		1													
	03:00-03:14	85			1												
	03:15-03:29	86			1												
	03:30-03:44	87			1												
	03:45-03:59	88			1												
	04:00-04:14	89		1													
	04:15-04:29	90		1													
	04:30-04:44	91		1													
	04:45-04:59	92		1													
	05:00-05:14	93		1													
	05:15-05:29	94		1													
	05:30-05:44	95		1													
	05:45-05:59	96		1													

Figure (20): Problem Setup in the Software (Sample Grid before Running the Model)

According to the full "AS IS" grid, as shown in Figure (21) below, the total cumulative duplicated viewership is about 51 million viewers. The current cost of the programmes needed to air this grid is QAR 6,943,500. (See Figure (22) below).

Entertainment			Economy			Science			Sports			Politics		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
150	300	250	60	30	50	40	50	60	30	40	40	100	70	50
≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
77	312	198	0	0	0	0	0	0	21	0	0	24	40	0
587			0			0			21			64		
Total Cumulative Duplicated Viewership (per week)														
Objective Function: Maximize Viewership										50,971,365				

Available programme type/quality ready to be scheduled

Current "AS IS" Programmes Schedule

"AS IS" viewership for current Schedule

Figure (21): Advanced Model (Sample Grid before Running the Model)

Programmes Type/Quality		Cost per Minute ($)	(v) Cost Per 15 Minute ($)	Programme Hours Scheduled	Programme Cost ($)
Entertainment	A	950	14,250	77	1,097,250
	B	750	11,250	312	3,510,000
	C	450	6,750	198	1,336,500
Economy	A	650	9,750	-	-
	B	595	8,925	-	-
	C	375	5,625	-	-
Science	A	765	11,475	-	-
	B	650	9,750	-	-
	C	250	3,750	-	-
Sports	A	850	12,750	21	267,750
	B	750	11,250	-	-
	C	400	6,000	-	-
Politics	A	950	14,250	24	342,000
	B	650	9,750	40	390,000
	C	350	5,250	-	-
					6,943,500

Figure (22): Programmes Cost (Sample Grid before Running the Model)

The advanced model was formulated and solved using Frontline Solver (add-in) software as a linear integer assignment-type 0-1 optimisation problem, where the variable $Y_{i,j,k,x}$ = 1 if a programme of that type and quality is selected in that particular time slot on that particular day or 0 otherwise. Here i (i = 1..7) is the day of the week, j (j = 1..96) is the time-slot, k (k = 1..5) is the programme type (Entertainment, Economy, Science, Sports, Politics), and x (x = 1..3) is the programme quality (A, B or C). Thus there are 10,080 0-1 decision variables. There are 20,160 upper or lower bounds on hours availability/allowance per programme type and 1948 other constraints. The value of the objective function is obtained by simply adding up applicable ratings for every time slot and every day.

The model was run using Windows 8.1 software installed on a laptop computer with Intel Core i7 (2.6 GHz) and 8 GB RAM. By running and solving the advanced model, the resulting schedule potentially increased the viewership by approximately 58%. The model has rescheduled the current programme portfolio of the sample channel differently resulting in a potential increase in viewership from 51 million reaching up to 80 million viewers. Table (10) below shows solver running times.

Problem setup time	1.61 seconds
Engine solve time	0.36 seconds
Solve time	5.73 seconds

Table (10): Advanced Model Solver Running Times (5 Types/3 Qualities)

In Figure (23) below, a demonstration of the same sample of the model as in Figure (20) is shown after running the optimisation model. As we can see in the figure, the sample channel should be airing different types/qualities of programmes such as Entertainment, Science, Politics, etc. throughout the Saturday night day part.

				Day (*i*), Sat														
		Time	Time Slot (*j*)	Entertainment			Economy			Science			Sports			Politics		
				A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Time Slot (*j*)	Night 11PM-6AM	23:00-23:14	69		1													
		23:15-23:29	70		1													
		23:30-23:44	71	1														
		23:45-23:59	72	1														
		00:00-00:14	73		1													
		00:15-00:29	74		1													
		00:30-00:44	75		1													
		00:45-00:59	76		1													
		01:00-01:14	77													1		
		01:15-01:29	78													1		
		01:30-01:44	79													1		
		01:45-01:59	80													1		
		02:00-02:14	81													1		
		02:15-02:29	82													1		
		02:30-02:44	83													1		
		02:45-02:59	84													1		
		03:00-03:14	85														1	
		03:15-03:29	86															1
		03:30-03:44	87															1
		03:45-03:59	88														1	
		04:00-04:14	89									1						
		04:15-04:29	90									1						
		04:30-04:44	91									1						
		04:45-04:59	92								1							
		05:00-05:14	93									1						
		05:15-05:29	94									1						
		05:30-05:44	95									1						
		05:45-05:59	96									1						

Figure (23): Model Outputs (after running)

According to the resulting optimised grid, as shown in Figure (24) below, the total "TO BE" cumulative duplicated viewership will have the potential to reach about 80 Million viewers with about the same cost to procure and/or produce these programmes: QAR 6,999,750 as shown in Figure (25) below.

Entertainment			Economy			Science			Sports			Politics		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
150	300	250	60	30	50	40	50	60	30	40	40	100	70	50
≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
80	193	20	56	30	18	40	14	60	30	16	17	64	14	20
293			104			114			63			98		
Total Cumulative Duplicated Viewership (per week)														
Objective Function: Maximize Viewership										79,786,170				

Available programme type/quality ready to be scheduled

"TO BE" Programmes Schedule

"TO BE" potential viewership

Figure (24): Advanced Model Schedule (Sample Grid after Running the Model)

Programmes Type/Quality		Cost per Minute ($)	(v) Cost Per 15 Minute ($)	Programme Hours Scheduled	Programme Cost ($)
Entertainment	A	950	14,250	80	1,140,000
	B	750	11,250	193	2,171,250
	C	450	6,750	20	135,000
Economy	A	650	9,750	56	546,000
	B	595	8,925	30	267,750
	C	375	5,625	18	101,250
Science	A	765	11,475	40	459,000
	B	650	9,750	14	136,500
	C	250	3,750	60	225,000
Sports	A	850	12,750	30	382,500
	B	750	11,250	16	180,000
	C	400	6,000	17	102,000
Politics	A	950	14,250	64	912,000
	B	650	9,750	14	136,500
	C	350	5,250	20	105,000
					6,999,750

Figure (25): Programmes Cost (Sample Grid after Running the Model)

Despite the fact that the potential viewership has increased dramatically, as discussed earlier in Chapter 3, the grid is not realistic and cannot be implemented, as programmes are fragmented in a way that is not practical to be aired.

In Figure (26) below, the Excel Sheet (2) outputs are demonstrated after running the advanced model. As we can see, the sample channel should be airing different types/qualities of programmes such as Entertainment, Science, Politics, etc. However, this time, the built-in logical formatting will force the model to select more realistic and practical grid that can be aired throughout the day parts. This will take care of all different programme lengths, airing times and frequency of airing decisions such as more run times per day, repeat daily or every other day, weekly, etc.

	Time	Time Slot (j)	Day (i), Sat														
			Entertainment			Economy			Science			Sports			Politics		
			A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Night 11PM-6AM	23:00-23:14	69		1													
	23:15-23:29	70		1													
	23:30-23:44	71		1													
	23:45-23:59	72		1													
	00:00-00:14	73							1								
	00:15-00:29	74							1								
	00:30-00:44	75							1								
	00:45-00:59	76							1								
	01:00-01:14	77	1														
	01:15-01:29	78	1														
	01:30-01:44	79	1														
	01:45-01:59	80	1														
	02:00-02:14	81													1		
	02:15-02:29	82													1		
	02:30-02:44	83													1		
	02:45-02:59	84													1		
	03:00-03:14	85														1	
	03:15-03:29	86														1	
	03:30-03:44	87														1	
	03:45-03:59	88														1	
	04:00-04:14	89									1						
	04:15-04:29	90									1						
	04:30-04:44	91									1						
	04:45-04:59	92									1						
	05:00-05:14	93									1						
	05:15-05:29	94									1						
	05:30-05:44	95									1						
	05:45-05:59	96									1						

Figure (26): Modified Model Outputs in Excel Sheet (2) (after running the model)

According to the resulted logical formatted grid, as shown in Figure (27) below, the total cumulative duplicated viewership will have the potential to reach up to about 78 Million viewers. The cost required to procure and/or produce these programmes is QAR 6,969,300 as shown in Figure (28) below.

Entertainment			Economy			Science			Sports			Politics		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
150	300	250	60	30	50	40	50	60	30	40	40	100	70	50
≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
88	144	36	64	24	20	56	16	64	36	16	12	60	24	12
268			108			136			64			96		
			Exceed			Exceed		Exceed	Exceed					
Total Cumulative Duplicated Viewership (per week)														
Objective Function: Maximize Viewership											77,897,700			

Available programme type/quality ready to be scheduled

"TO BE" Programmes Schedule

Programmes scheduled exceeds the available programmes in archives

"TO BE" potential viewership

Figure (27): Advanced Model Logical Schedule (Sample Grid after Running the Model)

Cost of Programmes		Cost per Minute ($)	Cost per 15 Minute ($)	Programme Hours	
Entertainment	A	950	14,250	88	1,254,000
	B	750	11,250	144	1,620,000
	C	450	6,750	36	243,000
Economy	A	650	9,750	64	624,000
	B	595	8,925	24	214,200
	C	375	5,625	20	112,500
Science	A	765	11,475	56	642,600
	B	650	9,750	16	156,000
	C	250	3,750	64	240,000
Sports	A	850	12,750	36	459,000
	B	750	11,250	16	180,000
	C	400	6,000	12	72,000
Politics	A	950	14,250	60	855,000
	B	650	9,750	24	234,000
	C	350	5,250	12	63,000
					6,969,300
Available Budget for All Programmes					7,000,000

Figure (28): Programmes Cost (Sample Grid after Running the Model)

As we can notice, the logical conditional scheduling grid resulted in a marginal lower potential viewership than the optimal schedule shown in Figure (24). The reason for this decrease is that we forced the schedule to book specific time slots based on the initial optimum decisions. This for sure will place some programmes in other time slots where they might receive lower attention than the original optimum selection in Excel Sheet (1). However, the resulting schedule will still deliver a dramatic increase in viewership when compared to the original “AS IS” sample channel grid.

However, as shown in Figure (27) above, the logical formatting optimal grid hours resulting from this step may cause a constraint to be broken – in this case, the new placement decision of Economy programmes of quality (A) will require 64 units, which exceeds the upper bound set at 60 units. In cases such as this, the scheduler will have to revisit every case separately and investigate the impact associated with it and change/edit the logic to finalise a decision that satisfies his/her priorities of scheduling.

In Figure (29) below, a conditional formatting is added to Excel Sheet (2) to easily locate the constraints that are violating and exceeding the pre-set upper and lower bounds. As we can see in the figure, the new schedule exceeds the number of time slots allocated from Entertainment programme type A by four additional time slots. It also placed fewer time slots from programme Science of type B and Sports of type A for instance. This for sure will have an impact on the cost and viewership number associated with this decision. The decision to keep the new schedule or to change it is the responsibility of the scheduler as he/she knows the programme archives and investment capabilities of his/her television station. In the following few pages, we will present some scenarios of different programme planning options that he/she can consider finalising the schedule.

Programme type/quality selected to be aired

Programme type/quality exceeded constraints.

