Master's Thesis in Engineering

Efficient Penetration Policy for Internet Connection in Pakistan Rural Areas

- An Analytical Hierarchy Process Approach -

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Technology Management, Economics and Policy Program

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Abstract

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Understanding the preferences of Internet users is useful for ICT (information and communication technology) policy and planning. Infrastructure of telecommunication is recognized as the key and fundamental factor for economic and social development outside the limits of geographical boundaries. Beyond Urban communities, Telecommunication technology infrastructure is a necessity for social benefits, growth, connection and competition, more in the rural communities in developing countries.

This study shows appearance of Internet connection in rural areas of Pakistan, and specifically the aim of this research is concerned with a comprehensive examination and analytical procedures on the selection of optimal telecommunications technology infrastructure in Pakistan’s rural areas.

Literature review was accomplished to investigate the knowledge and understanding in the areas of Multi-Criteria Decision-Making (MCDM) approaches, with particular focus on the analytical decision processes. The findings show that the Analytic Hierarchy Process (AHP) is a powerful decision method which is capable of modeling such a complex problem. An Analytic Hierarchy Process (AHP) method is presented that can be used for the evaluation of alternate technologies in telecommunications. The method is based on pair-wise judgment between various factors that affect the quality of service in a described hierarchical formation.

This research will provide valuable insights for the policy makers from both academics and professionals, on Telecommunications infrastructure providing demonstration and how such rural technology selection decisions can be made within Pakistan’s rural areas.

Keywords: Analytical Hierarchy Process (AHP), Internet penetration, telecommunication infrastructure, multicriteria decision making (MCDM), technology selection, rural Pakistan.

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Chapter 1. Introduction

1.1 Overview

In the modern information technology revolution the Internet plays an indispensable role. It is the fastest diffusing ICT to date. For instance, Internet access spread to 50 million users in the world in only 4 years compared to the television and the radio, which took 38 years and 13 years, respectively, to reach the same user access level (ITU, 1999). Another more attractive phenomenon is the number of countries linked to the global network. From over 20 in 1990, there were more than 200 nations linked to the Internet by July 1999 (ITU, 1999). Despite rapid word-wide diffusion of the internet, there has been a great disparity between developing and developed countries – rich and poor regions – in terms of the number of Internet hosts and internet users (Manandhar, S, P. 2012). This rapid technological change was driven by the demands of information access. Telecommunications technology became a tool for the delivery of information, affecting all sectors from business to education, from healthcare to entertainment. Telecommunications is an important element in any country's strategy for reconstruction and development as it suggests information links between urban and rural areas that can vanquish distance hurdles which interrupt development. In urban areas there is dynamic competition for long distance, wireless telephone, and broadband internet access. However, in rural areas, even basic telephone services may become difficult or impossible to maintain for many of their inhabitants. Such areas are technologically poor and need special consideration and efforts if they are to actively participate in the information age.

Rural communities need better services to compensate for their geographical isolation and cost of being far from the cities. Developments in telecommunications technologies make it possible to supply services in rural areas at reasonable prices, which were earlier not possible. The planning and development of telecommunication infrastructure in rural areas and risky environment require longer time involving a substantial number of manpower from many suppliers as compare to urban centers, but an infrastructure provider is responsible for providing transmission bandwidth for them, these include: Wireless, Fiber cables, undersea cables, satellite, etc.

There are several studies of International Telecommunications Union (ITU, 1989 and ITU-D, 1997) which identified the need to investigate various issues related to the deployment of telecommunication services to settlements of rural communities as a problem requiring urgent action. These studies have also shown that telecommunications, particularly in rural areas need access to the main Telecommunication network, which can facilitate many development activities, such as agriculture, industry, social, education, health care, etc. which are unevenly distributed in such areas.

Nowadays there are various criteria available for technology assessment and a different alternatives, the selection procedure becomes complicated. There are many of choices of technologies available in the market to be applied to rural areas, depending on the nearby conditions of the concerned areas. However, the selection and deployment of such rural technologies are characterized by complex issues that are not only technological but are complex due to the complexity of interactions among the different elements affecting the process (Andrew and Petkov, 2003). In general, the telecommunication backbone is a key problem for the rural areas information infrastructure.

1.2 Research motivation and objectives

This study is about telecommunications technology infrastructure in rural areas of Pakistan, to promote fundamental factors of modern services, non-existence of such proper telecommunication infrastructure will delay the delivery of such services. There is necessity to provide access to the central telecommunications network and enlarge connectivity to Pakistan's rural areas, by the choice of appropriate telecommunications infrastructure technology that will provide the required e-services within various constraints. The backbone network offers the long-haul signal transmission from the country's central telecommunication centre to the remote access network of the particular area. This network may be wireless or wire-line (copper wires), including analogue and digital transmission technology through fiber optic, wireless or satellite transmission media. But the deployment of telecommunication technologies infrastructure in rural areas is critical because of the presence of many associated problems, cost affordability and the correct choice of telecommunication technologies. For this problem there is a need of methodology that can help telecommunication infrastructure providers to understand better that how to reach to successful investing decisions in available different rural technologies and the need of account for technical, social and economic elements.

Furthermore, according to (Andrew and Petkov, 2003 and Nepal, 2005) the deployment of rural telecommunication services and infrastructures in developing countries is considered by many researchers as a difficult system of people and technology which are co-dependent on other systems or subsystems and characterized by multiple stakeholders. These issues initiated the need to think the selection process from several point of views to discover methodologies that will facilitate contribution and engagement, which contain improvement of the difficulties by the needed rural communities.

This study mainly addressing the questions of how can the telecommunications service providers establish the backbone network model for the rural areas of Pakistan? and how to select the most suitable backbone infrastructure technology for the rural areas of Pakistan? But there are complexities which are involved with the consideration of a set of criteria such as technical aspects, public issues and cost attributes. Taking these attributes into consideration, the problem of selecting the most appropriate telecommunications infrastructure technology for rural areas Pakistan is to be addressed in this study by using a multi-criteria approach, with particular focus on the analytical hierarchy process (AHP).

This study, thus, aims to provide a comprehensive examination regarding rural telecommunications infrastructure selection by conducting an analytical decision analysis within the context of Pakistan. Based on the motivation, background and objective of this research the main aim will be pursued through the following objectives:

1. To examine and analyze the issues and challenges involved in the selection of rural telecommunications technologies in Pakistan.
2. To explore and analyze suitable MCDM (Multi Criteria Decision Making) methods particularly the Analytic Hierarchy Process (AHP) that can be applied to choose the most appropriate telecommunications technologies for Pakistan’s rural areas.
3. To formulate AHP decision model for selecting potential technology options concerning rural telecommunications infrastructure for Pakistan.
4. To propose strategy for improvement of decision processes related to Pakistan’s rural telecommunications infrastructure selection.

And it is assumed that the conducted research and investigation can be modified to integrate the unique needs of other rural areas with similar characteristics.

1.3 Structure of the Thesis

This study is structured into five chapters and a brief description of the remainder is summarized as follow: Chapter one introduced the overall overview and information for the telecommunication infrastructure in rural areas, and specifically for Pakistan's rural areas. This chapter also included the background information about the problem of the selection of suitable backbone infrastructure, objectives, motivation and structure of the thesis.

The second chapter covers a review of the related work by exploring the attributes affecting the selection and deployment of rural telecommunications infrastructure in a Pakistani scenario. It also covers the importance of the application of telecommunication services in rural area. This chapter investigates deep analysis of rural situation and the requirement of telecommunication to growth and development, economic and social well-being. It also includes various factors faced by policy makers of rural infrastructure, and in particular, factors that influence the selection of rural telecommunications technologies. It presents an explanation of the activities that were used as means to consolidate the final list of selection criteria.

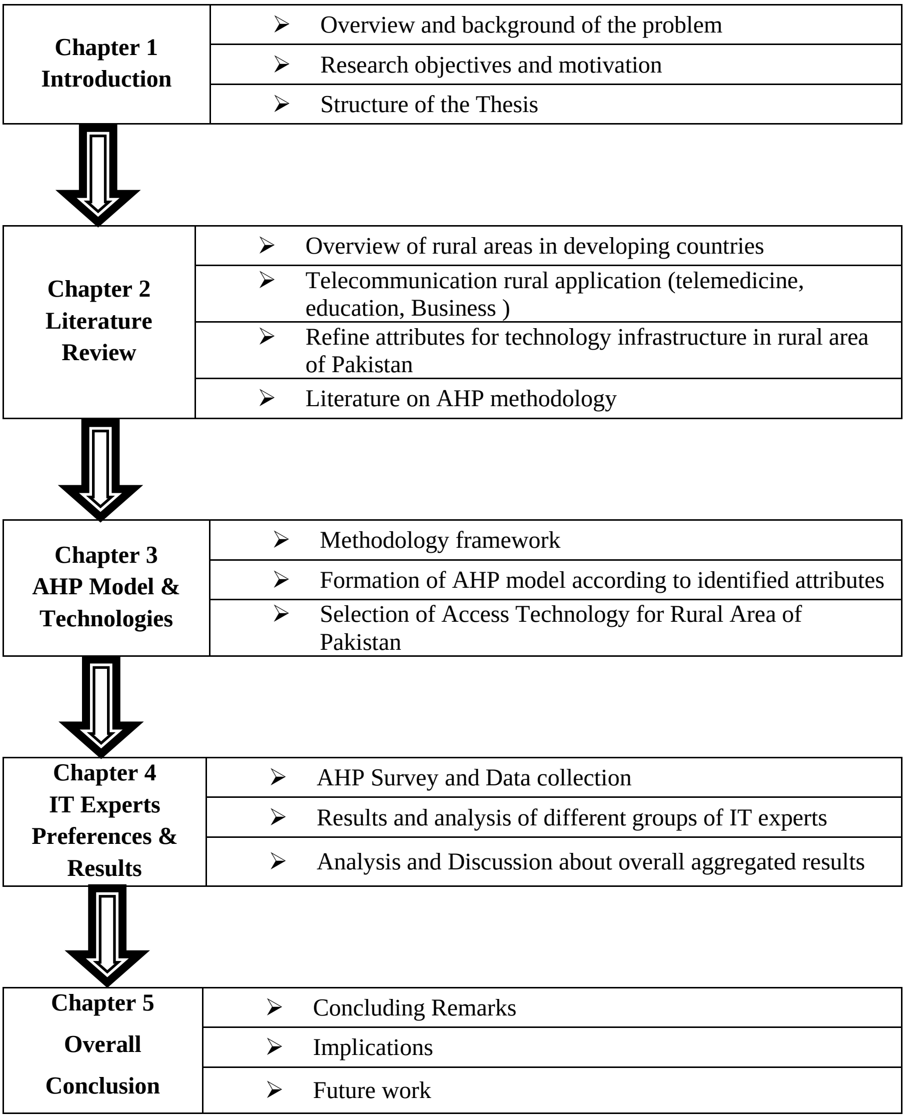

Figure 1.1: Structure of Thesis

Chapter three briefly introduced the AHP model and access technologies which is the fundamental methodology of the proposed approach. The Analytical Hierarchy Process (AHP) has been widely applied to a range of decision problems with diverse and sophisticated solution. So this chapter describes the structuring of AHP model for the selection of telecommunication backbone infrastructure and different media access technologies available for Pakistan’s rural areas.

Chapter four covers the collection of data and AHP analysis phase. For pair-wise comparisons of the identified attributes the AHP survey questionnaire was developed. Data was collected from planners of rural areas infrastructure and from different IT experts, government employees, Private employees, and technical staff, and data was analyzed using pair-wise comparison of the elements on a qualitative scale. So, chapter four describes the AHP survey, data collection and synthesizes of results, in detail related to the selection of technology infrastructure for Pakistan rural area case.

Chapter five concludes the overall objective of the research. It also discusses the implication of the findings, recommendation and suggestion for the future work.

Chapter 2. Literature Review on Rural Telecommunication

To find optimal connectivity access technology, it was needed to assess the technologies that could possibly be deployed in rural areas. From a technical point of view rural telecommunications systems should satisfy certain technical conditions, in order to be economically attractive. Proper decisions need to be made to ensure the provision of the most proficient network and most helpful system within numerous constraints (ITU-D, 1997). This chapter includes various factors that generally faced by policy makers of rural infrastructure, and in particular, factors that affect the selection of rural telecommunications technologies. It presents an explanation of the activities that were used as means to merge the final catalog of selection criteria.

This chapter investigates into deep analysis of rural situation and the requirement of telecommunication to growth and development, economic and social well-being. The summary is presented in the end of this chapter.

2.1 Characteristics of Rural Areas in Developing Countries

The population of rural areas is more in percentage and they are living with poor and low life standard. Majority of them are jobless and uneducated. Unluckily, if someone gains an education, they struggle to shift to urban areas for better jobs. If government thinks only about the education of rural people so that is not enough. There is requirement to develop their lives within their current locations; similarly they love to live there with their own resources. Therefore, there is requirement for horizontal co-ordination among Government sectors and vertical co-ordination between local leaderships and national policy-makers to make sure a united response to consider rural community and to support rural development.

Rural areas have distinctive characteristics that need appropriate technology to help the area. According to (ITU-D Group 7, 2000), in 2000 more than half the world's population lived in rural areas. Rural areas are described by one of the following features (Kawasumi, 2000):

- Challenging obstacles, such as mountains, lakes, rivers, deserts and long distances between settlement areas, which cause costly construction of wired telecommunication networks.

- Hard climatic conditions that make massive demands on certain components of telecommunications equipment (e.g., the remote switch and antenna), accordingly adding to the costs of maintenance and installation.
- Absence or lack of public facilities, such as usable water, regular transport, reliable and consistent electricity supply, access roads, and an existing communication infrastructure.
- Underdeveloped social framework, such as for education, health, small business and lack of most government services.
- Low level of economic activities with few jobs opportunities; the existing economic system may be based mainly on agriculture, fishing or handicrafts.
- Low per-capita incomes, as low-paying work precede to low family incomes. Ultimately, there is low demand for communication services.
- High illiteracy rates and low educational levels. Thus, there is insufficiency of technical personnel and that may become difficult or impossible to maintain for many of their inhabitants.