		Day (i), Sat														
Time	Time Slot (j)	Entertainment			Economy			Science			Sports			Politics		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
04:45-04:59	92									1						
05:00-05:14	93									1						
05:15-05:29	94									1						
05:30-05:44	95									1						
05:45-05:59	96									1						
		12	16	8	12	4	4	8	0	8	0	4	8	8	4	0
		≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤
Upper bound on type/grade per day		8	30	30	8	12	12	8	12	12	8	12	8	12	12	12
		≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
Lower bound on type/grade per day		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
onstraint Test ---------------------------->		Exceed			Exceed				Below		Below					Below
ng 6 AM-12 PM		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	4	0	4	4	0	0	0	0	4	8	0	0	0
		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Constraint Test ---------------------------->													Exceed			
Afternoon 12 PM-5 PM		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	8	4	8	0	0	0	0	0	0	0	0	0	0	0
		15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Constraint Test ---------------------------->																
Evening 5 PM-7 PM		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	4	0	0	4	0	0	0	0	0	0	0	0
		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Constraint Test ---------------------------->																
Prime Time 7 PM-11 PM		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		8	4	0	0	0	0	0	0	0	0	0	0	4	0	0
		14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Constraint Test ---------------------------->																
Night 11 PM-6 AM		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		4	4	0	0	0	0	4	0	8	0	0	0	4	4	0
		13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Constraint Test ---------------------------->																

Figure (29): Modified Model Outputs (Saturday, after running model showing violated constraints)

Another example of exceeding the limits of resources availability is shown in Figure (30) below. The figure represents the constraint of the availability of programmes hours from different types to be placed on the schedule. As shown in the figure, the resulting programmes grid in Excel Sheet (2) will require more hours to be scheduled from Economy (A), Science (A) and (C), and Sports (A) programmes. In this scenario, the required number of programmes is exceeding the upper bounds of available hours in the programmes library (shown in red). In similar cases, the decision to invest in producing/procuring more programme hours of those particular types/qualities is handed over to the end user. If this option is viable and increases viewership numbers within acceptable costs to the television station, then end users can decide to add more hours. Otherwise, programmes limits can be kept "as is" and another assignment choice is made.

Entertainment			Economy			Science			Sports			Politics		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
150	300	250	60	30	50	40	50	60	30	40	40	100	70	50
≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
88	144	36	64	24	20	56	16	64	36	16	12	60	24	12
268			108			136			64			96		
			Exceed			Exceed		Exceed	Exceed					

Figure (30): Modified Model Outputs (after running the model showing violated supply constraints)

To test the impact of increasing and/or decreasing the scheduled hours that are violating supply constraints, as in Figure (29), the end user can try different scenarios by reducing the hours scheduled from Entertainment programme type (A) by 4 time slots and giving these hours to another programme type such as Science of type (B) and Sports of type (A) for instance. The results of this particular example testing of hours placed by the model for that specific case is adjusted by the end user. However, by comparing the potential viewership numbers associated with this decision with the required costs, a dramatic drop in viewership can be noticed. Also, the cost associated with this change is slightly higher than the original model costs. The viewership decreased to 71,326,710 from 77,897,700 and the cost increased from QAR 6,969,300 to QAR 7,155,300.

In this case, the change in viewership numbers is because the demand for that particular type of programme is much higher than the demand on other types such as Science and Sports as the data suggests. Therefore, this change is not recommended as it involves losing viewership and requiring more investment.

Another testing scenario can be considered here by reducing the number of hours that are exceeding upper and lower bounds per day constraints as shown in Figures (31a) and (31b) below. The end user can re-assign the extra four time slots of Economy (A) to Science (B) and Politics (C) respectively. The results show that the viewership numbers have decreased again from 77,897,700 to 77,563,800 which is marginal if compared to the previous scenario. The cost associated with this option has dropped slightly to QAR 6,960,300 from QAR 6,969,300. In this scenario, a marginal reduction in viewership numbers accompanied by a reduction in investment may be justifiable and can be an option to be considered by the end user. Figure (31a) illustrates the Excel Sheet (2) grid for Saturday Afternoon time slots 25 to 40.

			Day (i), Sat														
	Time	Time Slot (j)	Entertainment			Economy			Science			Sports			Politics		
			A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Time Slot (j) / Afternoon 12PM-5PM	12:00-12:14	25			1												
	12:15-12:29	26			1												
	12:30-12:44	27			1												
	12:45-12:59	28			1												
	13:00-13:14	29				1											
	13:15-13:29	30				1											
	13:30-13:44	31				1											
	13:45-13:59	32				1											
	14:00-14:14	33				1											
	14:15-14:29	34				1											
	14:30-14:44	35				1											
	14:45-14:59	36				1											
	15:00-15:14	37		1													
	15:15-15:29	38		1													
	15:30-15:44	39		1													
	15:45-15:59	40		1													
			12	16	8	12	4	4	8	0	8	0	4	8	8	4	0
			≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤
	Upper bound on type/grade per day		8	30	30	8	12	12	8	12	12	8	12	8	12	12	12
			≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	Lower bound on type/grade per day		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Constraint Test ---------------------------->		Exceed			Exceed				Below		Below					Below

Figure (31a): Excel Sheet (2) Model Outputs (after running the model showing impact on changing constraint)

			Day (i), Sat														
	Time	Time Slot (j)	Entertainment			Economy			Science			Sports			Politics		
			A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Time Slot (j) / Afternoon 12PM-5PM	12:00-12:14	25			1												
	12:15-12:29	26			1												
	12:30-12:44	27			1												
	12:45-12:59	28			1												
	13:00-13:14	29								1							
	13:15-13:29	30								1							
	13:30-13:44	31															1
	13:45-13:59	32															1
	14:00-14:14	33				1											
	14:15-14:29	34				1											
	14:30-14:44	35				1											
	14:45-14:59	36				1											
	15:00-15:14	37		1													
	15:15-15:29	38		1													
	15:30-15:44	39		1													
	15:45-15:59	40		1													
			12	16	8	8	4	4	8	2	8	0	4	8	8	4	2
			≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤	≤
	Upper bound on type/grade per day		8	30	30	8	12	12	8	12	12	8	12	8	12	12	12
			≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	Lower bound on type/grade per day		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Constraint Test ---------------------------->		Exceed									Below					

Figure (31b): Excel Sheet (2) Model Outputs (after running the model showing the impact on changing constraint and adjusting sample exceeded constraints)

In addition to the above scenarios, the model can be adjusted and re-run a number of times so that different additional scenarios can be tested, such as increasing the cost-per-minute to produce and/or procure programmes for instance. A lower budgetary limit can be tested as well to measure the impact of reducing budgets, especially in difficult financial times, on the potential viewership numbers. The flexibility and interactive nature of the advanced computer optimisation model help decision makers to plan their future grids, considering different scenarios before they finalise their placement and budget decisions.

The model was tested and re-run a number of times for several scenarios. In every run, a dramatic potential increase in viewership was recorded when compared to the initial schedule used by the television station. Moreover, the same cost is incurred on average to produce/procure programmes for the "to be" schedule.

As discussed above, the proposed advanced interactive optimisation model is very flexible and gives the end user a very good starting point where he/she can take the initial schedule and apply his/her experience and logic for the benefit of the television station. The model will enable end users to build the optimal schedule that maximises viewership and minimises cost by examining a large number of different programming setups before the final schedule is produced.

5.3 Model Sensitivity & Parameter Analysis:

As discussed in Chapter 3, the availability of resources will have a positive or negative impact on total viewership numbers. Hence, the number of programme types and qualities that are available for scheduling will have an impact on placement decisions, viewership numbers, and programmes cost.

In this section, the parameter analysis function in Frontline Solver is used again to report the sensitivity of changing the number of hours available for resources on the optimum solution by running multiple optimisations. The function is set up in the model similarly to the scenario discussed earlier in Chapter 3.

The upper and lower bounds can be different for every programme type/quality and should be decided by the end user. This function will force the optimisation engine to use different numbers of programmes in each run. This parameter was set up in the model for all types/qualities of programmes. In addition, the solver optimisation is programmed to run multiple times (say 5 runs for testing purposes). By running the model, we get the figures shown in Table (11) below.

Run	Entertainment			Economy			Science			Sports			Politics			Viewrship	Cost	Viewership Increase	Cost Change
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C				
1	50	50	50	50	50	45	50	50	23	50	50	34	50	50	20	69255270	6655875	36%	-4%
2	77	77	54	56	72	15	56	21	38	56	22	14	77	16	21	77304375	6999825	52%	1%
3	80	105	36	56	60	14	56	17	53	54	18	15	72	16	20	78809040	6999600	55%	1%
4	80	132	23	56	55	14	54	14	60	53	15	15	65	16	20	79563240	6998775	56%	1%
5	80	160	19	56	37	14	53	14	65	49	14	15	60	16	20	80100360	6999900	57%	1%

Table (11): Advanced Model Parameter Sensitivity Analysis

The first run of the multiple optimisations has selected a number of hours to be scheduled for every programme type/quality (as shown in the table above in green font). That particular selection yields a 36% higher viewership than the original Channel 1 "as is" schedule together with a 4% reduction in cost. Moreover, every selection of programme hours' combination in the following model runs generates higher or lower total viewership as illustrated in Chart (2) below.

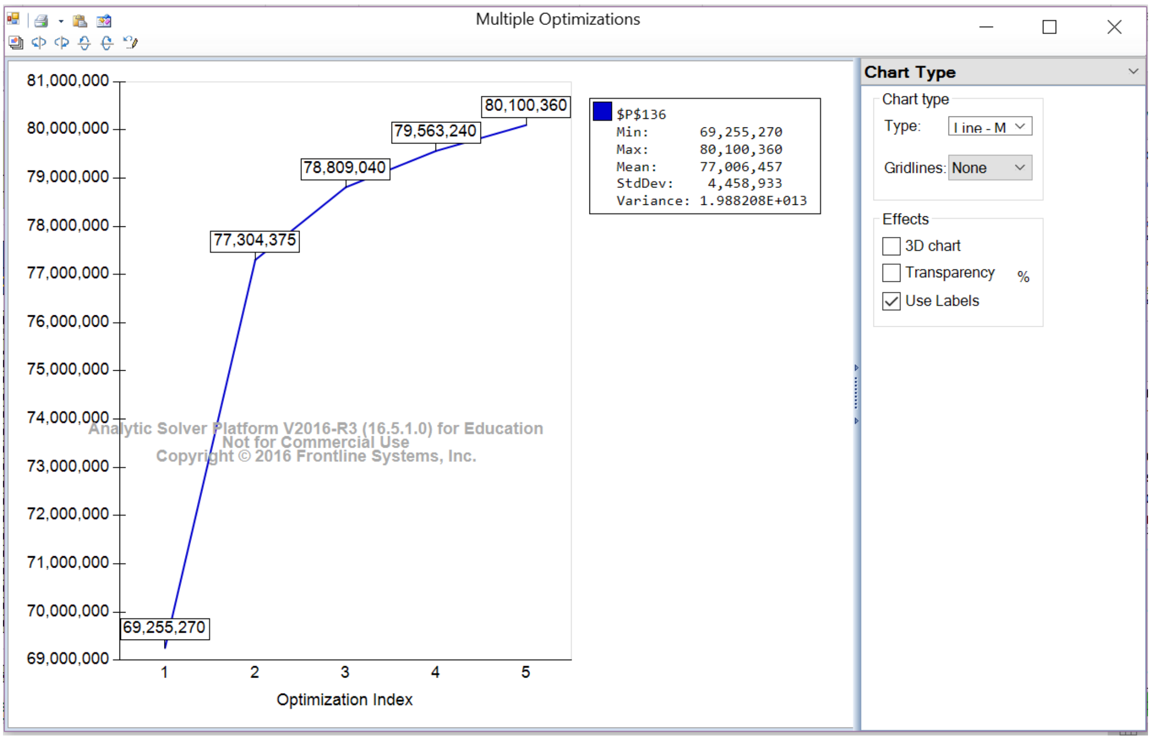


Chart (2): Advanced Model Parameter Sensitivity Analysis

As shown above, the overall improvement in viewership is significant, and it ranges from 36% to 57% by utilising the same budgets. This will depend on the combination of hours from different programmes types/qualities selected in every optimisation run.

5.4 Advanced Model Scalability:

As the model should be sufficiently general that it can work for different television channels, the scalability of the model was tested in order to handle more programme types, qualities and longer schedules. Different scenarios and problem setups are used and tested. Hypothetical television programme schedules and simulated viewership data are used to solve these scenarios.

5.4.1 Advanced Model with More Programme Types:

As shown in Figure (32) below, two more programme types were added to the model (Kids and History). The figure represents a one day sample (Saturday).

Day (i), Sat																				
Entertainment			Economy			Science			Sports			Kids			History			Politics		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C

Figure (32): Sample Advanced Model with 7 Programme Types and 3 Qualities

This new hypothetical scenario was formulated and solved using Frontline Solver (add-in) software as a linear integer assignment-type 0-1 optimisation problem, where the variable $Y_{i,j,k,x} = 1$ if a programme of that type and quality is selected in that particular time slot on that particular day or 0 otherwise. Here i ($i = 1..7$) is the day of the week, j ($j = 1..96$) is the time-slot, k ($k = 1..7$) is the programme type (Entertainment, Economy, Science, Sports, Kids, History, Politics), and x ($x = 1..3$) is the programme quality (A, B or C). Thus there are 14,112 0-1 decision variables. There are 28,224 upper or lower bounds on hours availability/allowance per programme type and 2458 other constraints. The value of the objective function is obtained by simply adding up applicable ratings for every time slot and every day.

The viewership recorded before running the model was about 46 million duplicated viewers in that hypothetical country for that specific week. All other model assumptions remain the same. By running the model, the potential viewership increased up to 74.2 million, which is approximately a 62% potential increase. Table (12) below shows Solver running times.

Problem setup time	2.22 seconds
Engine solve time	0.58 seconds
Solve time	9.02 seconds

Table (12): Advanced Model Solver Running Times (7 Types/3 Qualities)

5.4.2 Advanced Model with Fewer Programme Types and More Qualities:

As shown in Figure (33) below, four types of programmes were identified, and five qualities are introduced A, B, C, D, and E. The figure represents a one day sample (Saturday). It is assumed that *x* = (A, B, C, D, E) potentially attract 20%, 15%, 10%, 5% and 2.5% of available viewership respectively.

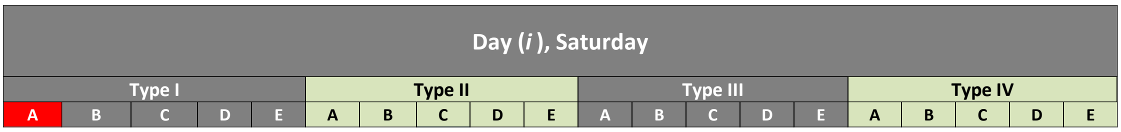


Figure (33): Sample Advanced Model with 4 Programme Types and 5 Qualities

This new hypothetical scenario was formulated and solved using Frontline Solver (add-in) software as a linear integer assignment-type 0-1 optimisation problem, where the variable $Y_{i,j,k,x}$ = 1 if a programme of that type and quality is selected in that particular time slot on that particular day or 0 otherwise. Here *i* (*i* = 1..7) is the day of the week, *j* (*j* = 1..96) is the time-slot, *k* (*k* = 1..4) is the programme type (Type I, Type II, Type III, Type IV), and x (x = 1..5) is the programme quality (A, B, C, D or E). Thus there are 13,440 0-1 decision variables. There are 26,880 upper or lower bounds on hours availability/allowance per programme type and 2373 other constraints. The value of the objective function is obtained by simply adding up applicable ratings for every time slot and every day.

The viewership recorded before running the model was about 42 million duplicated viewers in that hypothetical country for that specific week. All other model assumptions remain the same. By running the model, the potential viewership increased up to 66 million, which is approximately a 57% potential increase. Table (13) below shows Solver running times.

Problem setup time	2.11 seconds
Engine solve time	0.42 seconds
Solve time	7.94 seconds

Table (13): Advanced Model Solver Running Times (4 Types/5 Qualities)

5.4.3 Advanced Model for Longer Time Period:

As shown in Figure (34) below, longer time frame of three weeks' schedule is considered with five types of programmes and three qualities. The figure represents the availability per week for programme type/quality bound shown in yellow colour. It also represents the current programme schedule hours for that hypothetical television channel shown in light blue.

Week 1	Entertainment			Economy			Science			Sports			Politics		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	100	300	250	60	30	50	40	50	60	30	40	40	50	70	50
	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	77	312	198	0	0	0	0	0	0	21	0	0	24	40	0
	587			0			0			21			64		

Week 2	Entertainment			Economy			Science			Sports			Politics		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	100	300	250	60	30	50	40	50	60	30	40	40	50	70	50
	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	77	312	198	0	0	0	0	0	0	21	0	0	24	40	0
	587			0			0			21			64		

0

Week 3	Entertainment			Economy			Science			Sports			Politics		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	100	300	250	60	30	50	40	50	60	30	40	40	50	70	50
	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	77	312	198	0	0	0	0	0	0	21	0	0	24	40	0
	587			0			0			21			64		

Total Average Cumulative Duplicated Viewership (per week)	
Objective Function: Maximize Viewership	51,201,870

Figure (34): Advanced Model of Three Weeks with 5 Programme Types and 3 Qualities (AS IS)

This hypothetical scenario was formulated and solved using Frontline Solver (add-in) software as a linear integer assignment-type 0-1 optimisation problem, where the variable $Y_{i,j,k,x}$ = 1 if a programme of that type and quality is selected in that particular time slot on that particular day or 0 otherwise. Here i (i = 1..21) is the day during the three-week period, j (j = 1..96) is the time-slot, k (k = 1..5) is the programme type (Entertainment, Economy, Science, Sports, Politics), and x (x = 1..3) is the programme quality (A, B or C). Thus there are 30,240 0-1 decision variables. There are 60,480 upper or lower bounds on hours availability/allowance per programme type and 5844 other constraints. The value of the objective function is obtained by simply adding up applicable ratings for every time slot and every day.

The average viewership recorded per week before running the model was about 51 million duplicated viewers in that hypothetical country for that specific week. All other model assumptions remain the same. By running the model, the potential viewership increased up to 80.6 million, which is approximately a 57% potential increase. Table (14) below shows Solver running times.

Problem setup time	6.75 seconds
Engine solve time	1.90 seconds
Solve time	21.98 seconds

Table (14): Advanced Model Solver Running Times for 3 Weeks (5 Types/3 Qualities)

In Figure (35) below, illustrate the “TO BE” schedule after running the three weeks’ model. Its shows the television programmes hours per type/quality selected by the model to run for every week.

	Entertainment			Economy			Science			Sports			Politics		
Week 1	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	100	300	250	60	30	50	40	50	60	30	40	40	50	70	50
	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	80	208	30	56	30	14	40	26	14	30	40	14	50	20	20
	318			100			80			84			90		
	Entertainment			Economy			Science			Sports			Politics		
Week 2	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	100	300	250	60	30	50	40	50	60	30	40	40	50	70	50
	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	80	215	24	56	30	14	40	29	14	30	40	14	50	16	20
	319			100			83			84			86		
												0			
	Entertainment			Economy			Science			Sports			Politics		
Week 3	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	100	300	250	60	30	50	40	50	60	30	40	40	50	70	50
	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥	≥
	80	207	29	56	30	14	40	31	14	30	40	14	50	17	20
	316			100			85			84			87		

Total Average Cumulative Duplicated Viewership (per week)	
Objective Function: Maximize Viewership	80,601,315

Figure (35): Advanced Model of Three Weeks with 5 Programme Types and 3 Qualities (TO BE)

As discussed in this section, a number of different scenarios were tested with different datasets to solve the problem for more programme types and qualities. Also, longer time periods are considered and tested using hypothetical television schedules and simulated datasets. All model scenarios ran efficiently and delivered new optimal schedules with increased potential viewership considering given model limitations and constraints.

5.5 Potential Use of the Model:

After running the advanced computer optimisation model and testing different scenarios of building an optimum grid for television, the model was demonstrated in its fully functional mode to a group of media practitioners who were involved in the initial interviews. First, the initial shortcomings of the basic model were discussed and then the advanced model was run after adding the new assumptions and constraints.

The group were impressed by the research findings and the dramatic potential increase in viewership while utilising the same average budget. They discussed several scenarios such as booking longer or shorter time slots in specific days or weeks. The logical conditional formatting can take care of these scenarios as was shown to them.

They agreed that the model could be used and be beneficial as it will allow them to minimise the time it takes to develop the programme's schedule. Although the outputs of the model do not give a specific programme schedule, they appreciated the fact that knowing the type and quality placement decisions in advance are very important and can help them in their programme planning exercise. After that, they can schedule the actual programmes according to the optimal grid placement choices. An example to illustrate this process is given in the following section.

The model will also help them to simulate the impact of their different programme placement decisions changes on viewership instantly when they change constraints and rerun the model. They liked the fact that financial planning and budgeting is also possible when they plan their grids for a programming cycle, a full season or even more.

As reported in the literature review, scholars have followed different approaches and techniques to schedule programmes efficiently for television channels. The common dominator in their scheduling approaches was the consideration of a pre-known set of programmes in their programme placement decisions. While this approach is valid and has delivered higher viewership in most cases, the approach followed in this research is different and more comprehensive. The proposed model objective is to schedule programme type and quality rather than pre-known programmes. This is important, as discussed earlier, as all media organisations usually own a number of hours of programmes of different types that they place in the schedule. In addition, media organisations at the programme planning phase usually build their budgets for the year by considering the potential demand of new hours to add to their archives. Here the decision to produce or procure a programme becomes more critical as they need to know what type/quality of the programme is best for the return on investment both in terms of viewership and in terms of advertising sales. The proposed model will give them that option by allowing them to test all these different scenarios a long time in advance. The model will give them a grid of different types/qualities, and they are only left with assigning the name/title of the show.

The model will show the potential possible increase in viewership that can or cannot be achieved as discussed earlier in this thesis. Nevertheless, the increase of viewership is an objective that can be achieved by aligning all different functions and operations within the media organisation such as programmes department, sales department, distribution department, marketing department, etc. The ultimate goal is to achieve a better viewership experience that will attract more viewers and increase the television station's overall profits. The optimal grid should serve as the first input in the television channel strategy and planning cycle as it will set the agenda for weeks to come. Then comes the role of other functions within the media organisation to market the content properly and distribute it on different platforms so it can be consumed and viewed as much as possible.

5.6 Turning the Model Output into an Actual Schedule:

In the previous sections, a clear description of the model functionally and outputs were provided and discussed. This section gives an example of how model outputs can be transformed into an actual programmes schedule. For illustration purposes, a hypothetical programme archive is used to be placed in the schedule's time slots.

In Figure (36) below, an illustration of the model Excel Sheet (2) placement results for Saturday Morning (6:00 am – 12:00 pm) and Afternoon (12:00 pm – 17:00 pm) day parts are given. The advanced model has assigned 8 time slots of Sports (C) to run from 6:00 am to 8:00 am, 4 time slots of Sports (B) to run from 8:00 am to 9:00 am, 4 time slots of Economy (C) to run from 9:00 am to 10:00 am, 4 time slots of Economy (B) to run from 10:00 am to 11:00 am, 8 time slots of Entertainment (C) to run from 11:00 am to 1:00 pm, 8 time slots of Economy (A) to run from 1:00 pm to 3:00 pm, and 8 time slots of Entertainment (B) to run from 3:00 pm to 5:00 pm,

			Day (i), Sat														
	Time	Time Slot (j)	Entertainment			Economy			Science			Sports			Politics		
			A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Morning 6AM-12PM	06:00-06:14	1												1			
	06:15-06:29	2												1			
	06:30-06:44	3												1			
	06:45-06:59	4												1			
	07:00-07:14	5												1			
	07:15-07:29	6												1			
	07:30-07:44	7												1			
	07:45-07:59	8												1			
	08:00-08:14	9											1				
	08:15-08:29	10											1				
	08:30-08:44	11											1				
	08:45-08:59	12											1				
	09:00-09:14	13						1									
	09:15-09:29	14						1									
	09:30-09:44	15						1									
	09:45-09:59	16						1									
	10:00-10:14	17					1										
	10:15-10:29	18					1										
	10:30-10:44	19					1										
	10:45-10:59	20					1										
	11:00-11:14	21			1												
	11:15-11:29	22			1												
	11:30-11:44	23			1												
	11:45-11:59	24			1												
Afternoon 12PM-5PM	12:00-12:14	25			1												
	12:15-12:29	26			1												
	12:30-12:44	27			1												
	12:45-12:59	28			1												
	13:00-13:14	29				1											
	13:15-13:29	30				1											
	13:30-13:44	31				1											
	13:45-13:59	32				1											
	14:00-14:14	33				1											
	14:15-14:29	34				1											
	14:30-14:44	35				1											
	14:45-14:59	36				1											
	15:00-15:14	37		1													
	15:15-15:29	38		1													
	15:30-15:44	39		1													
	15:45-15:59	40		1													
	16:00-16:14	41		1													
	16:15-16:29	42		1													
	16:30-16:44	43		1													
	16:45-16:59	44		1													

Figure (36): Advanced Model Excel Sheet (2) Outputs Example

The example schedule described in Figure (36) above can be decoded into the following schedule in Figure (37) below. Programme (P1) is a Sports (C) programme and will be placed in the time slots 1 to 8 on Saturday morning. The end user places all other programmes P2 to P7 in a similar way. The end user can choose to rerun one or more programme(s) in later time slots with the same type and quality of the programme, on the same day or any other day, if he/she wishes to.