To provide a basic network infrastructure the above characteristics make rural areas a hard environment for Telecommunication Company. To understand rural problems and issues in developing countries, it is essential to investigate the demographic characteristics, benefits and challenges of rural environments. Furthermore, among these problems the most serious are lack of necessary funds and work opportunities, and as a result insufficiency of such cultural resources and opportunities for professional advancement faced, youths are likely to move to urban areas, which can provide higher education and career opportunities. The divide between rural and urban communities is increasing annually in terms of job opportunities, economy, education, health care, public service and public safety (Hudson, 1999).

2.2 Telecommunication in Rural Areas

"Telecommunications in rural areas should be offer the same services as offered in urban areas such as telephone, data transmission, video transmission and other services, both for individuals (private subscribers) and for the public communities" (ITU-D, 1997). In a developing country rural Telecommunications planning is a difficult procedure; The Planning of rural telecommunications services is characterized by a multitude of difficult problems (Andrewa, Rahoo, and Nepal, 2005). Aside from the provision of some infrastructure for the provision of services, the provision of proper telecommunications infrastructure is neglected in several rural areas in developing countries. It is the disadvantage of rural areas that they do not receive the technology as quickly as urban areas do. Rural communities are not benefiting from the quality of life and economic opportunities that new technologies bring because of the unavailability of telecommunication infrastructure. Therefore for developing countries it is a great challenge to provide and ensure the relevant telecommunication services and applications, such as telephone service, telemedicine, internet, e-learning etc. These services will promote the rural development and also the resulting advantages of economics, agriculture, cultural and social development are extended effectively and efficiently. The aim focus of this study is on the provision of telecommunication infrastructure for rural areas of Pakistan. Another study from (ITU-D, 2006) stated that "Planning of rural telecommunication infrastructure should first consider the development of rural areas as an essential part of a coordinated evolution in a given country".

According to (ITU, 2010) repot it stated that in most developing countries the rural telecommunication services are growing but still in need of improvement, statistics from (ITU, 2010) indicate about telephony services and internet access as follow

- Almost 90% of the world population is subscribed by mobile cellular network.
- 50% population of the world lives in rural areas and 75% of rural population subscribed by mobile cellular networks.
- Africa showed the lowest coverage; where over 50% population of the rural area is covered by a mobile cellular network. And in

Africa the biggest increase recorded in rural mobile subscription between 2000 and 2008.

- In developed countries 95% of rural areas are covered by a mobile cellular network signal. In which few have internet access and more than half of rural households have a telephone technology.
- In developing countries rural inhabitants rely more on mobile technology than on fixed telephony, mobile penetration rates are reaching over 50%, while fixed telephone penetration in rural households often below 5%.
- In developing countries over 80% of people still do not have access to the Internet and from world's population 26% was reported online at the end of 2009.
- Almost 60% of inhabitants in developed countries had Internet access as compared to 12% of inhabitants in developing countries. This showed very low internet penetration.

Despite government legislations, in developing countries rural areas remain far behind than urban in advanced telecommunication development. Theoretically it is simple for the governments to confirm development, but it is very hard to implement policies and strategies to encourage it. By the shift to an information economy, rural areas are being strongly affected. (Hudson, 1999). The provision of telecommunication indicates rural development and is therefore considered an essential infrastructure element, but development of rural culture and environment is not justified by installing telecommunications networks, equipment and computers. Many studies from around the world investigate and conclude positive relationship between in economic improvement and access to telecommunication capabilities. As we discussed above that telecommunication is a development tool but sometimes telecommunication has been ignored by planners and they put telecommunication in a low rank with other public utilities like roads, water, and power supply, although telecommunication is a key element of conveyance of information. Telecommunications is essential but not enough for rural development because of the lack of different utilities and facilities which are closely related with the need for improvement of rural telecommunications. In order for local telecommunication to be successful, there is a necessity for a basic level of literacy and training.

The Information technology literacy in rural areas is very low and the understanding of technologies and computers are neglected. Computer literacy and training should be the purpose for the people residing in rural areas, and the use of localized software solutions would be useful in providing support for their understanding. The majority of opinions are that providing connectivity to residents of rural areas can be an innovative way to empower the economy, community and individuals.

2.2.1 Telecommunication rural applications

Telecommunications have been verified to be the rapid medium to access services. The new applications being introduced by telecommunication companies are being created to meet rural requirements and are often connected to development efforts. Suchlike applications include telemedicine, distance education, and community and business development (ITU-D Group 7, 2000).

i. Telemedicine:

Telemedicine has been explained as the utilization of electronic information and communications to provide and support healthcare when distances split the members (Field, 2002). To consult a specialist physician, the people of rural areas have no choice but to travel to big cities, spend money and hard time on transportation. Most of the times, due to bad conditions of roads and traffic, the patients are unable to consult the concerned physician on the day of appointment.

In many developed countries it is an initiative for the delivery of medicine at a distance, using communications and information technologies. This approach provides a wide range of benefits to individuals such as monitoring and diagnosis of patient through multimedia communication connections between urban and remote rural facilities (health centers, hospital etc) which may develop home health care services for rural inhabitants. Telemedicine connections can develop the quality of rural health care by this mean.

There are some challenges which are linked with the utilization of telemedicine systems which include lack of physician interest, high telecommunication costs and failure to build evaluation into the design process. Experience has verified that important telemedicine applications contain training and in-service coaching of remotely situated health care staff. And for real time application of telemedicine a high speed of bandwidth will be required.

ii. Distance education:

Distance education is utilized in a broad range of purposes such as colleges and universities use it to increase the number of students who have approach to higher education; companies use it to upgrade their employees skills; individuals use it for their own professional advancement to boost their career opportunities; governments use it to provide on-the-job training to teachers or other employees to boost the quality of traditional primary and secondary schooling, and to convey instruction to rural areas that might not be served. The delivery of distance education through technology (satellite or internet) may provide an ideal way for rural schools to provide best education to their students available anywhere and anytime. Technology is an important contributor to the transformation of distance education, although the use of technology for distance education is not new television and radio has been used effectively. New technologies offer options to expand educational opportunity and improve quality, but inappropriate decisions whether to use technology or what type of technology to use can be costly and can delay the benefit of a distance education.

Utilizing video and voice capabilities need high bandwidth to deliver services to rural areas, which is a technical challenge. Rural and remote inhabitants can enjoy and get benefits from using telecommunication technologies which has the potential of new educational and training possibilities. Distance education programs need flawless management and financial planning to ensure sustainability.

iii. Community and Business Development

A big improvement is being made in business development and rural community through the introduction of telephony, Tele-centers, e-mail, and radio broadcasts. The successes of business development and community applications were found to depend on the availability of relevant content and local language support (ITU-D Group 7, 2000). In many developing countries rural communities access telecommunication through community centers, schools, coffee shops or available Internet café etc. Therefore, such centers allow emigrants to keep contacts with the friends and family that they have left behind in the villages, promoting profitable revenues from long distance calling charges.

These centers may also provides facilities of printing, scanning, composing etc which creates jobs opportunities and provides platform for small business in such rural and remote areas.

2.3 Attributes for deploying Rural Telecommunication Infrastructure

The selection and deployment of rural telecommunications technology is a complicated process. And the problem is defined for the selection of appropriate technology for rural areas based on criteria, so there is a need to consider technical, economical and public issues before deciding on a specific rural telecommunications technology. The most important and creative issue in making a decision is to adopt the factors that are relevant for that decision" (Saaty, 1990). Previous studies showed that each telecommunication infrastructure supplier have its own criteria, sub-criteria and alternatives for the particular problem. Several pieces of research have been undertaken concerning the selection of telecommunications infrastructure technology which is designed to extend e-services applications to rural areas. Without sufficient knowledge about particular rural area it is impossible to deploy a telecommunication infrastructure. Introducing advance telecommunication services to rural area and getting the people to adopting and having used to, take a lot time.

(Sasidhar and Min, 2005; Douligeris and Pereira, 1994) investigated cost, quality, and speed attributes and use Multi Criteria Decision Making (MCDM) methods particularly the Analytic Hierarchy Process (AHP) for selection of telecommunications network. (Chemane et al, 2005) explored several criteria with respect to financial and technical aspects and stated that selection of most appropriate Internet access technology is a challenging and complex process. With the use of broadband internet access, developed countries are enjoying the advantages of the technological transforms but developing countries have issues of selecting inappropriate choice of access technology, Low adoption of ICT and high cost of access to technologies.

(Andrew, P.Rahoo and T.Nepal, 2005) stated that the planning of rural telecommunication services is characterized by a great number of complex issues like uncertainty, multiple conflict objectives and security of physical technology infrastructure. AHP model is utilized for providing suitable solutions in the selection of telecommunication technologies for rural areas. And 51 sub criteria were categorized into 5 first level categories e.g. “Service Standard”, “Cost”, “Environmental issues”, “Social and demographic issues” and “Regulatory and technical standards”. For the deployment of telecommunication infrastructure it is a complicated challenge to provide affordable and accessible advance services to rural inhabitants who have low financial resources. To provide efficient and optimal telecommunication technology require different expertise in different disciplines which involves in designing, constructing equipment installing, testing, monitoring and managing further activities for consistent accessibility. Before designing and planning a telecommunication infrastructure in a rural area, it is highly recommended that the needs of the area and the infrastructure must be economical.

After discussion and conclusion from different studies on different issues that may affect the provision of telecommunication services in the rural areas, Pakistan rural areas need a list of possible criteria when selecting telecommunication technologies. Initially a list of 20 criteria (cost, technical aspect, public issues, regulatory, environmental issues, fixed cost, variable cost, subsidy, security, reliability, coverage, maintenance, flexibility, bandwidth, contents and development, community of interest, licensing issues, spectrum availability, parallel infrastructure and climate condition) was produced that affecting the choice of rural telecommunication technologies for the Pakistan rural areas. There were some attributes which were not suggested and the list was further revised and the criteria reduced to **17** different attributes (technical aspect, public issues, cost, Infrastructure, coverage, reliability, security, bandwidth, maintenance, contents & development, community of interest, government support, spectrum availability, supporting policies, fixed cost, variable cost and subsidy). With the main goal of this research being ‘Selection of efficient backbone technology infrastructure for rural areas of Pakistan’ the **17** criteria were categorized into **3** first level categories; ‘Technical Aspect’, ‘Public

Issues', and 'Cost'. We will talk in detail about all these attributes and grouped them together according to their perspective criteria.

2.3.1 Attributes for Technical Aspect

The process of establishing an integrated telecommunication infrastructure and selecting the most optimal backbone technology in rural areas of Pakistan was the primary objective of this study. The results of this study may be useful to other developing countries. Telecommunications infrastructure has shaped societies in various ways in order to provide basic Advance services, but in rural areas economic characteristics make is complicated to provide telecommunication services of a satisfactory prices and quality. In developing countries rural transportation systems are often not well managed and small, therefore most of the rural communities may not be reachable at all by road and technical staff availability on site is rare. And infrastructure maintenance became very costly. Similarly, many rural areas are not linked to national power grids, and so operators have to provide their own energy, (Gasmi and Virto, 2005).

Following are some technical attributes that may affect the choice of optimal technologies for access to rural areas that will provide the most efficient network. However, technical attributes can also be classified into attributes such as infrastructure, coverage, reliability, security, bandwidth (speed and service) and maintenance as explained below.

i. ***Infrastructure:*** To encourage rural development parallel infrastructure is needed which support rural telecommunication. Consumers of Telecommunications appeal for high quality of services from their providers, therefore Telecommunication Company should provide the best infrastructure with the provision of best quality with low prices (Douligeris and Pereira, 1994). Lack of optimal infrastructure has been predicted to double or triple the cost of supplying the services to rural areas; therefore government should consider some reforms for example price, interconnection agreement, cost allocation mechanisms in term of their impact on affordability and infrastructure (Gasmi and Virto, 2005).

ii. ***Coverage:*** Network coverage (geographically) is one of the successful attribute within a rural or remote area of a country. The penetration level will be more when the coverage is more. End-users based within the area covered by signals can have access to the internet (Chemane et al, 2005). According to Pakistan Telecommunication Authority (PTA, 2009) Broadband is a developing technology rather than a well-established industry in Pakistan, consequently its penetration is at very low level. Presently, Pakistan remains at 0.26 % in terms of broadband penetration. Lack of local content, low literacy rate and focus on big cities by operators rather than rural areas are the reasons for low penetration.

iii. ***Reliability:*** Rural telecommunication infrastructure must be highly reliable and the most important need for a rural communication system is to provide the best and reliable services. Many network technologies such as satellite and wireless may be affected by weather because of bad quality of transmission. Reliability belongs to consistent service and speed. The inhabitants of rural areas will not encourage unreliable telephone and other access technologies to arrange their social and economic affairs. Reliability is more important than maintenance, to provide consistent speed & service and provide safeguard against breakdown (Henry Chasia 1976; Sasidhar and Min 2005).

iv. ***Security:*** Protection of rural telecommunication networks from theft is a big problem also security must be considered risk to values and information utility. Every user connecting to the Internet who is using available access technologies has security needs, specific information and concerns (Sasidhar and Min, 2005; Douligeris and Pereira, 1994; Chemane et al. 2005). Security in general based on the software and the architecture of network.

v. ***Bandwidth:*** Bandwidth belongs to the capacity of data transferring through the access technology. High bandwidth channels are referred to as broadband, which typically means higher speed at which one can upload and download information (ITU, 1997). The transmission medium comprises of coax cable, twisted wire pairs, fiber optic cable, radio medium links, and wireless satellite transmission systems. High bandwidth channels are referred to as broadband which means higher speed at which one can upload and download information. (Chemane et al. 2005, Sasidhar and Min 2005). Bandwidth is directly associated to the effective performance and efficiency of the transmission connection (speed & service).

vi. ***Maintenance:*** It is very important in terms of efficiency and economic success. Mostly rural areas main power supply does not exist which lags behind telecommunication development. Power supply is required for the operations of telecommunications equipments. The instability of power supply in rural areas is dangerous situation, because exchange cannot occur for long hours. In most rural areas cables are laying by the road side when there is a fault occurs it is difficult to send expert to repair them on time. The requisite skills and necessary supplies may not exist in the immediate locality. Telecommunications networks, however, should be considered part of the basic infrastructure like roads, water mains, and electrical power grids which are justified on the basis of their importance to economic development and quality of life. (Hudson 1989, Henry Chasia 1976).

2.3.2 Attributes for Public Issues

Information and Communication Technology brings revolution in today's life style which brings together people from different environments and they may learn from one another. New changes needed for the interest of local community there should be more and more innovations for the development of public and social issues. The attributes to public issues including contents & development, community of Interest, government support, spectrum licensing and supporting policies.

i. ***Content and development:*** Because of unavailability of information & lack of communication, rural community is facing many problems like in Education, Healthcare, Agriculture information & other techniques etc. Through Information and Communication Technology (ICT) development, rural community can obtain ultimate benefits to improve their education, health, knowledge, agricultural skills, living standard and earnings (Kashif Sattar 2007, Herselman, 2003). Main complications in developing the infrastructure of rural areas are low priority given by the government and lack of interest of private sectors. The government must think about the 70% of Pakistan rural community, to provide them good manpower, up-to-date information and latest contents in less time for the better development.

ii. ***Community of interest:*** **(**Hudson, 2006; Andrew, P.Rahoo and T.Nepal, 2005) Rural communities have strong interests at their immediate geographical and administrative area so therefore their communication needs have to be taken into attention when planning rural telecommunications networks. For a successful telecommunication infrastructure relevant contents according to the community interest are considered. Social and economic changes are transforming rural and regional communities. There are many ways to attract rural community towards development by new employment, new jobs opportunities, and new ways of social interaction among communities.

iii. ***Government Support:*** Humble support from government and other federal departments will continue the creative use of existing services and facilities to provide new life to the rural communities (Nazem, S. M. 1996). Governments provide directly or indirectly telecommunication services to improved rural communities such as governments utilize communication technology and knowledge for administrative development, provide assistance to different departments, national agriculture research centers and other rural stakeholders. To observe the needs of rural communities, governments involve in telecommunication service for rural improvement.

iv. ***Spectrum Licensing:*** In many countries spectrum is licensed through auction and there is a high price to pay for some frequencies. Service delivery concern was to some extent due to the license restriction on telecommunication companies. Technology has been dramatically developed, spectrum resource is scarce and limited, which means spectrum resource should use as efficiently as possible (Andrew, P.Rahoo and T.Nepal, 2005). The radio spectrum is divided into various bands, which are used, by a wide variety of services like emergency, mobile phones, commercial radio and television, terrestrial microwaves, and satellites. In some cases only fixed telecommunications technology could be utilized to deploy voice services to rural communities.

v. ***Supporting Policies:*** Many countries have clear policy of promoting access to Infrastructure utilities, Including piped water, electricity, telecommunications and sewerage at affordable prices. (Clark, G. & Wallsten, J. 2002). In the telecommunications sector, various countries have clearly expressed their policies of promoting general access and supporting policies to telecommunication services. For the development of rural community rural collaborators promote Internet strategy and agricultural growth, access to use a communication for development, access to support telecommunication policies and to support local Internet service providers in rural areas. Also, to assist collaborators in supporting for Internet service provision and to policy advancement of existing Internet services to rural inhabitants.

2.3.3 Attributes for Cost

The selection of rural telecommunication technologies is greatly affected by the economics and "economics is the dynamic force following the innovation of technological clarifications to the problem of access to telecommunications services in those areas” (Gasmi and Virto, 2005). In developing countries, rural areas have some economic aspects that make it hard to provide a suitable telecommunication infrastructure. ICT and specially Internet is considered key driver for social and economic welfare development. Internet reduces isolation and eliminates hurdles of rural living by affordable prices. Internet penetration is low due to lack of infrastructure, skills and low-income communities in rural areas.

i. ***Fixed Cost:*** Fixed financing needed for the deployment of Internet access technology such as Purchasing, Deployment and Central Office etc (Andrew, P.Rahoo and T.Nepal 2005, Chemane et al. 2005, Sasidhar and Min 2005). Fixed costs are fixed they are one-time expenses, and investment needed for deploying of Internet access technology.

ii. ***Variable Cost:*** Variable cost refers to maintenance, administration, training, testing and up-gradation etc (Andrew, P.Rahoo and T.Nepal 2005, Sasidhar and Min 2005, Chemane et al. 2005). *Cost* capability is an important attribute of the selected technology because of the deficiency of finances for rural telecommunications. There should be relax and acceptable policy for variable cost.

Table 2.1: Attributes for rural telecommunications infrastructure

Criteria	Attributes	Related Literature
Technical Aspect	Infrastructure	Douligeris and Pereira (1994); Gasmi and Virto (2005); Clark G & Wallstern (2002).
	Coverage	Chemane et al. (2005).
	Reliability	Henry Chasia (1976); Sasidhar and Min (2005).
	Security	Douligeris and Pereira (1994); Sasidhar and Min (2005); Chemane et al. (2005).
	Speed & Services (Bandwidth)	ITU (1997); Sasidhar and Min (2005); Chemane et al. (2005).
	Maintenance	Hudson (1989); Henry Chasia (1976).
Public Issues	Contents & Development (by Govt)	Kashif Sattar (2007); Herselman, (2003).
	Community of Interest	Hudson (2006); Andrew, P.Rahoo and T.Nepal (2005).
	Govt Support	SM Nazem (1996).
	Spectrum Licensing	Andrew, P.Rahoo and T.Nepal (2005).
	Supporting Policies	Clark G & Wallstern (2002).
Cost	Fixed Cost	Sasidhar and Min (2005); Chemane et al. (2005); Andrew, P.Rahoo and T.Nepal (2005).
	Variable Cost	Sasidhar and Min (2005); Chemane et al. (2005); Andrew, P.Rahoo and T.Nepal (2005).
	Subsidy	Clark G & Wallstern (2002).

iii. ***Subsidy:*** For political reasons Government might wish to subsidize the deprived and rural customers, or as part of a development policy. New methods (Reforms) are necessary to raise subsidies and to ensure access by the poor people. When subsidies are introduced by Government, then they are repeatedly expanded to cover more and more parts of the population (Clark G & Wallstern, 2002).

2.4 Related Literature on Methodology

Based on the review of the previous literature, one can identify multi-criteria decision making (MCDM) as a suitable approach to understand and analyze the complexity in a rural telecommunications systems. In particular, the AHP technique is to be considered as applicable potential method for rural telecommunication infrastructure. In this study methodology part is presented in two sections. The first part briefly reveals an introduction of Analytical Hierarchy Process (AHP), previous literature and various aspects related to the AHP method. The second part reviews various studies with regard to Applications of the AHP in telecommunications.

2.4.1 Analytical Hierarchy Process (AHP)

The AHP was first presented and developed by Thomas Saaty in the early 70’s. AHP is a multi-criteria decision making (MCDM) method which decomposes a complex problem into a hierarchy consisting of specific elements. AHP technique is usually used to model substantial decision making process which is based on multiple attributes (Saaty, 1994). Additionally, AHP follows the natural attitude of human thinking. This technique explores the difficult problems based on their dealing effects. Analytical hierarchy process (AHP) is a favorite way to a Multi-Criteria Decision Making method (MCDM) and helps policy/decision makers to handle difficult problems with several contradictory criteria like location or selection of investment and projects position (Ishizaka and Labib, 2011). The AHP derives proportion scale priorities for attributes and by making paired judgments of attributes on a general criterion. "It is used for a complex decision-making problem by distribution of a complex, unstructured condition into its elements; organizing these elements into a hierarchical order; assigning values to judgments on the relative importance of each element; and synthesizing the judgments to decide the priority of elements" (Liao, 1998). Pair-wise observations allow the decision maker to focus on the observation of two items and then identify a preference on each decisive factor and for each decision alternative.

The basic objective of MCDM is to help decision makers to gain knowledge about the problem, state their judgments about the criteria preferences and importance relating to alternatives, tackles other contributors' judgment, recognize the final alternatives' standards, and use them in the problem solving actions. The AHP decision making process begins by forming the problem into a hierarchy. This hierarchical design helps simplify the description of the problem and brings it into a precondition that is easily understandable. At each level of hierarchy, importances of the concerned elements are calculated mathematically. Thereafter, the decision of the final objective is concluded seeing the importance of criteria and alternatives.

According to (Ishizaka and Labib, 2011), AHP method is based on four steps that include solving a decision problem e.g. problem designing, weight of importance estimation, weights of importance aggregation and analysis. The four steps utilized by AHP method and its development can be sum up as follows:

i. Structuring the decision problem

Decision making is an influential part of the design of a hierarchy to show a decision problem, because there is no set procedure for identifying the objectives, criteria and making hierarchy. When creating hierarchies one should contain related aspects to show the problem such as the issues, environment close to the problem, or attributes that may share the solution, and the participants who are associated with the problem. To elaborate the design of a hierarchy there are some suggestions such as to identify criteria and sub-criteria to fulfill the overall goal of the problem, to identify relevant factors and policies and to identify available options for the problem (Ishizaka and Labib, 2011; Saaty and Vargas, 1994).

A four-level hierarchy is shown in Figure 2.1, in which a decision problem is break down into a series of hierarchies. Each level of the hierarchy contains of a set of factors which is further decomposed into another set of sub-elements with respect to the next level. The final level consist decision alternatives which are relative to the problem.

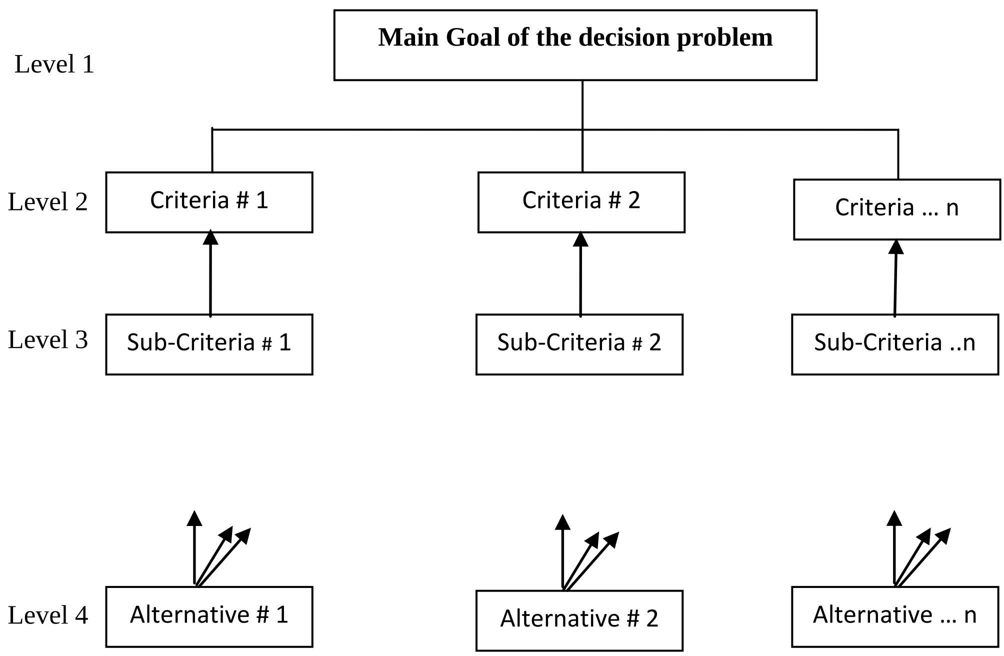

Figure 2.1 Four level Analytic Hierarchy Process (AHP) schema

ii. Pair-wise comparisons

After constructing the hierarchy describing the problem, the second step is the measurement and collection of data which involves conducting pair-wise judgment. Pair-wise judgment is the process of collecting input data of decision elements so that ratio scale priorities can be derived. It is therefore more scientific in deriving ratio scales because AHP uses a unit and estimates multiples of that unit rather than simply assigning numbers by guessing (Saaty, 2005). Judgments are stated in a positive reciprocal matrix (Ishizaka and Labib, 2011). The comparison procedure requires a series of paired judgments where the decision maker will evaluate two elements at a time with respect to objective element. It involves comparing the relative importance, preference of two elements in response to a question. It is only essential to make $n\,(n-1)/\,2$ comparisons to create the full set of pair-wise judgments, where n is the matrix size. For m alternatives and n criteria, there is a need to create and process a $n\ (m\ x\ m)$ matrices (Saaty, 1980).

During this procedure, it is possible to identify which alternatives and attributes are ideal. The data produced are accumulated according to the hierarchical map to its final significance. Additionally, decision attributes on the hierarchical diagram are utilized as a source for composing questions on the questionnaire. Hence, a judgment matrix $\boldsymbol{A}$ is constructed by putting the results of pair-wise comparisons in the position a_{ij} so that $= [a_{ij}]$, i.e. $(n\ x\ n)$ matrix.

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

All entries in this matrix are positive. Where, a_{ij} is the judgment among element i and j. If the matrix is entirely reliable, the transitivity rule (a_{ij} = a_{ik} . a_{jk}) possesses for all judgments. The matrix of pair-wise judgments ($A = [a_{ij}]$) shows the passions of the expert's preference among each pairs of alternatives (A_i versus A_j , for all i, j =1,2,3,……..,n). The pairs of alternatives are generally selected from a given scale$(1 \sim 9)$.

iii. Determination of matrix judgment

Once all pair-wise comparisons are performed at every level and comparison matrices are constructed, a scale of relative priorities is derived from the paired comparisons, which are based in the utilization of the pair-wise as a contribution to form a comparison matrix (Saaty, 1980). Ratio scales (as shown in the table) are the only likely quantities if one wants to aggregate quantities as in a weighted figure (Saaty, 1994).

The judgments are entered using the numbers 1, 3, 5, 7, and 9 which correspond to the verbal judgments. The values of 2, 4, 6 and 8 are intermediate values that can be utilized to indicate compromise values of importance among the five basic assessments.

vi. Synthesizing the relative weights

The ultimate step of the AHP method involves in synthesizing the results to determine the overall outcome considering local priorities across all criteria conclude the global priority (Ishizaka and Labib, 2011). If the Consistency Ratio (CR) is higher than 0.1 then the judgments are considered to be unreliable because they are very close for comfort to unpredictability and the exercise is insignificant or must be repeated. The alternative with the maximum weighted value is to be treated the preferred alternative (Andrew et al., 2005).

Table 2.2: AHP pair-wise comparison scale

Relative importance	Definition	Explanation
1	Equally Important	Two activities donate equally to the objective
3	Slightly more Important	Experience and judgment a little favor one activity over another
5	Strongly more Important	Experience and judgment strongly support one activity over another
7	Very Strongly Important	An activity is supported very strongly over another and its dominance is demonstrated
9	Extremely more Important	The importance of one activity over another is established at the highest possible order
2,4,6,8	Intermediate values	Used to denote a compromise between the priorities listed above

2.4.2 Applications of AHP in Telecommunications

(Douligeris and Pereira, 1994) used the AHP method to choose a telecommunication provider that best satisfy the needs for better service and quality like Fiber distributed data line and distributed dual bus that satisfies customer needs in terms of quality of service and also mentioned that consumers of Telecommunications services insist for a best quality from their providers.