Time	Time Slot	Saturday
06:00-06:14	1	P1
06:15-06:29	2	
06:30-06:44	3	
06:45-06:59	4	
07:00-07:14	5	
07:15-07:29	6	
07:30-07:44	7	
07:45-07:59	8	
08:00-08:14	9	P2
08:15-08:29	10	
08:30-08:44	11	
08:45-08:59	12	
09:00-09:14	13	P3
09:15-09:29	14	
09:30-09:44	15	
09:45-09:59	16	
10:00-10:14	17	P4
10:15-10:29	18	
10:30-10:44	19	
10:45-10:59	20	
11:00-11:14	21	P5
11:15-11:29	22	
11:30-11:44	23	
11:45-11:59	24	
12:00-12:14	25	
12:15-12:29	26	
12:30-12:44	27	
12:45-12:59	28	
13:00-13:14	29	P6
13:15-13:29	30	
13:30-13:44	31	
13:45-13:59	32	
14:00-14:14	33	
14:15-14:29	34	
14:30-14:44	35	
14:45-14:59	36	
15:00-15:14	37	P7
15:15-15:29	38	
15:30-15:44	39	
15:45-15:59	40	
16:00-16:14	41	
16:15-16:29	42	
16:30-16:44	43	
16:45-16:59	44	

Figure (37): Actual Saturday Programme Placement Example (6:00 am to 5:00 pm)

<table>
<tr><th>Time</th><th>Time Slot</th><th>Saturday</th><th>Sunday</th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th></tr>
<tr><td>06:00-06:14</td><td>1</td><td rowspan="8">P1</td><td rowspan="4">P8</td><td rowspan="8">P15</td><td rowspan="2">P23</td><td rowspan="8">P31</td><td rowspan="6">P39</td><td rowspan="4">P47</td></tr>
<tr><td>06:15-06:29</td><td>2</td></tr>
<tr><td>06:30-06:44</td><td>3</td><td rowspan="6">P24</td></tr>
<tr><td>06:45-06:59</td><td>4</td></tr>
<tr><td>07:00-07:14</td><td>5</td><td rowspan="4">P9</td><td rowspan="4">P48</td></tr>
<tr><td>07:15-07:29</td><td>6</td></tr>
<tr><td>07:30-07:44</td><td>7</td><td rowspan="2">P40</td></tr>
<tr><td>07:45-07:59</td><td>8</td></tr>
<tr><td>08:00-08:14</td><td>9</td><td rowspan="4">P2</td><td rowspan="8">P10</td><td rowspan="4">P17</td><td rowspan="4">P25</td><td rowspan="4">P32</td><td rowspan="4">P41</td><td rowspan="8">P49</td></tr>
<tr><td>08:15-08:29</td><td>10</td></tr>
<tr><td>08:30-08:44</td><td>11</td></tr>
<tr><td>08:45-08:59</td><td>12</td></tr>
<tr><td>09:00-09:14</td><td>13</td><td rowspan="4">P3</td><td rowspan="4">P18</td><td rowspan="4">P26</td><td rowspan="4">P33</td><td rowspan="8">P42</td></tr>
<tr><td>09:15-09:29</td><td>14</td></tr>
<tr><td>09:30-09:44</td><td>15</td></tr>
<tr><td>09:45-09:59</td><td>16</td></tr>
<tr><td>10:00-10:14</td><td>17</td><td rowspan="4">P4</td><td rowspan="4">P11</td><td rowspan="4">P19</td><td rowspan="4">P27</td><td rowspan="4">P34</td><td rowspan="4">P50</td></tr>
<tr><td>10:15-10:29</td><td>18</td></tr>
<tr><td>10:30-10:44</td><td>19</td></tr>
<tr><td>10:45-10:59</td><td>20</td></tr>
<tr><td>11:00-11:14</td><td>21</td><td rowspan="8">P5</td><td rowspan="12">P12</td><td rowspan="8">P20</td><td rowspan="8">P28</td><td rowspan="4">P35</td><td rowspan="4">P43</td><td rowspan="4">P51</td></tr>
<tr><td>11:15-11:29</td><td>22</td></tr>
<tr><td>11:30-11:44</td><td>23</td></tr>
<tr><td>11:45-11:59</td><td>24</td></tr>
<tr><td>12:00-12:14</td><td>25</td><td rowspan="4">P36</td><td rowspan="4">P44</td><td rowspan="2">P52</td></tr>
<tr><td>12:15-12:29</td><td>26</td></tr>
<tr><td>12:30-12:44</td><td>27</td><td rowspan="4">P53</td></tr>
<tr><td>12:45-12:59</td><td>28</td></tr>
<tr><td>13:00-13:14</td><td>29</td><td rowspan="8">P6</td><td rowspan="8">P21</td><td rowspan="4">P29</td><td rowspan="12">P37</td><td rowspan="12">P45</td></tr>
<tr><td>13:15-13:29</td><td>30</td></tr>
<tr><td>13:30-13:44</td><td>31</td><td rowspan="2">P54</td></tr>
<tr><td>13:45-13:59</td><td>32</td></tr>
<tr><td>14:00-14:14</td><td>33</td><td rowspan="4">P13</td><td rowspan="12">P30</td><td rowspan="4">P55</td></tr>
<tr><td>14:15-14:29</td><td>34</td></tr>
<tr><td>14:30-14:44</td><td>35</td></tr>
<tr><td>14:45-14:59</td><td>36</td></tr>
<tr><td>15:00-15:14</td><td>37</td><td rowspan="8">P7</td><td rowspan="8">P14</td><td rowspan="8">P22</td><td rowspan="8">P56</td></tr>
<tr><td>15:15-15:29</td><td>38</td></tr>
<tr><td>15:30-15:44</td><td>39</td></tr>
<tr><td>15:45-15:59</td><td>40</td></tr>
<tr><td>16:00-16:14</td><td>41</td><td rowspan="4">P38</td><td rowspan="4">P46</td></tr>
<tr><td>16:15-16:29</td><td>42</td></tr>
<tr><td>16:30-16:44</td><td>43</td></tr>
<tr><td>16:45-16:59</td><td>44</td></tr>
</table>

Figure (38): Actual (Sat- Fri) Programme Placement Example (6:00 am to 5:00 pm)

As shown in Figure (38) above, the end user can interpret all optimal model decisions in Excel Sheet (2) into a specific programme such as P1, P2, …. P56 to be aired in an actual week. The Figure (38) above represents a sample full week programme grid for the period 6:00 am to 5:00 pm every day.

Television stations are different and can potentially use the model differently. In Chapter 5, different running scenarios were discussed and illustrated by giving a number of different examples. However, experience in the media and broadcasting industry suggests that the first week's schedule will usually dictate the schedule for the following 8-12 weeks. The programming cycle can be planned by season, quarter and/or special occasions. Therefore, the number of weeks in the cycle can be different for every television station. Most of the placement decisions will be decided in the first week. The following weeks in a specific programming cycle will be mainly the repeats and/or reruns of the first-week grid but with different programme episodes, guests, etc.

Rerunning the advanced optimisation model will be required after every programme cycle ends as viewership behaviour might for the following ones.

The contribution to academia and practice is significant in this research as the literature review revealed very few attempts to optimise the programme's schedule. This research can be very useful for those who are studying media management and viewership research as it provides them with a comprehensive approach to understand the viewership industry, media industry and the way it can be utilised towards better viewership experience. Also, this research provides an interactive and powerful optimisation model that can be used by different television stations to plan for their production/procurement initiatives.

Chapter 6

This chapter is divided into three parts. The subject of the first part is the contribution of research to academia and real practice and is thus addressing how the current research answers the research aims discussed in Chapter 1. The second part is dedicated to discussing and outlining potential future research and development in this area. The remainder of the chapter is devoted to the summary and conclusion of this work.

6.1 Contribution of Research:

The literature contains very little evidence that analytical and computational approaches are used in modelling and optimising programme schedules in the television industry. This research into previous work carried out in programme planning and scheduling problems, along with the author's experience in the field, has helped in the development of a new approach to tackling programme scheduling problems. The outputs of this thesis will potentially help to fill some gaps in the academic literature and real practice at the same time.

Together, the thesis's findings and the computer optimisation model present a clear understanding of the history and current practices of both the Media industry and the Viewership Research industry, which are discussed in some detail in the thesis. In addition, the advanced computer optimisation model built for the purpose of this research combines the outputs of both industries and places them in an intelligent decision-making tool, allowing programme planners and directors to produce efficient, cost effective, and high potential viewership programme schedules.

6.1.1 For Research and Academia:

This section outlines and discusses the main areas of contribution to Academia. This should help in understanding the differences between this work and what has been done in this field in the past.

- The few attempts reported in the literature have taken no account of the viewership demand, per programme type, available in the market, in their effort to optimise the programme schedule. This work has taken this factor into consideration and considers it as one of the most important factors when making scheduling decisions. The proposed approach introduces a new way of utilising research data by giving a high weight to viewer expectation and demand in the market.
- In previous work, scheduling decisions were built on forecasting future ratings based on historical data, for a specific programme to change its airing time, aiming at higher potential viewership. The approach suggested in this work is different from previous approaches since the type and quality of programme are placed in the schedule based on the forecast ratings for a programme type rather than specific programme ratings.

  In other words, the previous ratings of a programme, such as "***The Oprah Winfrey Show***[31]" for instance, were used to decide the future placement of the same type and quality of programme. This work suggests a new strategy to measure the overall viewership demand for programmes and then hand over the decision to the computer optimisation model to select the optimum placement of all type of

[31] American talk show that aired nationally for 25 seasons from September 8, 1986 to May 25, 2011 in Chicago, Illinois. Produced and hosted by its namesake, Oprah Winfrey, it remains the highest-rated talk show in American television history according to Rose, Lacey (January 29, 2009). "America's Top-Earning Black Stars". Forbes. May 23, 2012.

programmes. Later, as discussed in Chapter 5, the final decision is handed over to the programme planner to select the programme that will be placed on the schedule.

- In the literature, multiple traditional programme scheduling approaches were discussed such as Lead In, Tent Pull, Counter Programming and others. The main idea of those scheduling strategies was to manually place programmes by leveraging the strength of a programme rating to another content offering. This work suggests a different approach as it proposes an intelligent decision making procedure taking into consideration experts' opinion by blocking time slots to run or not to run specific types of programme leaving the model to decide on the remaining vacant time slots.
- The quality of programme concept was introduced in this research and is considered as one of the main elements in making scheduling decisions. The previous literature failed in viewers' segmentation while the current approach is suggesting placing programmes automatically by taking into consideration the viewership habits and segments. The distribution of programmes, in different day parts, based on available viewership per programme type should potentially help in fair and balanced distribution of programmes throughout the schedule.
- The advanced computational capabilities utilised in this research helped in building long schedules while other work in the past suggested building partial schedules with limited numbers of variables and constraints.
- All previous researchers have only taken prime-time into consideration when scheduling programmes rather than considering the full day schedule as described in Chapters 3 and 5 of this thesis. The approach suggested in this work is different as it uses different peak-times for every programme type. In other words, previous work considered only one prime-time for television viewership that is generally the

evening time where viewership peaks. In this work, other peak-times are considered as well in programme placement decisions. For example, some types of programmes can only peak in the morning time, such as children's programmes.

- The push-pull scheduling strategy proposed in this thesis will put experts' judgment together with viewers' expectations when scheduling programmes for television. This approach will potentially help to switch from a manual, time-consuming model to an automated well-proven demand driven model where television planners offer viewers a programmes portfolio that meets or even exceeds their expectations.

6.1.2 For Current Media Practices:

This section will outline and discuss how this thesis contributes to real practice.

- The novel contribution of this work to real practice is to propose a tool that will potentially help in solving real life programme scheduling problems. The proposed tool should enable media practitioners to perform their work more effectively and help them in making better and informed decisions by utilising the power of data intelligence and optimisation models. This is done by allowing them to try different combinations of content offerings considering constraints, resources availability, market competition and viewership expectations and test the potential impact before they go live.
- The interactive computer optimisation model gives media practitioners a powerful tool to initially understand viewership demand in the market for different types of programmes and then to plan their production and content building according to available potential demand for their content. This should give them peace of mind when they finalise and freeze the programme schedule after testing and considering many different possible scenarios before going live.