(Sasidhar and Min, 2005) expressed that to select the high-speed access technology in rural communities with different characteristics of performance criteria e.g. high Speed, Low cost and high quality by using AHP model. (Tam and Tummala, 2001) explained application of AHP for the mutual selection of telecommunications system and vendor, and authors emphasized the applicability of the AHP and its possible potential to decrease the time taken in the selection process. Furthermore, (Andrew, P.Rahoo and T.Nepal 2005) summarized that the planning of rural telecommunication services is characterized by a great number of difficult issues like uncertainty, multiple conflict objectives and security of physical technology infrastructure. They also recommended AHP as an efficient technology selection approach for rural area telecommunications that would be regularly improved and updated.

(Chemane et al, 2005) presented that MCDM can help in selecting the optimum Internet access for end users; AHP method was utilized to get relative weights and utilizing pair-wise comparison for cost, link speed, Geographical Coverage and security. and by comparison results Wireless Access technology is the alternative with the maximum value and therefore recommended to be the selected one. "(Manandhar,S, P. 2012) expressed in his study that contents and network effect would provide deeper insight for internet adoption in rural areas, which are not included in his study". (Henry Chasia, 1976) recommends for future discussions that the choice of technology for rural telecommunication in third world countries, is not a decision among old and modern technologies but it is a decision based on appropriateness of the specified equipment of the socioeconomic situation in rural areas. (Douligeris, C., Pereira, I.J., 1994) noted that in AHP method there are several pair-wise comparisons when multiple respondents are involved, a miscalculated answer will not influence the result so a second round of questionnaires may be provided for updates so that a consistency index close to optimal is achieved. The questionnaires could also include questions related to the degree of risk aversion of the respondent (their expertise, their biases etc).

In sum, this study provide a great contribution to the literature on the telecommunication infrastructure in rural areas from many angles In order to achieve the aim and objectives of this research, a comprehensive analytical decision structure for the selection of rural telecommunication technologies will gradually be developed. There has no study considered the selection of telecommunication infrastructure technology to rural areas of Pakistan.

Chapter 3. Formation of AHP Model and Access Technologies

The process of modeling AHP model is one the mathematical method which is used for solving multi-criteria decision problems. The Analytical Hierarchy Process (AHP) has been widely practiced to a range of decision problems with diverse and sophisticated solution. However, the decision related to rural environment / nature is a complex issue because of the existence of different criteria. Therefore, an optimum way is needed that can make valuable solutions to the problem. This chapter describes the structuring of AHP model for the selection of telecommunication backbone infrastructure and different media access technologies available for Pakistan's rural areas.

3.1 Methodology Framework

The AHP methodology including the following sections, The First section is based on structuring of the decision problem, Second section related to measuring and data collection, the Third section including the normalized weights and synthesis and the fourth section including results and discussion with finding solution of the problems. The AHP methodology framework of this study covers a hierarchical decision scheme which is constructed by a broad literature review and by dividing the problem into decision elements comprised of the main goal, which is positioned at the top of the hierarchy, criteria and sub-criteria in the middle and then the alternatives at the bottom. Each particular element is pair-wise compared regarding its parent element by means of real data obtained from different fields of IT experts. Each section is explained to illustrate how to develop the AHP model, demonstrate how it could be used to priorities the three adopted technology alternatives, the attributes are described in chapter two, Table 2.1.

3.2 Structuring AHP Model

An AHP model will be structured to show how the model can be useful for a problem in the rural telecommunication environment. Every telecom provider may have their own criteria, but this model is based on attributes and alternatives which are identified from previous literature and from the views of experienced IT experts' (as describe in chapter 2). The model could be extended by policy makers for rural areas or by the company, to support a situation of the area.

To adapt AHP methodology for technology selection for rural area of Pakistan, the problem should be structured in the form of hierarchy. According to AHP methodology, the hierarchical tree should be designed accordingly as the first step of the AHP procedure. The structured hierarchy that was designed for this study is presented; a hierarchy that contains of four levels, and descends from the general to the more particular was developed as shown in Figure 3.1. The top level is the overall goal of the decision, which is the selection of optimum backbone infrastructure technology to provide quality telecommunications services to the rural areas of Pakistan, followed by the decision criteria which impact the goal directly in the second level. The sub-criteria level comes next against the alternatives to be calculated at the lowest level. Three traditional technologies have been chosen (DSL, Wireless and Fiber Optic) as candidate decision alternatives for this study.

The objectives of such a selection task are the enhancement of telecommunications access through the expansion of the connectivity to rural and remote areas, offer telecommunications services that can meet customer requirements, and increase the return on investments. This study expanded on previous literature by adding related attributes that have straightforward effects the objective of selection of optimum backbone infrastructure technology for rural areas of Pakistan. Moreover, both existing attributes in previous literature and the identified attributes for the Pakistan case have been classified into three categories:

(1) Technical Aspect Attributes

(2) Public Issues Attributes

(3) Cost or financial Attributes

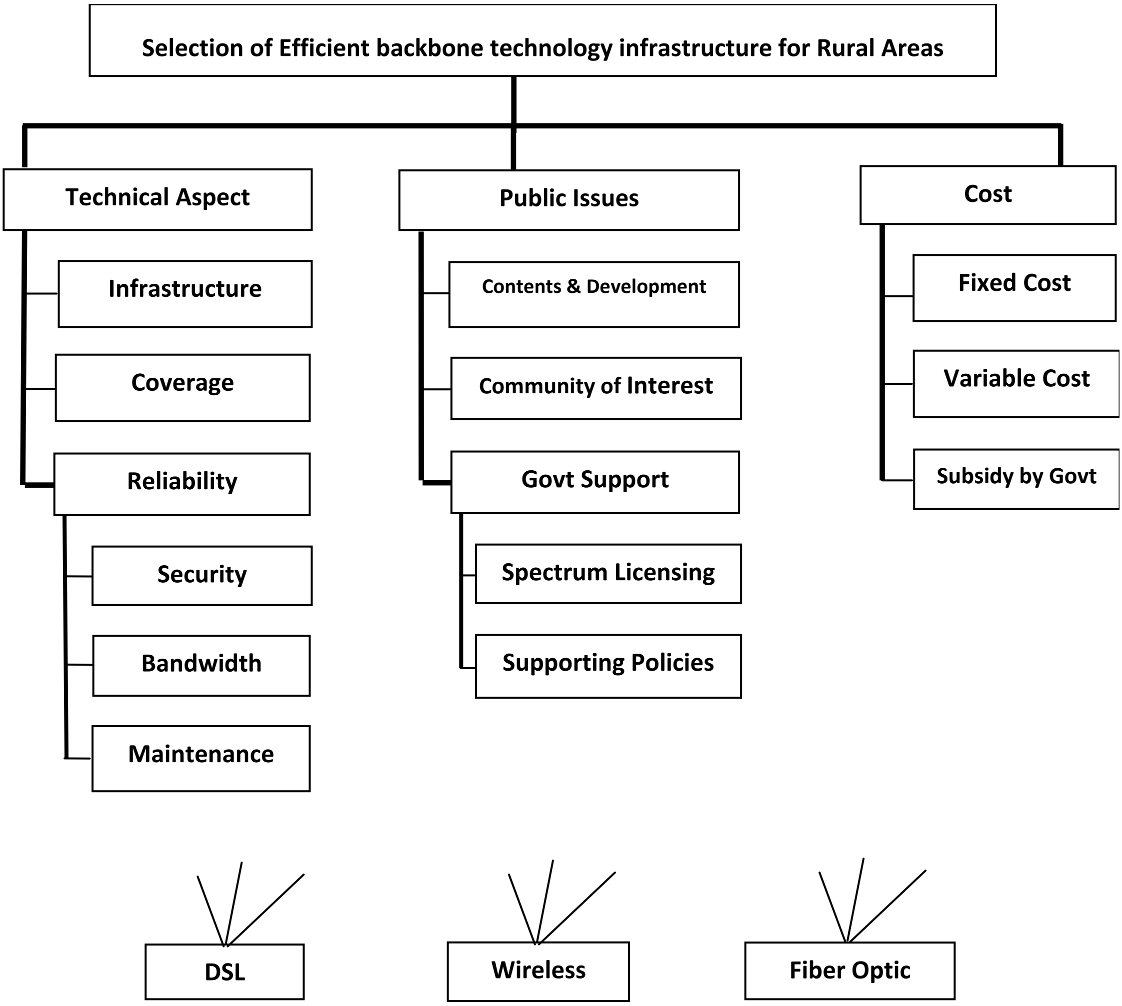

Figure 3.1: AHP Model for Selection of Backbone Technology Infrastructure in rural areas

Third level of the hierarchy contains the sub-criteria which have been classified from the above three categories. The criteria and sub-criteria used in the hierarchy can be determined by using the AHP approach of pair-wise comparison of attributes in each level with respect to every parent attribute placed one level above. The local priorities define a share of a given decision-making element in reaching the goal of the hierarchy at the upper level, where the global priorities of a given level represent each element in reaching the main goal, which is the selection of telecoms backbone technology for rural areas of Pakistan. Local priorities results directly from pair-wise comparisons of the Sub-criteria with respect to the criteria, while global priorities result from the multiplication of criteria and sub-criteria priorities. For instance, a set of global priority weights is produced for each of the sub-criteria by multiplying local weights of the sub-criteria with weights of all the parent elements based above it. Lowest level of the hierarchy is the alternatives which include different technologies for selection. Overall weighting of a technology is generated by adding the global priorities of all attributes in the hierarchy.

3.3 Selection of Access Technology for Rural Area of Pakistan

This section provides a review of telecommunication infrastructure access technologies in the context of how it can be deployed in rural areas of Pakistan. These consist of wired and wireless technologies, which are currently available for the backbone connection for Internet access in a remote/rural area of Pakistan.

Total population of Pakistan is 183 million in which 64% lives in rural areas[1]. The main goal is the technologies that can provide satisfactory telecommunications backbone infrastructure to rural areas. Although, based on the previous literature, it has been found that the uniqueness of rural areas in developing countries makes it useful to discover a technology that will offer the best solution to all areas e.g. (Sasidhar and Min, 2005), identified three technological solutions to offer rural backbone infrastructure that contain two wire-line technologies: Power Line Communication, Fiber Optic Cable and one wireless technologies.

1) Digital subscriber line (DSL) Access Technology

It is a wired access technology that utilizes regular telephone lines to transfer access to businesses and homes. In fact, DSL proposes upload speeds of up to 128 Kbps and download speeds of 1.5 Mbps for single connections. Both analogue voice and data travel over the same piece of copper cable with DSL technology. Voice frequency is from 0 to 4 KHz which is transmitted over low bands, whereas data frequency is from 10 Hz to 1 MHz which is transmitted over higher band. The efficiency of Digital subscriber line (DSL) also depends on the nature of wire (Mervana *et al*., 2001).

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1. http://ansr.io/blog/pakistan-market-trends-2013-online-mobile-social/

2) Cable media Access Technology

It is a wired media access technology which allows communication through a physical medium. For Internet access in Pakistan, these are considered to be the most common media access technologies. When evaluating which media access technology can be used for a network deployment then these factors like cost, broadband, reliability and maintenance are to be considered with observe to user-application requirements.

3) Wireless media access technologies

Wireless access Technology utilized electromagnetic waves to transmit the signal. Where there is a need for mobility or where there is lack of fixed infrastructure, wireless technologies perform a rapidly emerging area for providing Internet connectivity. Wireless technologies can often provide cost-effective solutions and support to the institution mission. When evaluating the deployment of wireless access technology in rural area of Pakistan the Important attributes which to be considered are cost, reliability, Public issues, security, and maintenance.

4) Fiber Optic media Access Technology

Fiber Optic is a glass fiber or plastic designed to convey information using infrared or even noticeable light beam. Thus, Fiber Optic is anti electrical noise, and can transmit large amounts of data. It is possible to modulate 500 to 1000 video signals on a single fiber optics cable because the bandwidth of a fiber optics cable is 100 to 1000 MHz. Fiber Optic cable has drawbacks in terms of system configuration. The cost of Fiber Optic is more than the ordinary wires, which are cheaper alternatives for deploying network in rural areas.

According to PTA (Pakistan Telecommunication Authority) $2012 - 2013\ annual\ report$[2], total broadband users in Pakistan crossed 2.72 million at the end of 2013 as correlated to 2.1 million at the end of 2012 characterizing 30% increase correlated to last year. Figure 3.1 represents the users of the key broadband technologies in Pakistan over the five years (2009 ~ 2013). It is clear from the users that the wireless technologies have developed rapidly since their beginning while development of DSL has been gradually increased. Though, market has been changed over the last fiscal year as WiMAX has gone down and EvDO has taken off.

And report from propakistani indicates that broadband subscriber crossed 3.35 million subscriptions at the end of January 2014[3], and EvDO technology became the largest utilized technology for broadband services in Pakistan[4].

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2. Pakistan telecommunication authority annual report (2013) [Available online] http://www.pta.gov.pk/annual-reports/annreport2013_1.pdf
3. http://propakistani.pk/2014/04/04/broadband-subscribers-in-pakistan-reach-3-35-million/
4. http://www.ispak.pk/

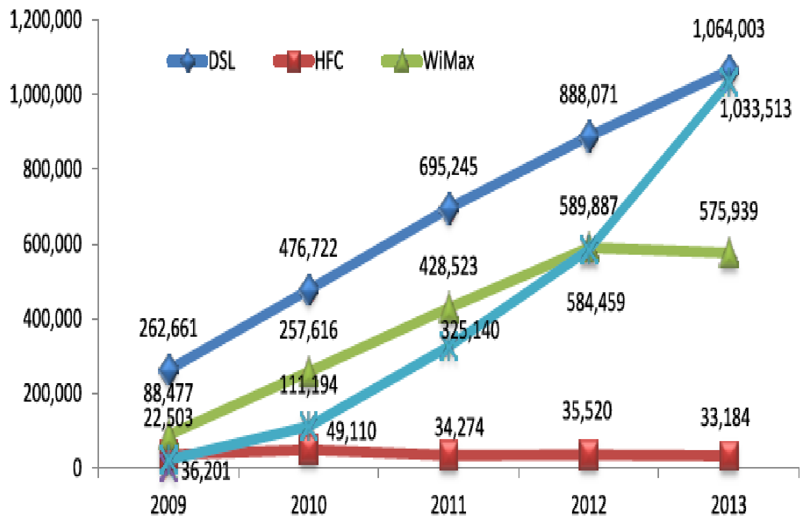

Figure 3.2: Technology wise Broadband subscribers in Pakistan (2009 - 2013)

PTCL (Pakistan Telecommunication Corporation Limited) offers and delivered both (EvDO and DSL) technologies which controls majority of broadband subscribers in the country with roughly 65 % market share in terms of subscribers. In the last three months EvDO technology acquired 256.543 new subscribers. The subscribers of the EvDO technology reach to 1.52 million which account to 45 % of market-share in terms of broadband subscribers. It is evident that wireless technologies are rising rapidly to restore wired systems in various sectors of Pakistan and to make life easier. Wireless networks remain as valuable resources for the rural consumers who cannot afford or do not have the Internet at home.

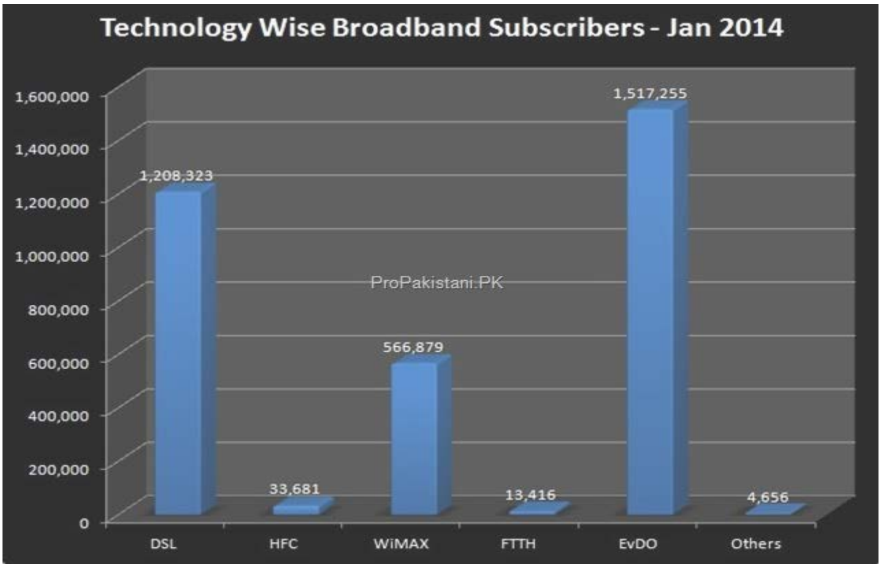

Figure 3.3: Technology Wise Broadband Subscribers Throughout Pakistan

On the bases of responses from participants on feasible infrastructure technologies for rural areas of Pakistan, Most of the respondents are considered very relevant to the subject matter, among these four technology alternatives, three technology alternatives have been selected for this model. Table 3.1 shows a review of access technologies with their main characteristics for rural applications.

Table 3.2 will briefly compare some features of these infrastructural options in terms of advantages and disadvantages of the selected backbone infrastructure technologies for the rural areas of Pakistan.

Table 3.1: Main Technology Alternatives for rural areas of Pakistan

1	**DSL**	DSL is the largest and the fastest growing Broadband service in Pakistan.
2	**Cable**	HFC (Hybrid fiber-coaxial) providing broadband Internet over cable
3	**Wireless**	WiMAX & Ev-DO (Enhanced Voice-Data Optimized) wireless transmission of data through radio signals.
4	**Fiber Optic**	FTTH (Fiber To The Home) the installation and use of optical fiber from a central point.

Table 3.2: Optimum Telecommunication infrastructure for rural areas

Technology	**Advantages**	**Disadvantages**
DSL	Coverage	High cost
	Ease of deployment	Limited bandwidth
	Efficient	Latency
Wireless	Low cost equipment	Less bandwidth
	High reliability	Low reach and line of sight
	Fast deployment	Licensing constraints
Fiber Optic	High flexibility	Most difficult to deploy
	High reliability	Long rollout time
	High speed	High cost

Chapter 4. Configuration & Estimation of Results

After the formation of AHP hierarchy (described in chapter 3), next is the data gathering and analysis phase. The job of addressing a big number of pair-wise questions required in this study would be requiring intensive efforts and extended time. As discussed in Chapter 2, the AHP is depended on four steps: problem modeling (pair-wise comparison design, weights aggregation, and sensitivity analysis). Therefore, the procedure of AHP in this study was to solve a decision problem using these four steps for a particular decision maker (Saaty, 1980). Based on the hierarchy structured, the AHP survey questionnaire was developed. Data was collected from planners of rural areas infrastructure (IT experts, government employees, Private employees, consultants and technical staff) corresponded to the hierarchal structure, and was analyzed using pair-wise judgment of the attributes on a approximate scale. Pair-wise comparison is one of the major strengths of the AHP. It derives precise ratio scale priorities as different from usual ways of assigning weights which can also be hard to justify. Respondents rated the judgment as equal, slightly more important, more important, much more important and absolutely important. This chapter describes the AHP survey and data collection in detail related to the selection of technology infrastructure for Pakistan rural area case.

4.1 Survey and Data

4.1.1 AHP Survey

The AHP survey questionnaire was used to collect the data, the experts were asked to fill the questionnaire in using numbers from the basic scale to represent their judgements: “1 = equal, 3= moderately dominant, 5 = strongly dominant, 7 = very strongly dominant and 9 = extremely dominant” (Saaty, 2001). The questionnaire was designed in three parts. From the hierarchy shown in Figure 3.1(chapter 3), there are **18** sets of pair-wise comparison matrices; the first part contains pair-wise questions for **3** main criteria and **14** sub-criteria with respect to each criterion. The second part contains the pair-wise comparisons of **12** attributes for the alternatives with respect to the selection of telecommunication backbone technology. The last part contains the general demographics of respondents. The respondents were IT experts from different public and private sectors; which assure us that the participants filled the questionnaire carefully not randomly, and gave judgment for comparisons according to their expertise. According to the pair-wised judgment planned by AHP method, a survey questionnaire for this study was designed with three main parts:

Part A: Pair-wise comparison questions with respect to criteria

The pair-wise comparison matrices were constructed from the hierarchy (shown in Figure 3.1, in chapter 3) which describes each and every criteria and sub-criteria concerned in the hierarchical tree of this study in order to making respondents to know the meaning of each factor comparison. These descriptions and pair-wise comparisons are shown as a table in fourth page of the survey questionnaire. The experts were asked to fill the questionnaire in using numbers from the fundamental scale to represent their judgments.

Part B: Pair-wise comparison questions with respect to sub-criteria and alternatives

In this part the pair-wise judgments are related to the selection of telecommunication backbone technology in rural areas of Pakistan. The pair-wise comparison matrices were constructed from the hierarchy (shown in Figure 3.1, in chapter 3) which describes each and every sub-criteria and alternatives involved in the hierarchical tree of this study in order to making respondents to understand the meaning of each factor comparison and the meaning of alternatives and different criterias and their levels before answering the pair-wise comparison questions. These descriptions and pair-wise comparisons are shown as a table in Sixth page of the survey questionnaire.

Part C: Demographic and general Information

The last part of the survey questionnaire was about the demographic and general information of respondents. The respondents are generally concerned with telecommunication sectors, in which some respondents are particularly dealing with rural telecommunications projects. The respondents' expertise showed from telecoms engineers, consultants and academics. Moreover, the respondents were allowed to remain the demographic part empty in case they think this part is confidential. Descriptions are shown on Ninth page of the survey questionnaire.

4.1.2 Collection of Data

After building the AHP hierarchical structure, next is the pair-wise comparison phase which is one of the major strengths of the AHP. For data collection a survey based instrument is used as a technique for this study. The questionnaire was used to gather the data as shown in Annex (1). Survey questionnaire was sent via email to many IT experts of different sectors, and the experts were asked to fill the questionnaire in using numbers from the basic scale to represent their judgments: "1 = equal, 3= moderately dominant, 5 = strongly dominant, 7 = very strongly dominant and 9 = extremely dominant" (Saaty, 1994). After that, we collected a survey data from **43** respondents. The respondents were from different sectors like planners of rural areas infrastructure, IT experts, government employees, Private employees, consultants and technical staff. Out of **43** respondents, **5** samples were invalid due to the incompletion of answers of the questions or their inconsistency rate is too high. **5** of responses were invalid and had been removed as a result.

The obtained responses effectively reached to **38** responses. The Respondents have been divided by their professional backgrounds into three groups in which each group has a collection of individuals (participants from different organizations). Out of **38** participants, the first group has **16** participants from government sectors, while the second group has **17** participants as private sectors employees and **5** participants are from semi-government organizations. AHP procedure has been used to aggregate information since there is more than one group participates in the decision making process. This procedure follows:

(1) Accumulating the individual judgments for each set of pair-wise comparison into a collective hierarchy.

(2) Synthesize each hierarchy and accumulating the resulting priorities in which the overall inconsistency of each individual is not larger than > 0.1 to guarantee the reliability of the judgments, however the respondent who had a larger inconsistency than 0.1 has been removed and regarded as an invalid response.

(3) Accumulating the individual's resulting priorities in each node in the hierarchy to construct a group decision. The following table 4.1 shows the different groups of participants.

Table 4.1: Participants Grouping

Groups	Group 1 : Government Employees	Group 2 : Private Employees	Group 3 : Semi-government Employees	Total Respondents
No. of Respondents	16	17	5	38

4.1.3 Descriptive statistics

The survey data was collected from IT experts (government employees, Private employees) corresponded to the hierarchal structure, and was analyzed using pair-wise comparison of the decision making standard on a qualitative scale. The survey was conducted via e-mail. The dataset was restricted to IT professionals who are literate.

AHP survey was conducted from **43** respondents in which **5** samples were invalid due to incompletion of answers of the questions or their inconsistency rate was too high and had been removed as a result. Therefore, only **38** acceptable answers were obtained to be eligible to make the AHP survey. Table (4.2) shows the outline of the sample design.

The survey also collected information of the respondent's socio-demographic and professional background such as: gender, age, educational level, occupation, and working experience.

Table 4.2: Sample design

Description	
Participants	Ranging in age from 25 to 60 years and working in different sectors (government, private and semi-government)
Sample size	38 respondents
Survey period	April 2014
Survey mechanism	Via e-mail

The survey answers show that the majority of the 38 respondents were males (89% males and 11% females). This distribution reflects the fact of the Pakistan national statistics forecasting vulnerable employment of male and female in the country. This gender distribution is shown if figure (4.1)

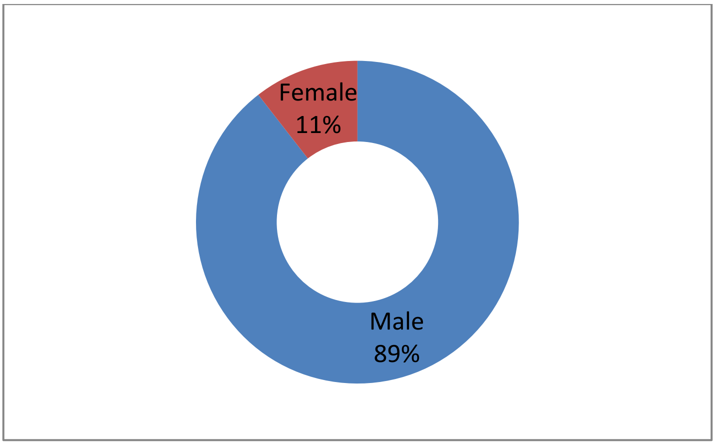

Figure 4.1: Gender Distribution of respondents

Age distribution shows in figure (4.2), a majority number of the 58% respondents were in the ages between 31 and 40, while 8% respondents were between the ages of 25 and 30. 29% of them were between the ages of 41 and 50 and 5% respondents were between 51 to 60 years.

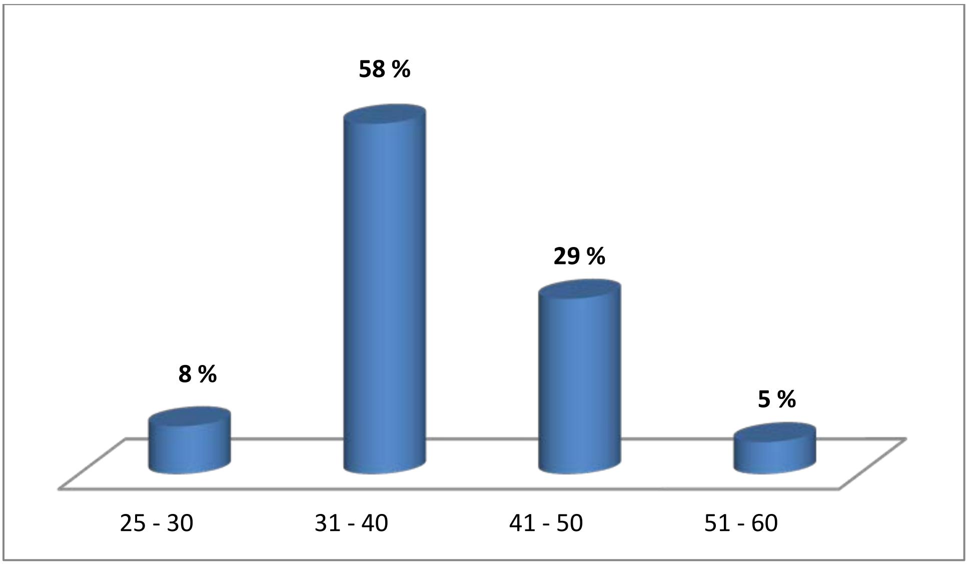

Figure 4.2: Age Distribution of respondents

In terms of education, the results show in figure (4.3) that the majority of the respondents have a master degree, taking 55% out of 38 respondents. And 21% respondents having doctoral degree out of 38 respondents; this indicates that a significant number of respondents are well qualified and experts in their fields. Moreover, the results also have shown that 16% of the respondents have bachelor degree, while 8% have only diploma qualification. As described earlier that participant of this study are generally concerned with telecommunication sectors, in which some participants are particularly dealing with different rural telecommunications projects.