- The interactive computer optimisation model will show the potential increase in viewership. However, as discussed in Chapter 4, other operations and functions in the television station should play vital roles to help in achieving the potential viewership increase.
- The upper and lower bounds on programmes per day parts and the full day will give media experts the flexibility and freedom to decide on the right balance of programme distribution in the schedule. Previous attempts did not take this into consideration as reported in the literature.
- Programme planning and cost benefit analysis becomes possible before making any real investment decisions as the model simulates different scenarios of programme combinations and their potential impact on cost and viewership numbers.
- Short as well as long schedule planning becomes possible with the advanced computer optimisation model.
- Knowing the programmes schedule for a season or full programme cycle will help media organisations in aligning and scheduling all their resources such as studios, presenters, camera operators, engineers, etc. and make the best out of their financial resources.

6.2 Future Research and Development:

As discussed and suggested in this work, traditional scheduling methodologies will remain of high importance to all media practitioners across developing countries for many years to come. It is therefore very important to highlight some challenges to be faced in the future for further research and development in this area. This will probably also apply to other developed regions around the globe.

- Current viewership ratings reported by audience research companies only cover the ratings for television programmes. However, comprehensive data gathering and analysing research is required in order to report quantitative and qualitative outputs per programme type as it represents the main input to the proposed advanced computer optimisation model. Forecasting models can then help in predicting future ratings per programme type. Accurate and reliable data is very important in order to produce programme schedules which are as effective as possible.
- In this direction, further research to understand the viewership behaviour for each programme type when compared to total television viewership is required. It will help media experts to understand the potential of knowing programme type viewership rather than just understanding competition content offerings.
- Further research is required to confirm the impact of the quality of the programme on viewers' choices when they decide to stay or leave the channel. In the proposed computer model, for simplification reasons, different combinations of programme types/qualities were tested and simulated. However, detailed studies of viewers' tendency to watch different types and qualities would be helpful to improve the proposed model scheduling outputs.

6.3 Summary and Conclusion:

To produce a television programme schedule, the research presented in this thesis has proposed and described an intelligent decision-making model to optimise the distribution of the pool of programmes automatically utilising viewership data as a baseline in making placement decisions under certain constraints. The objective of this research is to help programme planners and media experts in planning and budgeting their programme schedule. The proposed tool should allow them to consider different programme attributes and other different variables and constraints in making scheduling decisions.

The suggested model is developed and tested considering several assumptions and constraints including data availability, one single feed television channel, a single time zone that is covering one country and using the 15-minute slot as the basic unit for programme distribution, although slots will probably be combined in most cases, often to create 45-minute, 60-minute or even longer slots.

Previous research in this area is very limited but has revealed very important facts on different strategies that are available to schedule programmes for television efficiently. The literature review (Chapter 2) gives a comprehensive summary and detailed discussion about several attempts in academia to solve similar problems in the past. The basic and advanced computer models developed for the purpose of this research were discussed in detail, and the difference from previous attempts was presented. To make the model more realistic and reflective of the current changes and advances in the media industry, the author conducted several face-to-face interviews and group discussions with experts from the media and research industry in order to understand the logic behind viewers' consumption behaviour. The outcomes revealed very interesting concepts of how media planners perform their day-to-day job and how they use viewership research in their planning and scheduling process. The focus group discussions helped provide a better understanding of audiences' tendencies to watch different programme types and qualities.

This research has confirmed several parts of the literature review but has also introduced new challenges and new concepts that need to be reconsidered. The methodology used is comprehensive and puts both viewers and media practitioners at the heart of schedule building. The originality of this research comes from introducing a new way of utilising research data differently by giving a high weight for viewer expectation and demand in the market. The push-pull strategy discussed earlier is a key concept that gives decision makers as well as end users the power to select the best portfolio of programmes to be aired according to available viewers' demand.

The proposed model logic is very comprehensive and requires a lot of work in data collection and calculation as well as in building conditional logical formatting to distribute programmes in the grid. The software package used gives the ability to solve large scale optimisation problems with thousands of variables and constraints. This will help media planners and decision makers to plan for months if not years ahead.

To demonstrate the model and concept viability and functionality, a real case scenario of existing television channel schedule in the Middle East region is input into the computer model. By running the basic optimisation model, a huge potential increase of about 58% in expected viewership is seen. The model was tested further for scalability so it can work for different channels. A test to handle more programme types, qualities and longer schedules was completed. Different scenarios and problem setups were used and tested. Hypothetical television programme schedules and simulated viewership data were used to solve these scenarios. All model scenarios ran efficiently and gave new optimal schedules with increased potential viewership that ranged between 38%, and 63% for the basic model.

In the advanced model part of this thesis, the important roles of the decision maker and programme planner in setting up their conditions and assumptions are presented and discussed both before and after running the model. Initially, and before running the model, they can block required time slots based on their experience and set their upper and lower bounds of programmes available to be scheduled, programmes allowed to run and/or not to run in the whole day as well as in each day part. New budgetary and cost constraints have also been added to allow television officials and programme planners to consider the availability and efficiency of their financial resources when they make scheduling and investment decisions, while still regarding the maximisation of their viewership as their main objective. The output of the model should give the planner a large number of different options to consider before finalising the actual schedule. The planner can test different scenarios and their impact on viewership and cost.

The advanced model was tested in the same way as the basic model and has produced programme schedules for all different programme types/qualities and lengths scenarios discussed earlier. All scenarios ran efficiently and gave new optimal schedules with increased potential viewership that ranged between 57% and 62%. The potential use of the model and how to turn the schedule output by the model into an actual schedule that could be used in practice was discussed in Chapter 5.

Subject Matter Experts' views of the problem were captured in this work and challenges were flagged to be understood and tackled in the efforts of producing better programme scheduling for the television industry. This work reported several procedural as well as structural challenges in the media environment and the need to improve viewership data collection and analysis.

A comprehensive discussion of the viewership rating and audience research industry background is presented in this thesis. Different data collection tools and techniques such as telephone interviews, face to face interviews, diaries and people meters were discussed in more detail. The advantages, disadvantages, quality and costs that are associated with each tool were presented and discussed, and it was concluded that no single tool is recommended over another. A combination of different techniques available at a reasonable quality and cost will definitely help media organisations and media practitioners to understand viewership behaviour.

A clear and comprehensive understanding of viewership ratings and audience behaviour was presented in this work followed by different strategies of data usage in programme scheduling and grid optimisation. Limitations of data accuracy and availability are discussed as well, and an organisational structure of a broadcast media company was presented for the reader to understand, in more details, the importance of different functions and operations within media organisations and the data importance and usability in each different function. Future work in this area should concentrate on data collection, analysis and predicting future viewership behaviours.

In summary, the thesis outputs along with the computer model should help the media industry gain a better understanding of programme distribution strategies and potentially can help programme planners to plan the production and distribute their programmes in the schedule efficiently, ensuring optimum increased viewership while considering other constraints and limitations.

References:

1. Adams, W.J. (1997). "Scheduling Practices Based on Audience Flow: What are the Effects on New Program Success?", *Journalism and Mass Communication Quarterly,* Vol 74, Issue 4, pp. 839-858.
2. Adams, W.J. and Eastman, S.T. (1997). "Prime-Time Network Television Programming". In: Eastman, S. T. and Ferguson, D. A. (Eds.), *Broadcast/Cable Programming: Strategies and Practices* (Fifth Edition) (pp.99–139). Belmont, CA: Wadsworth.
3. Brusco, M., (2008). "Scheduling Advertising Slots for Television" *Journal of the Operational Research Society,* Volume 59, Number 10, pp. 1363-1372.
4. Bollapragada, S., Bussieck M., and Mallik S (2004). "Scheduling Commercial Videotapes in Broadcast Television" *Operations Research,* Vol. 52, Issue 5, pp. 679–689.
5. Buzzard, K. (2012) "Tracking the Audience: The Ratings Industry from Analog to Digital". Routledge. Taylor & Francis Group
6. Danaher, P.J. and Dagger, T.S. (2012). "Using a nested logit model to forecast television ratings." *International Journal of Forecasting*, 28(3), pp. 607-622.
7. Danaher, P.J., Dagger, T.S., and Smith, M.S. (2011). "Forecasting Television Ratings" *International Journal of Forecasting*, 27(4), pp. 1215-1240.
8. Danaher, P.J. and Mawhinney, D.F. (2001). "Optimizing Television Program Schedules Using Choice Modeling", *Journal of Marketing Research,* Vol. 38, No. 3, pp. 298-312.
9. Dowling, G. (2004). *The Art and Science of Marketing*. Oxford University Press.

10. Dubin, J.A., Graetz, M.J., Udell, M.A., and Wilde, L.L. (1992). “The Demand for Tax Return Preparation Services” *The Review of Economics and Statistics*, 74(1), pp. 75-82.

11. Eastman, S.T., Neal-Lunsford, J. and Riggs, K. A. (1995). “Coping with Grazing: Prime-Time Strategies for Accelerated Program Transitions” *Journal of Broadcasting & Electronic Media*, 39, pp. 92–108.

12. Eastman, S.T. (1998). “Programming Theory Under Stress: The Active Industry and The Active Audience”. In: *Communication Yearbook*, 21: pp. 323–377.

13. Eastman, S.T. and Ferguson, D.A. (2006). *Media Programming: Strategies and Practices* (Seventh Edition). Belmont, CA: Wadsworth.

14. Edwards, R. and Holland, J. (2013) *What is Qualitative Interviewing?* London: Bloomsbury.

15. Forkan, J.P. (1986). Nielsen Waters Down TV Forecasters’ Tea Leaves. *Advertising Age*, (April 7), pp. 24-79.

16. Fournier, G.M. and D.L. Martin (1983), “Does Government-Restricted Entry Produce Market Power? New Evidence from the Market for Television Advertising.” *Bell Journal of Economics*, 14 (1), pp. 44-56.

17. Ghassemi Tari, F. and Alaei, R. (2013). “Scheduling TV commercials using genetic algorithms” *International Journal of Production Research*, Vol. 51, No 16, pp. 4921-4929

18. Gantz, W., Zohoori, A. (1982) “The Impact of Television Schedule Changes on Audience Viewing Behaviors” *Journalism Quarterly*, v59 n2 pp. 265-272

19. Gensch, D. and Shaman, P. (1980a), “Models of Competitive Television Ratings” *Journal of Marketing Research*, 17 August, pp. 307-15.

20. Gensch, D. and Shaman, P. (1980b), “Predicting Television Ratings” *Journal of Advertising Research*, 20 August, pp. 85-92.
21. Goettler, R. and Shachar, R. (2001), “Spatial Competition in the Network Television Industry”, *RAND Journal of Economics*, Vol. 32, No 4, pp. 624-656.
22. Head, S.W. (1985), "A Framework for Programming Strategies," in *Broadcast/Cable Programming: Strategies and Practices (Second Edition)*, Eastman, S. T., Head, S. W. and Klein, L. (Eds.), *Wadsworth, Belmont, CA*, pp. 3-38.
23. Head, S.W. and Sterling Christopher, H. (1987). *Broadcasting in America. A Survey of Electronic Media*. (Fifth Edition). Boston, USA.
24. Headen, R.S., Klompmaker, J.E. and Rust, R.T. (1979), "The Duplication of Viewing Law and Television Media Scheduling Evaluation," *Journal of Marketing Research*, 16, pp. 333-340.
25. Henry, M.D. and Rinne, H.J. (1984a), "Predicting Program Shares in New Time slots," *Journal of Advertising Research*, 24 (2), pp. 9-17.
26. Henry, M.D. and Rinne, H.J. (1984b), "Offensive versus Defensive TV Programming Strategies," *Journal of Advertising Research*, 24 (3), pp. 45-56.
27. Hinkelman, E. and Putzi, S. (2005). *Dictionary of International Trade – Handbook of the Global Trade Community*. World Trade Press.
28. Horen, J.H. (1980), "Scheduling of Network Television Programs," *Management Science*, 26 (4), pp. 354-370.
29. Kelton, C., Schneider, L. (1998), “Optimal Television Schedules in Alternative Competitive Environments” *European Journal of Operational Research*, Vol.104(3), pp. 451-473