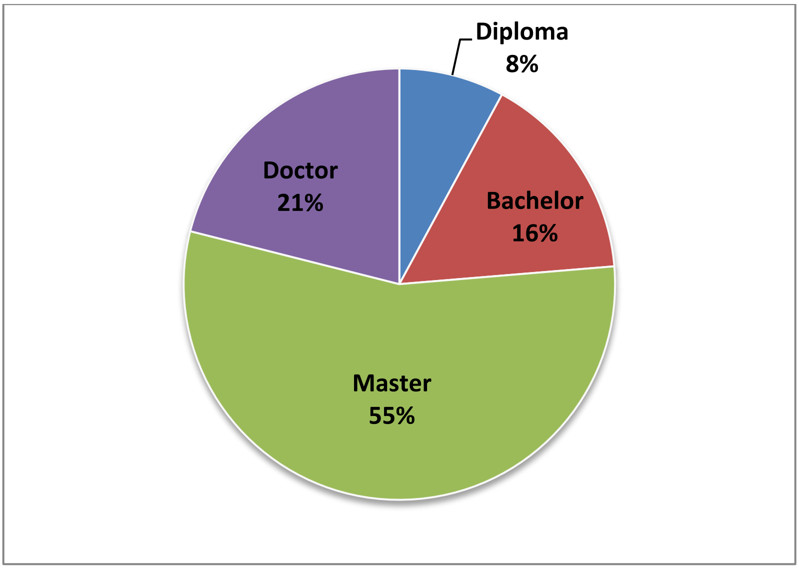

Figure 4.3: Educational Level Distribution of respondents

In terms of job status, the obtained results shows that respondents were from different sectors related to Information technology and telecommunication e.g. government employees, private employees, and semi-government employees. Figure (4.4) shows that out of 38 respondents 42 % are government employees (IT directors, lecturers, assistant professors and professors), 45 % are private employees from different telecom sectors (IT managers, telecom engineers, network engineers, communication engineers, system engineers, network administrators). And 13 % are semi-government employees (communication engineer, IT officer, networks monitoring officer).

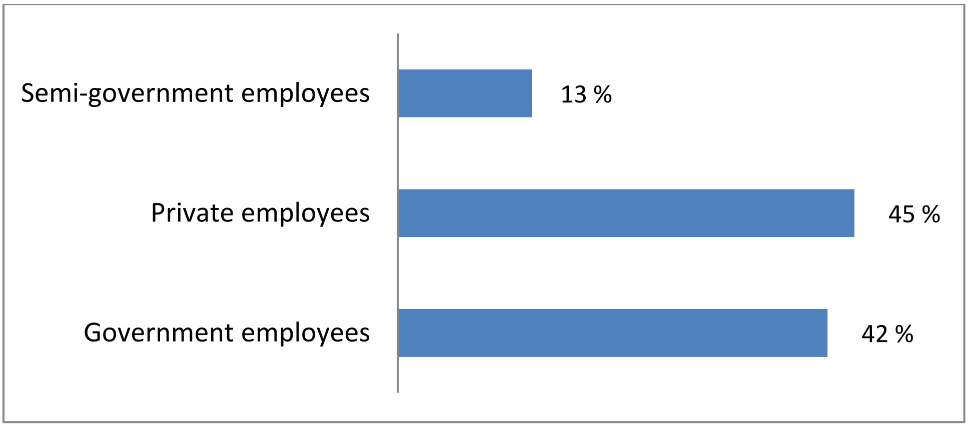

Figure 4.4: Respondents Job Status Distribution

By analyzing the working experience, according to obtained results the majority of respondents have … years experience in their perspective fields of expertise. Figure (4.5) shows the distribution of respondents working experience with different clusters of years.

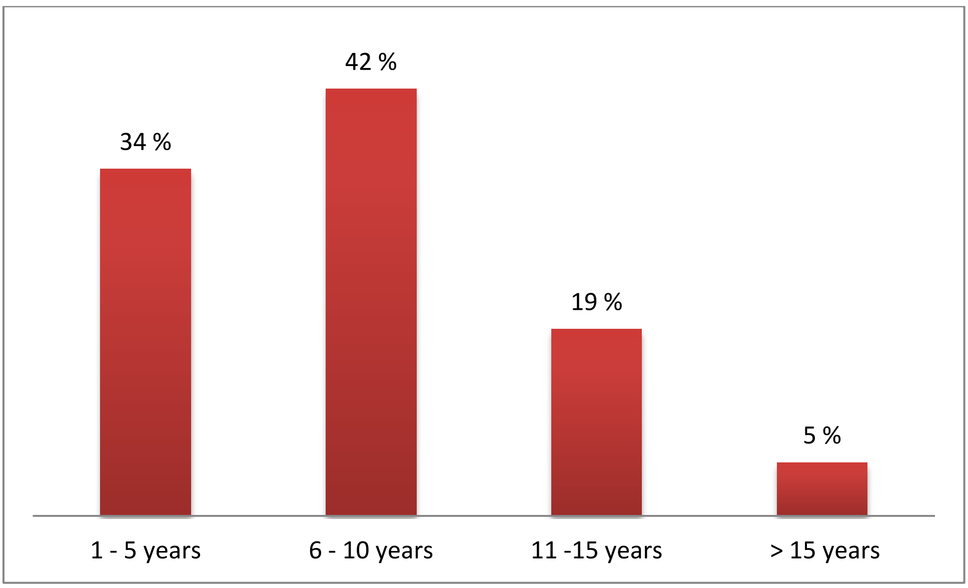

Figure 4.5: Respondent Working Experience

Table (4.3) summarized respondent's demographic profile information.

Table 4.3: Respondents demographics profile

	Category	Frequency	Percentage
Gender	Male	34	89%
	Female	4	11%
Age	25 ~ 30	3	8%
	31 ~ 40	22	58%
	41 ~ 50	11	29%
	51 ~ 60	2	5%
Educational Level	Diploma	3	8%
	Bachelor	6	16%
	Master	21	55%
	Doctor	8	21%
Job Status	Government Employees	16	42%
	Private Employees	17	45%
	Semi-government Employees	5	13%
Working Experience	1 ~ 5 years	13	34%
	6 ~ 10 years	16	42%
	11 ~ 15 years	7	19%
	> 15 years	2	5%

4.2 Results and Analysis

AHP gives mean of break downing the problem into a hierarchy of sub problems which can more easily be understandable and evaluated. This section explains in-depth how this research followed the AHP procedure to get the results.

4.2.1 Prioritizing Identified Attributes

The AHP methodology can be developed in the following steps of the AHP procedure (Saaty, 2008, Ishizaka and Labib, 2011). However, decision making studies made us to involve these following steps.

1. AHP procedure starts with *Setting up the Decision Hierarchy* where the problem is break downed into a hierarchy of goal, criteria, sub-criteria and alternatives. The hierarchy shows the relationship among attributes of one level with the attributes of the level directly below as shown in the hierarchy diagram (See Figure 3.1, chapter 3). In this study, the criteria are the attributes approached in the “identifying the success attributes that contribute to the selection of telecommunication backbone technology in rural areas of Pakistan”. According to AHP method, the succeeding attributes of each criterion must depend on associated criterion (Saaty, 2008), the attributes were categorized into three main criterias which are Technical aspects, Public Issues and Cost. Each main criterion has different sub-criterias and at the last level there are alternatives related to the goal.

2. Performing the *Pair-wise Comparisons of attributes*. Pair-wise judgment is the major strengths of the AHP. "Each element in a higher level is used to evaluate the elements in the level directly below with respect to it" (Saaty, 2008). This is utilized to find out the relative importance of the elements involved. And also performing the collectio*n of data regarding the hieratical structure*. However, these steps have been discussed in details in the AHP survey design as presented in the previous section 4.1.
3. *Convert the judgment into weights and consistency*. The AHP transforms comparisons of participants into weights, which are then automatically normalized to sum 1. Many conversion techniques are available, but the AHP use mathematical approach based on Eigen values (Goodwin and Wright, 2004). Because of the complication of this method, computer software called *Expert Choice 2000* is utilized to carry out calculations.

4.2.2 Synthesis – Finding a solution to the problem

Last step of AHP procedure is *synthesizing the Results for* finding a solution to the problem. AHP uses the priorities achieved from the comparison to weight the priorities in the level directly below and keep continue this process for every element. After that for each element in the below level adds its weighted values and achieve its global or overall priority. It continues on this procedure of weighting and adding till the final priority of the decision alternatives at the base level is achieved. Therefore, AHP calculates the local priority related to each criterion. Local priorities are then multiplied by the local priority weight of each attribute with the local weight of its parent attribute, i.e. from which it is connected and aggregated to obtain the global ratings.

4.2.3 Participants Preferences for different groups

From the obtained **38** respondents data now we will take different group's (Academia, Telecom and Job Experience > = 10 years) views and their preferences in different ways: by considering the importance of each attribute in each level utilizing the global importance of each node, or by considering about the relative importance of each attribute within a branch utilizing local importance of each node in the AHP hierarchy. The following are the preferences obtained from each group with different ways according to their expertise and related sector.

A) Preferences of participants from Academia

The Academia group consists of different participants from both (Government employees, Private employees) sectors. Out of **38** participants, the *academia group* has **17** participants, the employees preferences can be viewed in the above mentioned ways. The weights of the local and global importance of each criterion for the academia group were obtained with the AHP technique using the *Expert Choice 2000* software as illustrated in Table 4.4.

According to the group of academia participants, one can observe that the comparison of the criteria with respect to the goal yields that the Cost criterion has the highest priority of **40.10 %,** expressing a certain advantage among others, which indicates more importance in comparison to other Technical aspects and Public Issues attributes. The lowest priorities are for Technical Aspects and Public issues with **30.30 %** and **29.60 %**, respective. Once the global priorities of all sub-criteria are obtained, they were multiplied by the local priority of each alternative with respect to each criterion to obtain the evaluation score (weight) of each alternative (see (2.4.1, iv) in chapter 2). Finally, an overall score for each alternative is obtained by summing each evaluation score row as shown in Table 4.5. The resulting priorities of the alternatives are illustrated in Table 4.5. From the Grand total column, *Wireless* technology is the most preferred alternative and has the highest score in this AHP model with a priority of **0.488**. DSL comes next with a priority of **0.338** and then Fiber Optic technology with **0.174**. The sum of the priorities in this column is equal to one. This complies with the AHP procedure and demonstrates that its steps are applied properly towards the goal of the problem, which is the efficient technology selection for Pakistan rural areas.

Table 4.4: Academia participants Preferences for the criteria & subcriteria

Overall Inconsistency = 0.01

Goal: Selection of backbone technology infrastructure for Rural areas of Pakistan				
Criteria	**Local Priorities**	**Subcriteria (Local Priorities)**	**Subcriteria (Local Priorities)**	**Global Priorities**
Technical Aspect	0.303	Infrastructure (0.108)		0.034
		Coverage (0.496)		0.15
		Reliability (0.396)	Security (0.137)	0.016
			Bandwidth (0.638)	0.077
			Maintenance (0.225)	0.027
Public Issues	0.296	Contents & Development (0.274)		0.081
		Community of Interest (0.130)		0.039
		Government Support (0.596)	Spectrum Licensing (0.378)	0.066
			Supporting Policies (0.622)	0.11
Cost	0.401	Fixed Cost (0.302)		0.12
		Variable Cost (0.224)		0.089
		Subsidy by Government (0.475)		0.191
Grand Total				**1**

Table 4.5: Synthesized priorities for the alternatives from Academia participants

Alternatives	Criteria (Local Priorities)			Grand Total
	Technical Aspect (0.303)	Public Issues (0.296)	Cost (0.401)	
DSL	0.091	0.099	0.148	0.338
Wireless	0.161	0.151	0.176	0.488
Fiber Optic	0.052	0.046	0.076	0.174
Grand Total	0.304	0.296	0.4	**1**

From the above analysis, one can observe that the AHP is capable of structuring the problem and providing a systematic approach to decision making. It allowed for diverse qualitative factors to be examined in a mathematical model, which can help to reduce the time needed to evaluate the alternatives. By using the traditional selection process in such problems, the decision may take months to be reached. As the criteria are defined and the problem is prepared analytically, the AHP allows the decision makers to visualize the strengths and weaknesses of each technology alternative by comparing their scores against each attribute. The obtained final weights in Table 4.5 provide information about the alternatives and the way they are used to satisfy the selected attributes, as well as the importance of these attributes in order to reach the goal of the model. Taking this into consideration, a result where one can affirm which alternative is more preferable from Academia participant's point of view is reached. However, the priority weights of the three technologies are actually quite different from each other and although Wireless achieved the highest score, it is above DSL weights by less than 15 %. And, Fiber Optic weight is 35 % less than DSL.

Table 4.6: Ranking of attributes according to their global priorities for Academia group

Synthesis with respect to efficient policy infrastructure in rural areas

Rank	Subcriteria	Global priorities (%)
1	Subsidy by Government	19.10
2	Coverage	15.00
3	Fixed Cost	12.00
4	Supporting Policies	11.00
5	Variable Cost	8.90
6	Contents & Development	8.10
7	Bandwidth	7.70
8	Spectrum Licensing	6.60
9	Community of Interest	3.90
10	Infrastructure	3.40
11	Maintenance	2.70
12	Security	1.60

In above table 4.6, the sub-criteria are arranged for ranking in a descending order of their global priorities. The table shows that the most important sub-criterion among all is ‘Subsidy by government’ with a priority of 19.10 % followed by ‘Coverage’ with 15 % and ‘Fixed Cost’ with 12 %. The top four attributes comprised a variety of sub-criteria that belong to all criterions. The least important sub-criteria among others considered in the model with priorities of less than 5% are ‘Community of Interest’, ‘Infrastructure’, ‘Maintenance’ and ‘Security’ with 3.90 %, 3.40 %, 2.70 % and 1.60 % respectively.

B) Preferences of participants from Telecom Sectors

The participants of Telecom Sector group are from different Telecom Organizations in Pakistan. Out of **38** participants, the Telecom Sector group has **21** participants; many of them are involved with deployment of Telecommunication infrastructure projects. The employee’s preferences can be viewed in the previous mentioned ways. The weights of the local and global importance of each criterion for the Telecom Sector group were obtained with the AHP technique using the expert choice 2000 software as illustrated in Table 4.7.

According to the Telecom Sectors participants, one can observe that the comparison of the criteria with respect to the goal yields that the *Cost criterion* has the highest priority of **41 %,** expressing a certain advantage among others, which indicates more importance in comparison to other *Technical aspects and Public Issues* attributes. The lowest priorities are for Technical Aspects and Public issues with **40.10 %** and **18.90 %**, respective. Once the global priorities of all sub-criteria are obtained, they were multiplied by the local priority of each alternative with respect to each criterion to obtain the evaluation score (weight) of each alternative (see (2.4.1, iv) in chapter 2). Finally, an overall score for each alternative is obtained by summing each evaluation score row as shown in Table 4.8. The resulting priorities of the alternatives are illustrated in Table 4.8. From the Grand total column, *Wireless* technology is the most preferred alternative and has the highest score in this AHP model with a priority of **0.5**. *DSL* comes next with a priority of **0.321** and then *Fiber Optic* technology with **0.179**. The sum of the priorities in this column is equal to one. This complies with the AHP procedure and demonstrates that its steps are applied properly towards the goal of the problem, which is the efficient technology selection for Pakistan rural areas.

From below analysis, one can observe that the AHP is capable of structuring the problem and providing a systematic approach to decision making. It allowed for diverse qualitative factors to be examined in a mathematical model, which can help to reduce the time needed to evaluate the alternatives. By using the traditional selection process in such problems, the decision may take months to be reached.

Table 4.7: Telecom Sector participants Preferences for the criteria & subcriteria

Overall Inconsistency = 0.01

Goal: Selection of backbone technology infrastructure for Rural areas of Pakistan				
Criteria	**Local Priorities**	**Subcriteria (Local Priorities)**	**Subcriteria (Local Priorities)**	**Global Priorities**
Technical Aspect	0.401	Infrastructure (0.149)		0.059
		Coverage (0.524)		0.211
		Reliability (0.327)	Security (0.135)	0.017
			Bandwidth (0.628)	0.082
			Maintenance (0.237)	0.032
Public Issues	0.189	Contents & Development (0.285)		0.054
		Community of Interest (0.164)		0.031
		Government Support (0.550)	Spectrum Licensing (0.606)	0.063
			Supporting Policies (0.394)	0.042
Cost	0.410	Fixed Cost (0.255)		0.104
		Variable Cost (0.302)		0.123
		Subsidy by Government (0.444)		0.182
Grand Total				**1**

Table 4.8: Synthesized priorities for the alternatives from the group of Telecom Sector participants

Alternatives	Criteria (Local Priorities)			Grand Total
	Technical Aspect (0.401)	**Public Issues (0.189)**	**Cost (0.410)**	
DSL	0.124	0.057	0.14	0.321
Wireless	0.211	0.103	0.186	0.5
Fiber Optic	0.066	0.03	0.083	0.179
Grand Total	0.401	0.19	0.409	**1**

As the criteria are defined and the problem is prepared analytically, the AHP allows the decision makers to visualize the weaknesses and strengths of each technology alternative by comparing their scores against each attribute. The obtained final weights in Table 4.8 provide information about the alternatives and the way they are used to satisfy the selected attributes, as well as the importance of these attributes in order to reach the goal of the model. Taking this into consideration, a result where one can affirm which alternative is more preferable from Telecom experts' point of view is reached. However, the priority weights of the three technologies are actually quite different from each other and although Wireless achieved the highest score, it is above DSL weights by less than 20 %. And, Fiber Optic weight is 35 % less than DSL.

Table 4.9: Ranking of attributes according to their global priorities for Telecom Participants

Synthesis with respect to efficient policy infrastructure in rural areas

Rank	Subcriteria	Global priorities (%)
1	Coverage	21.10
2	Subsidy by Government	18.20
3	Variable Cost	12.30
4	Fixed Cost	10.40
5	Bandwidth	8.20
6	Spectrum Licensing	6.30
7	Infrastructure	5.90
8	Contents & Development	5.40
9	Supporting Policies	4.20
10	Maintenance	3.20
11	Community of Interest	3.10
12	Security	1.70

In Table 4.9, the sub-criteria are arranged for ranking in a descending order of their global priorities. The table shows that the most important sub-criterion among all is ‘Coverage’ with a priority of 21.10 % followed by ‘Subsidy by Government’ with 18.20 % and ‘Variable Cost’ with 12.30 %. The top four attributes comprised a variety of sub-criteria that belong to all criterions. The least important sub-criteria among others considered in the model with priorities of less than 5% are ‘Supporting Policies’, ‘Maintenance’, ‘Community of Interest’ and ‘Security’ with 4.20 %, 3.20 %, 3.10 % and 1.70 % respectively.

C) Preferences from participants having Job Experience more than 10 years

In this group we judge and evaluate the preferences of participants who have job experience more than or equal to 10 years from both (government and private) sectors. The participants of this group are from different Organizations in Pakistan. Out of **38** participants, **15** participants have job experience more than or equal to 10 years. The participant’s preferences can be viewed in the previous mentioned ways. The weights of the local and global importance of each criterion for the this group were obtained with the AHP technique using the *Expert Choice 2000* software as illustrated in Table 4.10. According to the participants of this group, one can observe that the comparison of the criteria with respect to the goal yields that the *Cost criterion* has the highest priority of **41.30 %,** expressing a certain advantage among others, which indicates more importance in comparison to other *Technical aspects and Public Issues* attributes. The lowest priorities are for Technical Aspects and Public issues with **32.50 %** and **26.20 %**, respective. Once the global priorities of all sub-criteria are obtained, they were multiplied by the local priority of each alternative with respect to each criterion to obtain the evaluation score (weight) of each alternative (see (2.4.1, iv) in chapter 2).

Table 4.10: Participants have Job experience > = 10 years

Overall Inconsistency = 0.01

Goal: Selection of backbone technology infrastructure for Rural areas of Pakistan				
Criteria	**Local Priorities**	**Subcriteria (Local Priorities)**	**Subcriteria (Local Priorities)**	**Global Priorities**
Technical Aspect	0.325	Infrastructure (0.111)		0.033
		Coverage (0.530)		0.151
		Reliability (0.359)	Security (0.123)	0.016
			Bandwidth (0.677)	0.071
			Maintenance (0.199)	0.024
Public Issues	0.262	Contents & Development (0.273)		0.071
		Community of Interest (0.156)		0.04
		Government Support (0.571)	Spectrum Licensing (0.387)	0.053
			Supporting Policies (0.613)	0.104
Cost	0.413	Fixed Cost (0.306)		0.161
		Variable Cost (0.214)		0.074
		Subsidy by Government (0.480)		0.202
Grand Total				**1**

The resulting priorities of the alternatives are illustrated in Table 4.11. From the Grand total column, *Wireless* technology is the most preferred alternative and has the highest score in this AHP model with a priority of **0.512**. *DSL* comes next with a priority of **0.326** and then *Fiber Optic* technology with **0.162**. The sum of the priorities in this column is equal to one. This complies with the AHP procedure and demonstrates that its steps are applied properly towards the goal of the problem, which is the efficient technology selection for Pakistan rural areas.

Table 4.11: Synthesized priorities for the alternatives from participants - Job Experience > = 10

Alternatives	**Criteria (Local Priorities)**			**Grand Total**
	Technical Aspect (0.325)	**Public Issues (0.262)**	**Cost (0.413)**	
DSL	0.09	0.092	0.144	0.326
Wireless	0.161	0.136	0.215	0.512
Fiber Optic	0.044	0.04	0.078	0.162
Grand Total	0.295	0.268	0.437	**1**

Based on the above analysis, one can observe that the AHP is capable of structuring the problem and providing a systematic approach to decision making. It allowed for diverse qualitative factors to be examined in a mathematical model, which can help to reduce the time needed to evaluate the alternatives. The obtained final weights in Table 4.11 provide information about the alternatives and the way they are used to satisfy the selected attributes, as well as the importance of these attributes in order to reach the goal of the model. Taking this into consideration, a result where one can affirm which alternative is more preferable from the point of view of participants who have job experience more or equal to 10 years. However, the priority weights of the three technologies are quite different from each other and although Wireless achieved the highest score, it is above DSL weights by less than 15 %. And, Fiber Optic weight is 35 % less than DSL.

In Table 4.12, the sub-criteria are arranged for ranking in a descending order of their global priorities. The table shows that the most important sub-criterion among all is ‘Subsidy by Government’ with a priority of 20.20 % followed by ‘Fixed Cost’ with 16.10 % and ‘Coverage’ with 15.10 %. The top four attributes comprised a variety of sub-criteria that belong to all criterions. The least important sub-criteria among others considered in the model with priorities of less than 5% are ‘Community of Interest’, ‘Infrastructure’, ’Maintenance’ and ‘Security’ with 4.00 %, 3.30 %, 2.40 % and 1.60 % respectively.

Table 4.12: Ranking of attributes according to their global priorities for Experienced Participants (Job Experience > = 10 years)
Synthesis with respect to efficient policy infrastructure in rural areas

Rank	Subcriteria	Global priorities (%)
1	Subsidy by Government	20.20
2	Fixed Cost	16.10
3	Coverage	15.10
4	Supporting Policies	10.40
5	Variable Cost	7.40
6	Contents & Development	7.10
7	Bandwidth	7.10
8	Spectrum Licensing	5.30
9	Community of Interest	4.00
10	Infrastructure	3.30
11	Maintenance	2.40
12	Security	1.60

4.2.4. Comparison Perspectives of Groups' Preferences

From the total 38 obtained respondent data now we will examine and compare the attributes and technologies alternatives with different ways and different criteria with respect to the goal of this study. We examine three groups and got different results from each other, several differences existing in the results of each group. Several gaps were found in the Academia group respondents, Telecom sector respondents and from those respondents who have experience more than 10 years. The sum of the global priorities of each group is equal to one. This complies with the AHP procedure and demonstrates that its steps are applied properly towards the goal of the problem, which is the efficient technology selection for Pakistan rural areas. In table 4.13 we can notice the differences between the scores (weights) of the attributes with respect to criteria and sub-criteria of AHP model. And next we will compare technologies alternatives preferences for all discussed groups according to their obtained results.

As represented in the Table 4.13, the order of the importance for the same attributes is observed from the different participants groups, Academia, Telecom sector and experienced participants. In the first level of the hierarchy, all groups’ preferences are in similarities in order of importance for all the criteria in the same level, Technical aspect, Public issues and Cost. There are also similarities in order of the importance within the second and third levels of the hierarchy.

Table 4.13: Comparison of Groups' Preferences

Group of Participants from Academia. (Global priorities)	Group of Participants from Telecom Sectors. (Global priorities)	Group of Participants having job experience > = 10 years. (Global priorities)
<u>Level – 1</u>		
Technical Aspect (0.303)	Technical Aspect (0.401)	Technical Aspect (0.325)
Public Issues (0.296)	Public Issues (0.189)	Public Issues (0.262)
Cost (0.401)	Cost (0.410)	Cost (0.413)
<u>Level – 2</u>		
Technical Aspect attributes		
Infrastructure (0.034)	Infrastructure (0.059)	Infrastructure (0.033)
Coverage (0.15)	Coverage (0.211)	Coverage (0.151)
Reliability (0.12)	Reliability (0.131)	Reliability (0.111)
Public Issues attributes		
Contents & Development (0.081)	Contents & Development (0.054)	Contents & Development (0.071)
Community of Interest (0.039)	Community of Interest (0.031)	Community of Interest (0.04)
Government Support (0.176)	Government Support (0.105)	Government Support (0.157)
Cost		
Fixed Cost (0.12)	Fixed Cost (0.104)	Fixed Cost (0.161)

Variable Cost (0.089)	Variable Cost (0.123)	Variable Cost (0.074)
Subsidy by Govt. (0.191)	Subsidy by Govt. (0.182)	Subsidy by Govt. (0.202)
Level – 3		
Reliability attributes		
Security (0.016)	Security (0.017)	Security (0.016)
Bandwidth (0.077)	Bandwidth (0.082)	Bandwidth (0.071)
Maintenance (0.027)	Maintenance (0.032)	Maintenance (0.024)

In level-1, in Telecom sector group the Technical aspect and public issues attributes shows dissimilarities with two other groups. In the level-2, the Technical aspects attributes shows slightly dissimilarity from the groups 2, where group 1 and 3 have similarity in the order of importance of the same attributes. Other attributes of level-2 have almost same similarities. Moreover, in the third level, in reliability attribute the Telecom sector participant's shows slight dissimilarity among the three groups.

Nevertheless, the respondents from different sectors e.g. planners of rural areas infrastructure, IT experts, government employees, Private employees, consultants and technical staff evaluate *'Cost attribute'* as most important in the first level of the hierarchy model, followed by the *'Technical aspect'* and *'Public issues'* attributes, and the same situation can be seen in level-2. The level-3 shows slightly dissimilarities among attributes from all groups. In general, the judgments and preferences from respondents might be justified for the selection of telecommunication backbone technology for rural area of Pakistan, because the inconsistencies in all groups are less than 0.01.

Table 4.14: Groups' Preferences comparison of technology alternatives

Alternatives	Participants from Academia.	Participants from Telecom Sectors.	Participants having job experience > = 10 years.
Wireless	0.488	0.5	0.512
DSL	0.338	0.321	0.326
Fiber Optic	0.174	0.179	0.162

From the above Table 4.14, the order of the importance for the technology alternatives is observed from the different participants groups e.g. Academia, Telecom sector and experienced participants. The obtained final weights in Table 4.15 provide information about the alternatives and the way they are used to satisfy the selected attributes, as well as the importance of these attributes in order to reach the goal of the model. Taking this into consideration, a result where one can affirm which alternative is more preferable from the point of view of participants from the three groups. However, the priority weights of the three technologies are quite different from each other and although Wireless technology achieved the highest score among three groups, followed by DSL and Fiber Optic technologies.