30. Khalili-Damghani, K., Tavana, M., Sadi-Nezhad, S., (2012), "An integrated multi-objective framework for solving multi-period project selection problems" *Applied Mathematics and Computation 219 (6)*, pp. 3122-3138
31. King, N. and Horrocks, C. (2010), *Interviews in Qualitative Research*. London: Sage.
32. Lupo, T. (2014), "Non-dominated trade-off solutions in television scheduling optimization" *International Transactions in Operational Research 22,* pp. 563-584
33. Lupo, T. (2014), "Economic-statistical design approach for a VSSI X-bar chart considering Taguchi loss function and random process shifts" *International Journal of Reliability Quality and Safety Engineering 21(2):23*
34. Liamputtong, P., (2011). *Focus Group Methodology: Principle and Practice*. London: Sage.
35. McDowell, W. and Dick, S. (2003) "Has lead-in lost its punch? An analysis of primetime inheritance effects: Comparing 1992 with 2002" *International Journal on Media Management*, Vol. 5 (4), pp. 285-293
36. Meyer, D. and Hyndman, R., (2006) "The Accuracy of Television Network Ratings Forecasts: The Effect of Data Aggregation and Alternative Models" *Model assisted statistics and applications*, 1(3), pp. 147-155.
37. Mytton, G., Diem, P., and van Dam, P. (2016), "Media Audience Research: A Guide for Professionals". (Third Edition). Sage Publications.
38. Napoli, P.M. (2001), "The Unpredictable Audience: An Exploratory Analysis of Forecasting Error for New Prime-Time Network Television Programs." *Journal of Advertising* 30 (2), pp. 53-60.
39. Napoli, P.M. (2010), "Audience Evolution: New Technologies and the Transformation of Media Audiences". Columbia University Press, New York

40. Napoli, P.M. (2011), “Ratings and Audience Measurement” in *The Handbook of Media Audiences,* First Edition. Virginia Nightingale, Blackwell Publishing, pp. 286-301.
41. Peter, J. and Donnelly, J. (2002). “A Preface to Marketing Management”. McGraw-Hill Professional.
42. Reddy, S., Aronson, J., and Stam, A. (1998), “SPOT: Scheduling Programs Optimally for Television”, *Management Science*, 44(1), pp. 83-102.
43. Rust, R.T., and Alpert, M (1984), “An Audience Flow Model of Television Viewing Choice” *Marketing Science*, 3 (2), pp. 113-124.
44. Rust, R.T. and Echambadi, N.V. (1989), “Scheduling Network Television Programs: A Heuristic Audience Flow Approach to Maximizing Audience Share” *Journal of Advertising*, 18 (2), pp. 11-18.
45. Sapsford, R. and Jupp, V. (2006). *Data Collection and Analysis.* London: Sage.
46. Stipp, H. and Schiavone, N. (1990), “Research at a Commercial Television Network: NBC 1990” *Marketing Research*, (September), pp. 3-10.
47. Tiedge, J.T. and Ksobiech, K.J. (1986), “The `Lead-In' Strategy for Prime-Time TV: Does It Increase the Audience?” *Journal of Communication*, 36 (Summer), pp. 51-63.
48. Tiedge, J.T. and Ksobiech, K.J. (1987). “Counterprogramming Primetime Network Television” *Journal of Broadcasting & Electronic Media*, 31, pp. 41–55.
49. Tiedge, J.T. and Ksobiech, K. J. (1988). “The Sandwich Programming Strategy: A Case of Audience Flow”, *Journalism Quarterly*, 65, pp. 376–383.
50. Tiedge, J.T. and Ksobiech, K.J. (2006). “The Lead-In Strategy for Prime-Time TV: Does It Increase the Audience?”. *Journal of Communication* 36(3): pp. 51 – 63.
51. Uribe, R., Buzeta, C., Hurtado, D., (2011). “Looking for the audiences: The effect of using partial counterprogramming and a friendlier style of news presentation”. *INNOVAR*. 21 (42), pp. 151–159.

52. Webster, J.G. (1985), “Program Audience Duplication: A Study of Television Inheritance Effects” *Journal of Broadcasting and Electronic Media*, 29 (2), pp. 121-133.

53. Webster, J.G. (2006), “Audience Flow Past and Present: Television Inheritance Effects Reconsidered” *Journal of Broadcasting and Electronic Media*, 50 (2), pp. 323-337.

54. Webster, J.G. and Phalen, P.F. (1997), “The Mass Audience: Rediscovering the Dominant Model.” *Mahwah*, NJ: Lawrence Erlbaum Associates.

55. Webster, J.G., Phalen, P.F. and Lichty, L.W. (2014), “Ratings Analysis: Audience Measurement and Analytics” (Fourth Edition).

List of Websites:

1- http://encyclopedia.thefreedictionary.com/

2- http://www.thefreedictionary.com/content/

3- http://en.wikipedia.org/wiki/Audience_measurement

4- http://www.dataxis.com/

5- http://www.mideastmedia.org/industry/2016/tv/

6- http://www.lindo.com/

7- http://www.statista.com/statistics/273288/advertising-spending-worldwide/

8- http://www.zenithoptimedia.com/

9- http://www.scheduall.com/broadcast.html

10- http://www.solver.com

11- https://en.wikipedia.org/wiki/Gurobi

12- https://en.wikipedia.org/wiki/Push%E2%80%93pull_strategy

13- http://www.ipsos.com/

14- https://en.wikipedia.org/wiki/Computer-assisted_telephone_interviewing

15- http://www.barb.co.uk/

16- http://en.wikipedia.org/wiki/Marketing

17- http://www.beinsports.com

18- https://en.wikipedia.org/wiki/Block_programming

19- https://en.wikipedia.org/wiki/Prime_time

Appendix 1. Sample Questions (Quantitative Research):

Below is a sample set of questions in the MENA region, specifically in UAE, for collecting data for Quantitative viewership research.

"Hello I am………. from "XYZ" research company which is conducting a comprehensive media survey in UAE. Can I please speak with a responsible adult person of the household?

(In case the person contacted is the right person, continue or else once the right person is identified and contacted, reintroduce self and company and continue.)

We will be grateful if you could give us a few minutes of your time to answer our questions. I would like to assure you that all the information given will be treated in strictest confidence and no one will see it on its own.

Your household has been selected randomly and I would like to talk to one adult person in your household; so first I want to ask you to give me the names of the various members of your household aged between 15 years and 45 years. By members of household I mean those who live in this house in a permanent manner excluding maids and house helpers and including yourself.

(Write the names and ages on a list from the eldest to the youngest, including the person that answered your call, and ask to speak to the member that his/her rank matches the last number of the phone number you called.)

(Ask for an appointment if the right person is not available and register his/her name in the appointment window. Write in the box below the number of the adult family members.)

- **Record respondent gender : (Do not read responses)**
    1. Male
    2. Female

- **Can I please know your nationality: (accept only one response)**

Arabs

1- UAE local
2- Egyptian / Sudanese
3- Lebanese / Syrian
4- Palestinian / Jordanian
5- Other Arabs

Non Arabs

1. Indian – Malayalam
2. Indian - Other South Indians
3. Indian - Rest of India
4. Pakistani
5. Sir Lankan / Bangladeshi
6. Iranian
7. European / American
8. Pilipino
9. Other Non-Arabs

- **Can I please know what's your Marital Status : (accept only one response)**
    1. Single
    2. Married with no children
    3. Married with children
    4. Widowed or divorce

- **Can I please know what's your Household Monthly Income: (accept only one response)**
    1. Less than 4,000 Dirhams
    2. 4,000 to 6,999 Dirhams

3. 7,000 to 9,999 Dirhams
4. 10,000 to 14,999 Dirhams
5. 15,000 Dirhams or more
6. No answer

- **What's your Occupation: (accept only one response)**
  1. Manager
  2. Employee
  3. Professional (Doctor, Lawyer, Engineer….)
  4. Businessman
  5. Student
  6. Housewife
  7. Retired/Unemployed
  8. Technician
  9. Others

- **How old are you: (accept only one response)**
  1. 0-14 years
  2. 15-19 years
  3. 20-24 years
  4. 25-29 years
  5. 30-34 years
  6. 35-39 years
  7. 40-45 years
  8. 46+ years
  9. No answer

- **How often do you watch TV? (accept one response only)**
  1. Once a week
  2. Twice a week
  3. Three times a week
  4. Four times a week
  5. Five times a week
  6. Six times a week

7. Seven times a week
8. Less than Once a week
9. Don't watch TV / Doesn't own a TV

- **Did you watch TV yesterday?**
    1. Yes
    2. No
- If No then say: "Thank you for your time, the questions are over, Bye" and hang-up.
- If yes go to the next question

- **Read the answers as if they are part of the question and choose all the possible answers.**

- **When did you view TV yesterday: (Multiple answers)**
    1. **In the morning (8 am – Midday)**
    2. **In the noon (Midday- 4 pm)**
    3. **In the afternoon (4 pm – 8 pm)**
    4. **At Night (8 pm – 1 am)**
    5. **Late at Night (1 am – 3 am)**
    6. **Other than these**

- **Can you tell me What did you watch yesterday for at least 5 minutes (programs, channels or by time)**

(Choose all the possible answers)

<u>Arabic Channels:</u>

1. Dubai TV
2. Sama Dubai
3. Emirates TV
4. Dubai Sports
5. Abu Dhabi TV
6. Abu Dhabi Sports

7. Sharjah TV
8. Ajman TV
9. ART
10. LBC
11. Future TV
12. Aljazeera
13. Aljazeera Sports
14. Alarabia
15. Rotana Cinema
16. Rotana Music
17. Rotana Clips
18. Dubai Sport
19. Rotana Khaleejia
20. Space Toon
21. Nojoom TV
22. Others

Common Channels:

1. MBC 2
2. MBC 3
3. MBC 4
4. CNBC Arabia
5. One TV
6. Space Toon English
7. Orbit
8. Show Time
9. Others

Non Arabic Channels:

1. Zee TV
2. Asia Net
3. Sony TV
4. Ary Digital
5. Star Plus

6. Kairalli
7. Star News
8. Zee News
9. B4U Music
10. B4U Movies
11. Pakistan TV
12. Sahara
13. ND TV
14. E- masala
15. Others

16- Don't recall any channel

❖ **The questions are over; thank you for your time and bye.”**

Appendix 2. Sample Focus Group Questions[32] (Qualitative Research):

Below example is given for a set of sample questions (in the MENA region) for collecting data for Qualitative Viewership Research.

"XYZ" TV Channel Evaluation SCREENING QUESTIONNAIRE	QUESTIONNAIRE No. Write In ____________________
Respondent's name:	**FOR OFFICE USE**
Residential address:	**NATIONALITY** Local 1 Expat 2
Interviewers name:	**AGE** 18 - 23 1 24 – 29 2 31 – 43 3
Area:	**LOCATION** Country A 1 Country B 2 Country C 3 Country D 4

[32] Please note that some data and text are deleted and/or hidden for copyrights and confidentiality purposes.

<table>
<tr><td colspan="2"></td><td>GENDER
Female 1
Male 2</td></tr>
<tr><td>Res. Tel. No</td><td>Office Tel. No</td><td rowspan="2">For the purpose of this research, we will use focus groups from 6 – 8 respondents per group.

We need to conduct a minimum of 000 Focus group per country to cover the various demographic profiles.

This will also ensure that we have a good representation of respondents to evaluate both programs</td></tr>
<tr><td colspan="2">METHODOLOGY :
000 Focus Group Discussions
000 FGs / Country
Each group (6 – 8 Respondents)
All Respondents are Regular viewers of “XYZ” channel, (social and political programs)</td></tr>
</table>

Country A Sample

Age Group	Males	Females
18 - 23	1 (Local)	1 (Local)
24 - 29	1 (Local)	1 (Local)
31- 43	1 (Local)	1 (Local)
	3	**3**

Country B Sample

Age Group	Males	Females
18 - 23	-	1 (Local)
24 - 29	1 (Local)	-
31- 43	2 (Local)	2 (Local)
	3	**3**

Country C Sample

Age Group	Males	Females
18 - 23	1 (Expat Arab)	1 (Local)
24 - 29	1 (Expat Arab)	1 (Expat Arab)
31- 43	1 (Local)	1 (Expat Arab)
	3	**3**

Country D Sample

Age Group	Males	Females
18 - 23	1 (Local)	1 (Local)
24 - 29	1 (Expat)	1 (Expat)
31- 43	1 (Local)	1 (Local)
	3	**3**

INTRODUCTION

Good morning / afternoon / evening, I am __________, from **"ABC"**, research agency. We are currently conducting a study on TV programs and would like to invite you to participate.

DO NOT REVEAL IDENTITY OF CLIENT AT ANY TIME

Would you be interested to participate? **(IF 'Yes', CONTINUE)**

SECTION 1: DEMOGRAPHIC CRITERIA

First of all, I will need to ask you a few questions to find out more about you

1.0 Gender

Male	1	**CONTINUE**
Female	2	**CONTINUE**

1.1 When was the last time that you participated in a group discussion or a one-to-one interview in any research or commercial organisation?

Less than 6 months	1	**THANK and TERMINATE**
More than 6 months ago	2	**CONTINUE FOR ALL**
Never	3	

1.2. Do you or any of your family members work in the following industries?

Advertising	1	**TERMINATE**
Journalism / Media	2	
Market Research	3	
None of these	x	**CONTINUE**

1.3 May I please ask you a few questions about yourself? Can you please tell me your nationality?

Country 1 Locals	1	**CONTINUE according to the country**
Expat Arabs	2	
Country 2 Locals	3	
Country 3 Locals	4	
Country 4 Locals	5	
Any other	6	

1.4. Can you please tell me your age group **(Also please write down EXACT age)**

Below 18 years	1	**TERMINATE**
18 – 23	2	**ENSURE A MIX ACROSS AGES**
24 – 29	3	**ENSURE A MIX ACROSS AGES**
31 - 43	3	**ENSURE A MIX ACROSS AGES**
Above 43 years	5	**TERMINATE**

SECTION 2: CATEGORY INVOLVEMENT

2.1 Do you watch TV programs?

Yes	**CONTINUE**
No	**TERMINATE**

2.2 Which of these TV channels are you watching of?

TV CHANNEL	**Code**
Al-Arabiya	1
Aljazeera	2
MBC	3
Rotana	4
BBC	5
NBC	6

Dubai	7
Melody	8
Nile	9
others _____________ record verbatim	10

Respondents should be regular viewers of XYZ channel

2.3 Could you tell me which of these programs are you watching usually?

Programs	**Code**
Serials	1
Movies	2
Live TV Show	3
Political Show	4
Social Show	5
Documentary programs	6
Current affairs programs	7
Economical programs	8
Debates	9
others (____________) record verbatim	10

RESPONDENTS SHOULD BE REGULAR VIEWERS OF POLITICAL – SOCIAL-ECONOMICAL – CURRENT AFFAIRS – DEBATES PROGRAMS OR TOPICS

SECTION 3: RESPONDENT AVAILABILITY

3.0 We are planning to conduct a focus group interview on ___________________________ (Date) at ___________________________ (Time). The discussion will last for 2 hours. Could you please attend and give us your valuable opinions?

Willing to participate	1	CONTINUE
Not willing to participate	2	TERMINATE

Thank you for your time

Discussion Guide[33]

Flow: (Total time: 2 hours)

1. Warm up – Respondent introduction
2. Context setting – Understanding television viewership habits
3. Self-filling questionnaire fill up by respondents
4. Overall feedback of the concept 2

Introduction

- Moderator's name,
- Explain that you don't work for any of the companies or brands that we will be talking about, so don't mind what is said about them
- Opinions, no right or wrong answers … want their honest views
- Importance and value of participant's contribution
- Explanation of audio and video recording
- Confidentiality of discussions

A	RESPONDENT INTRODUCTION and UNDERSTANDING LIFESTYLE 5 – 7 minutes
	It's really great to have you all here and we hope to have a good time in the session 1. Let's start with introducing ourselves; could you tell me something about yourself? **MODERATOR TO NOTE RESPONDENT'S NAME, FAMILY INFORMATION, OCCUPATION ETC…** 2. How does your typical day look like? Tell me about your routine, about your work, about your evening, etc. 3. □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□□□□□□□□□□□□□□□□□□□□□ 4. □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

[33] For copyrights reasons, some questions in the discussion guide are hidden and represented as "□□□□□□□"

5. [illegible]

MODERATOR TO MAKE RESPONDENTS FEEL COMFORTABLE BEFORE PROCEEDING THE GROUP

B	TELEVISION VIEWERSHIP 15 minutes

Today we are here to discuss mostly about your media habits.

6. [illegible]
7. I would like you to describe your full day and all the moments throughout the day when you would typically watch television. To make this easier I have drawn a 24 hour clock and I would like each one of you to tell me about each point in time and your television viewing habits during this time of the day. If you don’t watch television at this moment, please let me know

MODERATOR TO RESTRICT DIVISION OF TIME ZONE MAXIMUM TO FOUR FOR A DAY i.e. Moderator to divide the whole day to four time zones and ask respondents the following questions

8. Let’s start with 6:00 am or the time you wake up : please describe to me;
   a) What do you typically do at this point of time? Why do you say so?
   b) What are the typical channels do you watch during this time?
   c) [illegible]
   d) [illegible]

MODERATOR TO PROBE : ANCHORS, ACTORS , TOPIC DISCUSSED, CONTENT , VISUALS , SHOW TIMING ETC

e) How do you watch these channels? By this I mean do you watch them through television or your mobile phones? Why do you say so?

f) Where do you watch television at this point of time? Why do you say so?

g) □□□

h) □□□

i) What are the kind of information do you like to view in television at this point of time? Why do you say so?

MODERATOR TO LOOK AT ACTUAL INFORMATION SOUGHT AT THIS POINT OF TIME : MULTIPLE TYPE OF INFORMATION ARE POSSIBLE

j) Is this type of information important for you at this point of time? Why do you say so?

k) Does the current channel/programme offer these kind of information that you are looking for? Why do you say so?

MODERATOR: PROBE AS ABOVE FOR EACH MOMENT ON THE CLOCK UNTIL RESPONDENT DECLARES A CERTAIN TIME AS INAPPLICABLE. TRY TO ELICIT ANY DIFFERENCES IN VIEWERSHIP BY RESPONDENTS WITHIN THE GROUP.

9. □□

[illegible]

C EXPOSURE TO RESEARCH CONCEPT - 40 minutes

MODERATOR TO EXPOSE RESEARCH CONCEPT BOTH TO YOUTH AND OLDER GROUP SEGMENT

Let us get into the main discussion today. I have a video with me which I would like to show you. Please watch it as a programme you watch it in your television

MODERATOR TO LOWER THE LIGHT AND PLAY THE VIDEO TO THE GROUP

[illegible]

MODERATOR TO ALLOW RESPONDENTS TO FILL THE SELF FILLING QUESTIONNAIRE. POST FILLING COLLECT THE SELF FILLING QUESTIONNAIRE AND THEN CONTINUE ASKING FOLLOWING QUESTION

Now that you have seen the video, I would like you to fill this sheet based on your observation.

MODERATOR TO ALLOW RESPONDENTS TO FILL THE SELF FILLING QUESTIONNAIRE AND CONTINUE ASKING QUESTION

SPONTANEOUS THOUGHTS

10. What comes to your mind immediately post seeing the video? What are the thoughts, moods, ideas that come to your mind after seeing the video? Why do you say so?

11. □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□□

MESSAGE COMPREHENSION

12. What do you think the video is about? Why do you say so?
13. □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□
14. □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

OVERALL APPEAL

15. What is that you liked in this video? Why do you say so?
    a. □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□□□□□□□□□□□□□□□□□□□□□□
16. □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□□□□□□□□□□□□□□□□□□□□

UNDERSTANDING SPECIFIC ELEMENTS

<u>FORMAT</u>

17. How did you like the format of the video?
18. □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□□□□□□□□□□□
19. □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□

<u>ANCHOR</u>

20. What are your views on anchor of the video?
    a. What do you think about the anchor?
21. Are you able to understand what anchor is telling about? Why do you say so?
22. □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

23. [illegible]

    a. [illegible]

TOPIC

24. What are your feelings on the topics covered? Why do you say so?
25. Do you find the topics discussed here is relevant? Why do you say so?
26. [illegible]
27. [illegible]
28. [illegible]

VISUALS

29. What do you think about the clarity and the sound of video? Why do you say so?
30. What are your views about sound played with video? Do they synchronize with each other?
31. [illegible]
32. [illegible]
33. [illegible]

UNIQUENESS

34. Have you watched this kind of programme before?
35. If yes, what is the programme about and where have you watched this [illegible]
36. [illegible]

RELEVANCE

37. Do you think this kind of programme suits your preference? Why do you say so?
38. □□□

USER IMAGERY

39. Who do you think would watch this kind of programme? Describe them to me in terms of their demographic, age, personality, etc.. Why do you say so?
40. □□□

INTENTION TO VIEW

41. If aired, would you watch this kind of programme? Why do you say so?
42. When do you think would this kind of programme be aired into channels? Why do you say so?
43. □□
44. □□□

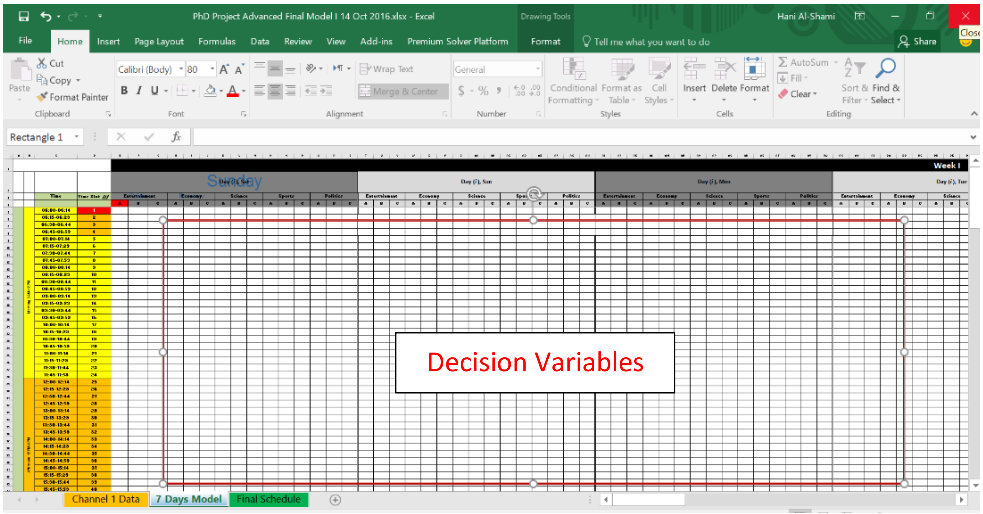
SUGGESTIONS FOR IMPROVEMENT

45. What do you think should be added to the programme to make it more attractive? Why do you say so?

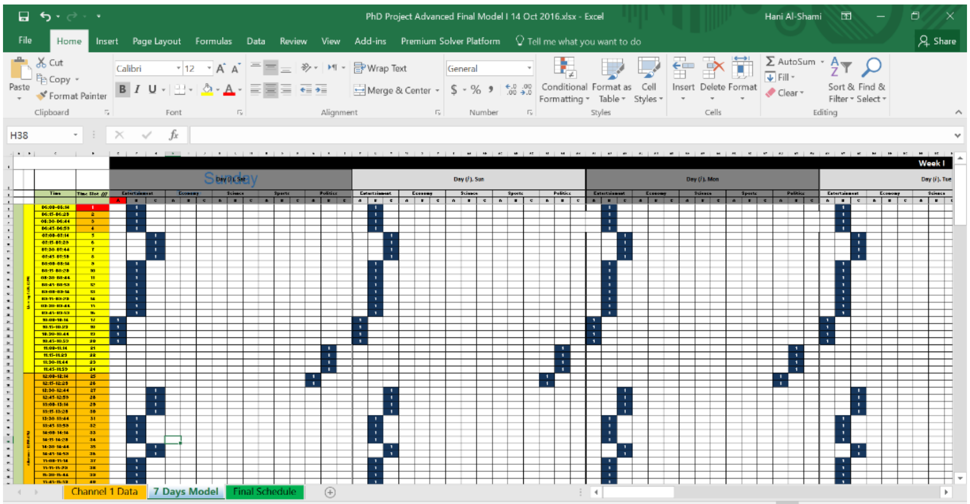
THANK and END THE DISCUSSION

Appendix 3. Running the computer model (step by step):

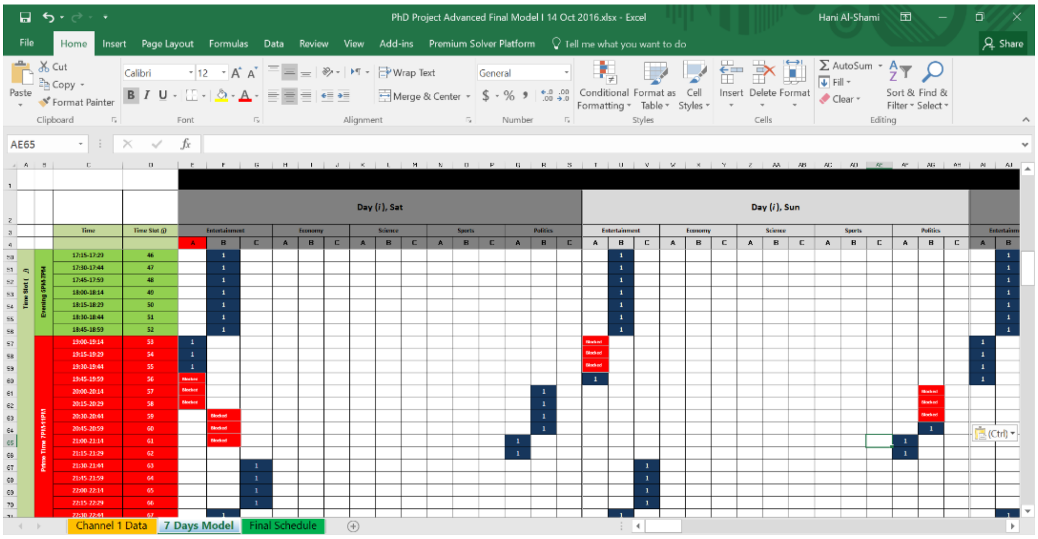
Step 1: As shown in Picture (1) below, Decision Variables is inputted in to the model by the programme planner. It can be the previous schedule, or it can start from scratch, Picture (2). The planner should set the time slots he / she need to block or to restrict to a specific programme type and quality as shown the Pictures (3). This will require programming in the solver.



Picture 1: Decision Variables



Picture 2: Decision Variables

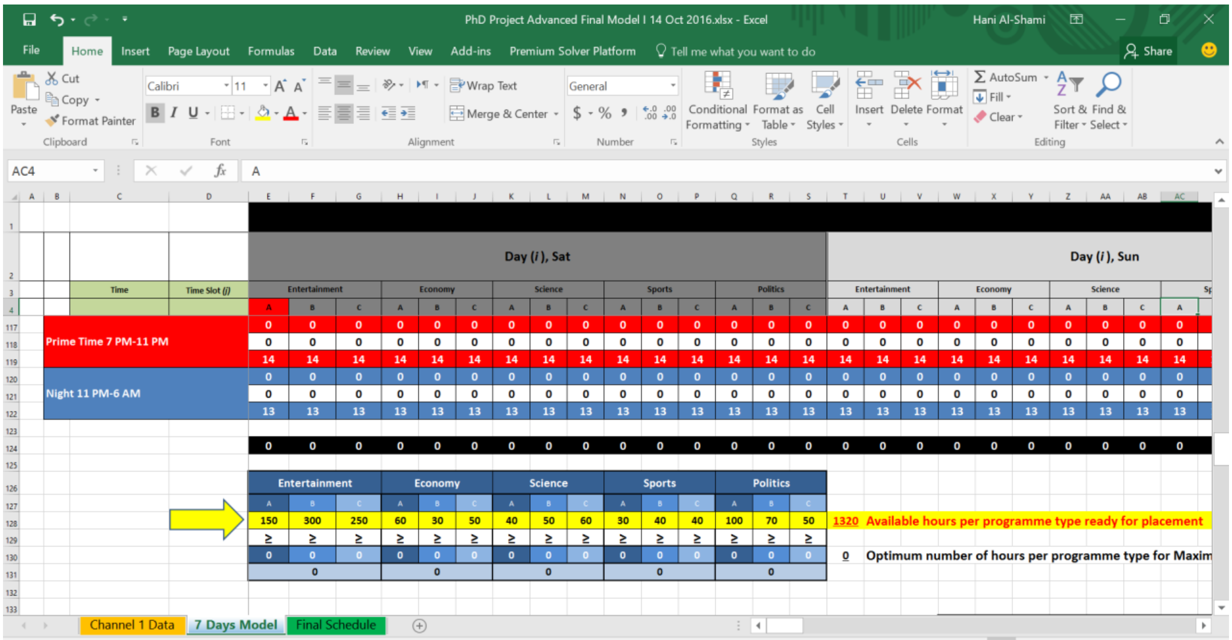


Picture 3: Decision Variables (blocking time slots)

Step 2: the programme planner can set the upper and lower limits that are allowed for each programme type and quality for the total day as well as the specific day parts as shown in Picture (4).

Picture 4: Upper and Lower limits for day and day parts

Step 3: The programme planner then inputs in this step the available hours in the television station archives ready to be scheduled. In addition, the planner can add more hours on some programme types and qualities to test and see the impact of buying or commissioning new programme hours on the viewership and cost. This is shown in Picture 5 below.



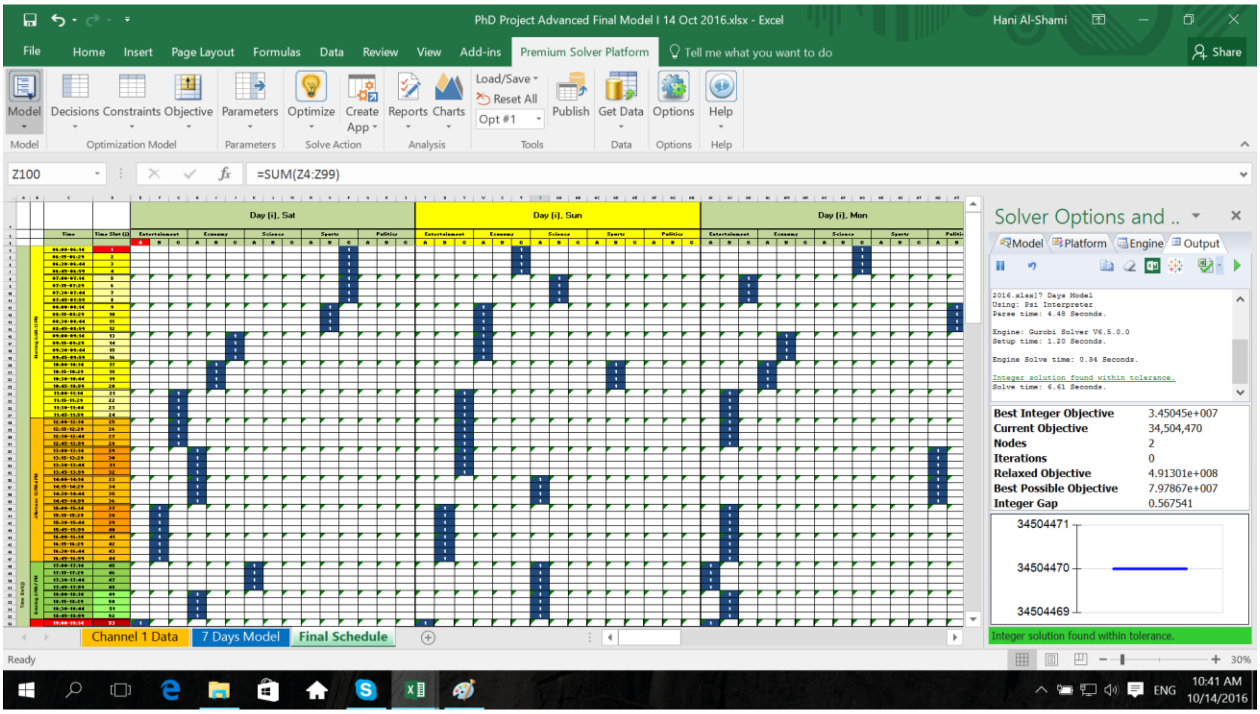
Picture 5: Available Hours for Scheduling

Step 4: The cost per programme and budget available to be allocated for the total schedule is inserted in this step for the planner to test the impact of increasing and/or decreasing in programmes cost per minute on viewership. Decision makers can also test the impact and return of investment for the television station in terms of viewership numbers. Different scenarios can be tested until the planners arrive at a final schedule that can attract the maximum number of viewers within budget limitation. This is shown in Picture (6) below.

Cost of Programmes		Cost per Minute ($)	(v) Cost per 15 Minute ($)	Programme Hours	
Entertainment	A	950	14,250	-	-
	B	750	11,250	-	-
	C	450	6,750	-	-
Economy	A	650	9,750	-	-
	B	595	8,925	-	-
	C	375	5,625	-	-
Science	A	765	11,475	-	-
	B	650	9,750	-	-
	C	250	3,750	-	-
Sports	A	850	12,750	-	-
	B	750	11,250	-	-
	C	400	6,000	-	-
Politics	A	950	14,250	-	-
	B	650	9,750	-	-
	C	350	5,250	-	-
					-
Available Budget for All Programmes					7,000,000

Picture 6: Available budget and Cost per Programme Minute

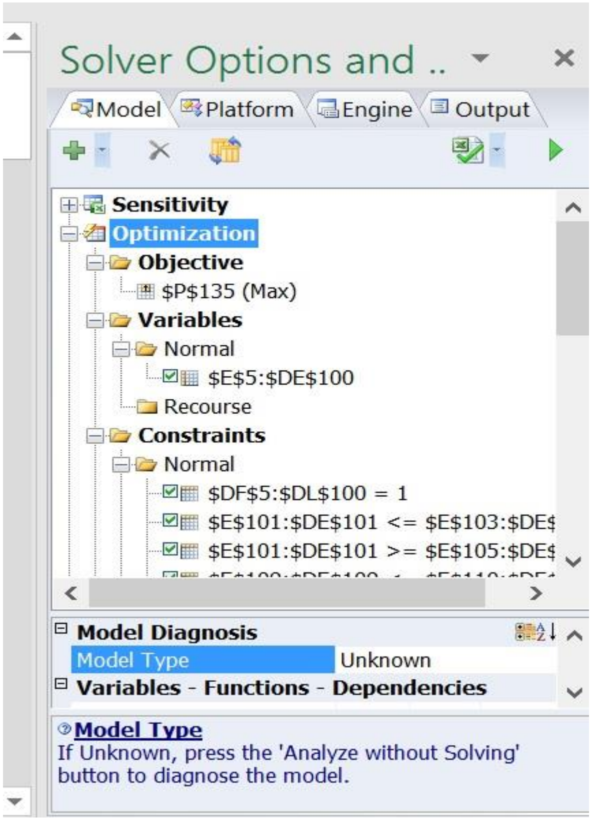
Step 5: The first 4 steps will give the initial optimum programme schedule that maximises viewership within the limitation set in the computer model. However, as discussed in the thesis, the second Excel sheet showed in Picture (7) below is where the schedule planner builds the logic to book a number of time slots such as 3 or 4 for each programme based on his experiences as well as the available programmes in the archives. In this step, the programmer can decide on the number of repeats per day, the frequency of repeats every day, every other day, etc.



Picture 7: Excel Sheet 2 where the logical formatting is built

Appendix 4. Optimisation Model Options and Specifications:

In addition to the formulas built in the excel sheet, all variables, constraints, bounds and objective function formulas are programed in the frontline solver input module as shown in in the Figure below.



In the table below, the codes of the input demand data for the software that is used in this work is presented in order to give an idea of how the scheduling problem is built and solved.

Optimisation Model Options and Specifications	
Objective Function	$P$135 (Max)
Variables	$E$5:$DE$100 (Normal)
Constraints	$DF$5:$DL$100 = 1
Constraints	$E$101:$DE$101<=$E$103:$DE$103
Constraints	$E$101:$DE$101>=$E$105:$DE$105
Constraints	$E$109:$DE$109<=$E$110:$DE$110
Constraints	$E$109:$DE$109>=$E$108:$DE$108
Constraints	$E$112:$DE$112<=$E$113:$DE$113
Constraints	$E$112:$DE$112>=$E$111:$DE$111
Constraints	$E$115:$DE$115<=$E$116:$DE$116
Constraints	$E$115:$DE$115>=$E$114:$DE$114
Constraints	$E$118:$DE$118<=$E$119:$DE$119
Constraints	$E$118:$DE$118>=$E$117:$DE$117
Constraints	$E$121:$DE$121<=$E$122:$DE$122
Constraints	$E$121:$DE$121>=$E$120:$DE$120
Constraints	$E$128:$S$128>=$E$130:$S$130
Constraints	$H$153>=$H$155
Bounds	$E$60:$E$62=1
Bounds	$F$63:$F$65=1
Integers	$E$5:$DE$100 (Binary)