4.2.5. Overall Preferences Results (Combined ALL Groups)

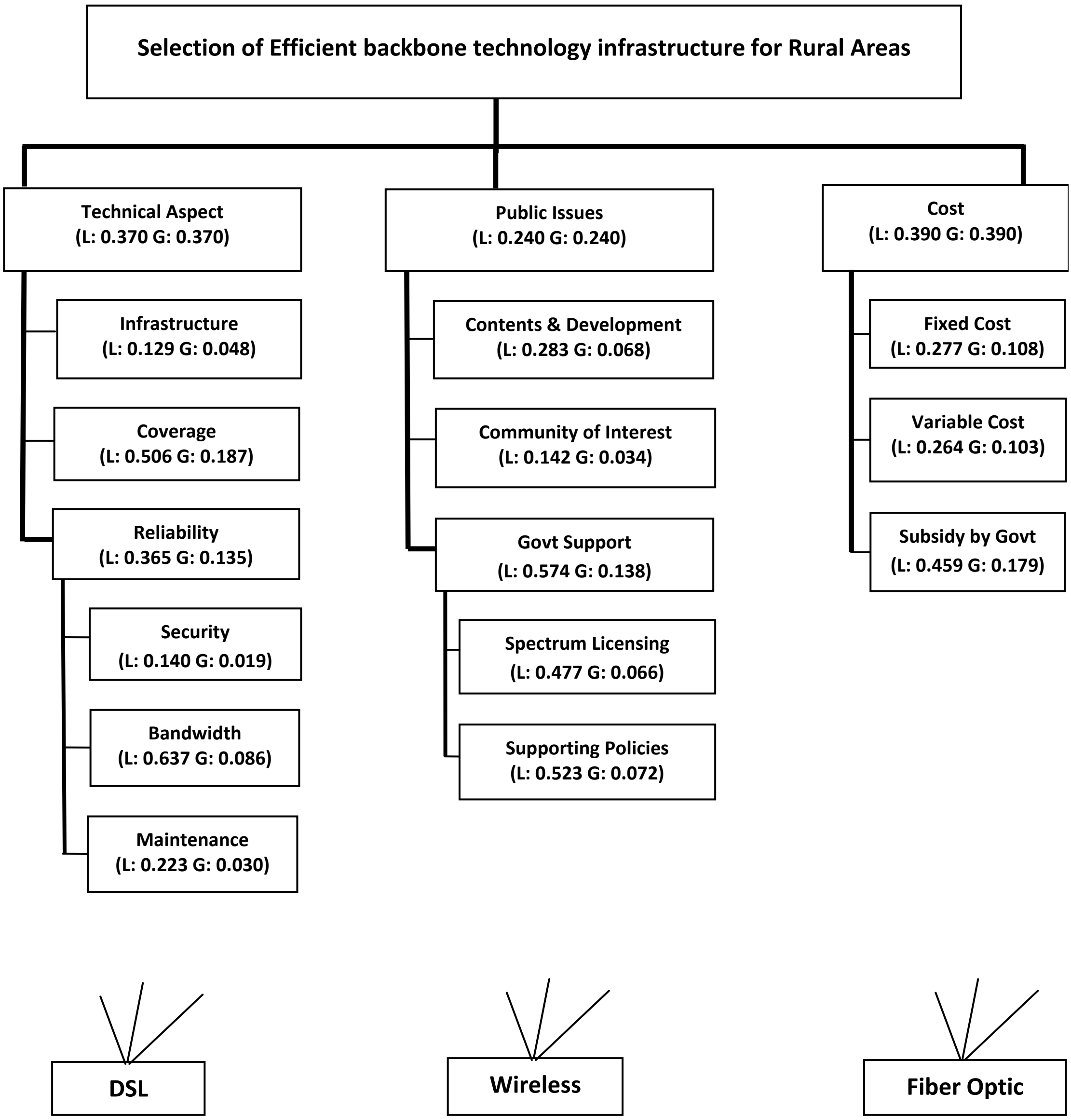

Figure 4.6: All Groups Aggregated Preferences

The overall preferences within each level (branch) are discussed by using the relative local importance of each attribute inside the branches of the hierarchal tree as displayed in the above Figure 4.6.

Table 4.15: Overall Preferences for the criteria & subcriteria – overall Inconsistency = 0.00

Goal: Selection of backbone technology infrastructure for Rural areas of Pakistan				
Criteria	**Local Priorities**	**Subcriteria (Local Priorities)**	**Subcriteria (Local Priorities)**	**Global Priorities**
Technical Aspect	0.370	Infrastructure (0.129)		0.047
		Coverage (0.506)		0.187
		Reliability (0.365)	Security (0.140)	0.02
			Bandwidth (0.637)	0.086
			Maintenance (0.223)	0.03
Public Issues	0.240	Contents & Development (0.283)		0.068
		Community of Interest (0.142)		0.035
		Government Support (0.574)	Spectrum Licensing (0.477)	0.066
			Supporting Policies (0.523)	0.072
Cost	0.390	Fixed Cost (0.277)		0.108
		Variable Cost (0.264)		0.103
		Subsidy by Government (0.459)		0.178
Grand Total				**1**

The weights considering the participants judgment are demonstrated in above Table 4.15 for all 38 participants from both group (government employees & private employees). The overall aggregated weights resulted from aggregating all groups are shown in Figure 4-1. (Overall AHP Model). The global and local priority of each criteria and sub-criteria according to all groups (38 participants) are shown in above Tables 4.15.

4.3 Analysis and Discussion

Once the global priorities of all sub-criteria are obtained, they were multiplied by the local priority of each alternative with respect to each criterion to obtain the evaluation score (weight) of each alternative (see (2.4.1, iv) in chapter 2). Finally, an overall score for each alternative is obtained by summing each evaluation score row as shown in Table 4.16.

The resulting priorities of the alternatives are illustrated in Table 4.16. From the Grand total column, *Wireless* technology is the most preferred alternative and has the highest score in this AHP model with a priority of ***0.494***. *DSL* comes next with a priority of ***0.326*** and then *Fiber Optic* technology with ***0.180***. The sum of the priorities in this column is equal to one. This complies with the AHP procedure and demonstrates that its steps are applied properly.

Table 4.16: Synthesized Final Survey Data

Alternatives	Criteria (Local Priorities)			Grand Total
	Technical Aspect (0.370)	Public Issues (0.240)	Cost (0.390)	
Wireless	0.196	0.127	0.171	0.494
DSL	0.111	.076	0.139	0.326
Fiber Optic	0.063	0.038	0.079	0.18
Grand Total	0.37	0.241	0.389	**1**

Moreover, from Table 4.15, one can observe that the comparison of the criteria with related to the goal yields that the Cost criterion has the highest priority of **39 %**, expressing a certain advantage among others, which indicates more importance in comparison to other Technical aspects and Public Issues attributes. The lowest priorities are for Technical Aspects and Public issues with **37 %** and **24 %**, respective.

The obtained final weights in Table 4.16 provide information about the alternatives and the way they are used to satisfy the selected attributes, as well as the importance of these attributes in order to reach the goal of the model. Taking this into consideration, a result where one can affirm which alternative is more preferable from telecoms experts' point of view is reached. However, the priority weights of the three technologies are actually quite different from each other and although Wireless achieved the highest score.

Table 4.17: Overall ranking of attributes according to their global priorities

Synthesis with respect to efficient policy infrastructure in rural areas

Rank	Subcriteria	Global priorities (%)
1	Coverage	18.70
2	Subsidy	17.80
3	Fixed cost	10.80
4	Variable Cost	10.30
5	Bandwidth	8.60
6	Supporting Policies	7.20
7	Contents & Development	6.80
8	Spectrum Licensing	6.60
9	Infrastructure	4.70
10	Community of Interest	3.50
11	Maintenance	3. 00
12	Security	2.00

In Table 4.17, the sub-criteria are arranged for ranking in a descending order according to their global priorities. The table shows that the most important sub-criterion among all is ‘Coverage’ with a priority of **18.70 %** followed by ‘Subsidy’ with **17.80 %** and ‘Fixed Cost’ with **10.80 %**. The top four attributes comprised a variety of sub-criteria that belong to all criterion. The least important sub-criteria among others considered in the model with priorities of less than **5%** are ‘Infrastructure’, ‘Community of Interest’, ‘Maintenance’ and ‘Security’ with **4.70 %, 3.50 %, 3 %** and **2%** respectively.

In general, AHP model’s hierarchy is considered the allocation of a goal between the attributes being compared which factor has a superior influence on that goal.

Chapter 5. Conclusion and Policy Implications

5.1 Overall Conclusion

In general, telecommunication plays a vital role to serve a community and especially Telecommunications infrastructure plays an important role in the primary development of the rural area and its inhabitants. In actuality, telecommunication is a very important and essential factor for Pakistan's rural development because Pakistan's 64% population lives in rural areas, and they have insufficient resources to telecommunication services. There are many attributes (economic, social, technical etc) identified for the rural environment which can be considered to achieve e-services from backbone technologies.

The issues surrounding the rural telecommunications infrastructure selection is not only technological but a complex system of other interrelated factors cutting across various aspects of rural areas and their inhabitants. Based on these issues which are associated with the infrastructure technology selection, this research was essential for the rural areas of Pakistan. Because of the complex structure of rural settings there are several factors to be considered. These factors have a big impact on the selection process, related to social, environmental, infrastructure and maintenance concerns. Based on the information and knowledge obtained from IT experts (from different sectors), this study discussed that how the goal was achieved and how to promote the telecommunication services in rural areas of Pakistan.

The previous literature (explained in chapter 2) covered some of the developmental aspects and universal access of rural telecommunications. But still the provision of rural telecommunications infrastructure is regarded as main economical and technology issues in developing countries. Research on this study indicated that the multicriteria (MCDM) approach would play an important role in the development of the AHP model for the selection of rural telecommunication infrastructure.

To obtain the goal of this study, the researcher applied AHP model which is based on the MCDM approach. For the selection of optimum backbone technology the AHP hierarchy was structured based on the identified attribute from the previous literature. Those attributes were considered to be the best solution for the selection of suitable backbone technology and rural development of Pakistan. Moreover, In Pakistan there are different access technologies available which deliver the connectivity of Internet. These contain the wired and wireless access technologies. The wired access technologies contain DSL and Fiber Optic, while the wireless access technologies are WiMAX and EvDO. These technologies were evaluated in terms of their cost, where they can be deployed according to their subscription. Available access technologies were explained in detailed in chapter 3.

The estimation results of the AHP hierarchy expressed in chapter 4 of this study. Data were obtained from IT experts, where IT experts are from different (government, private and semi-government) organizations of Pakistan. The collected data from participants were then combined using the Expert Choice 2000 software. The AHP survey and collection of data was discussed in detailed in chapter 4. The proposed AHP model empowers decision makers to observe the weaknesses and strengths of the problem, by comparing several technology options, with respect to an appropriate gauge for judgment. The total obtained data were classified into different groups (academia, Telecom and experienced participants) to judge the views and expertise of the respondents related to the selection of backbone technology infrastructure. By the comparisons of different groups there were slightly dissimilarities in the obtained results from each group of participants, which are described in chapter four and the obtained synthesis show inconsistency less than 0.1 which mean that their judgments were satisfactory.

After individuals group judgment an overall aggregated results were obtained which shows the priorities (local and global) weights of the attributes according to the preferences. From the grand total weights of the overall results, *Wireless* access technology was the most preferred alternative and has the highest score in this AHP model for the rural areas of Pakistan. However, it is the author understanding that the process of structuring models of any condition is hard and specifically rural areas, and the key to success in this challenge is the identification of the restrictions of any modeling technique utilized and structure shaped. Moreover, there is a limitation of AHP that it is dependent on the decision makers because the weightings obtained are based on the expert's opinion. Hence, the achieved results reveal the preferences of specialists who made the comparisons and therefore, should not be viewed as a goal evaluation of the relative appropriateness of the three technologies as backbone infrastructure in rural areas of Pakistan.

5.2 Key finding and Policy Implications

From the results and analysis there are some important implications which can be described as: In Pakistan' rural areas service cost and coverage of the technologies is the most important factors. The inhabitants of the Pakistan rural community prefer to use the internet stably and smoothly in their own homes with a more suitable bandwidth and specifically in their own local language. Mostly they give preference to Wireless technologies as compared to wired technologies, and wireless networks remain as valuable resources for the rural consumers who cannot afford or do not have the Internet at home. Telecommunication service providers need to focus on providing reliable and fast Internet services, not only in urban areas but also in rural areas of Pakistan, which will energize the market for improved penetration. The priority settings for policies were constructed to derive proper policy implications that help telecommunication service providers and policy makers to successfully establish backbone technology infrastructure in rural areas of Pakistan. For the establishment of new telecommunication infrastructure there is a need of sufficient funding and these deficiencies in funding require policy makers to prioritize technologies that the telecommunication provider has to start with.

The proposed AHP model empowers decision makers to observe the weaknesses and strengths of the problem, by comparing several technology options, with respect to an appropriate judgment for Pakistan’s rural telecommunication infrastructure selection. The strengths include sufficient time and money to spend on the selection process, careful evaluation, expertise from different sectors and many criteria considered. While weakness includes that the selection criteria not clearly defined and lengthy selection process. To overcome these weaknesses a systematic structure for the selection of rural telecoms infrastructure is encouraged, by prioritize relevant criteria, and several different elements like technical, social and economic, etc. The formation of the pair-wise comparison matrices in the AHP method is a time consuming and complex task, but the Expert Choice software helped us to efficiently model the problem by clarifying, organizing and presenting it in the way like decision makers think. The Expert Choice software also allowed modification of the model by flexible and easy to learn and use.

For Pakistan's rural areas the telecommunication service providers must provide a suitable technological infrastructure that meets the technology requirements of the area, which is the need and the goal for the provision of effective communication systems to transfer data between individuals, and society. And the government should also give subsidy to telecommunication organizations to support them for the enhancement of networks that interconnect different rural areas. As discussed above that there is a need of training and skills for the people of rural areas to promote the telecommunication services more effectively, for that workshops, training sessions and short term courses should be offered for the maintenance of the telecommunication infrastructure and long term sustainability. There should be a policy from the telecommunication service providers and policy makers for highlighting and improvement the social issues of the rural areas people.

Policy recommendation for the government and telecommunication service providers in Pakistan toward providing of reliable and fast Internet services to the rural areas of Pakistan. As this study was concerned to successfully establish backbone technology infrastructure in rural areas, the researcher suggests some key components for possible better performance. Currently, the rural areas of Pakistan have telephone and internet services but that are unreliable. This is due to the frequent breaks in the long-haul signal broadcast from the country's main telecommunication point to the remote access network. Information on the area coverage is insufficient; hence, there is a need to reduce downtime on telecommunication services to improve coverage and reliability. Also there is need for telephones to provide better information on demand, increase the capacities and improve the affordability of telecommunication services. Additionally, governments should cooperate with the private sectors to promote Internet penetration especially for remote and isolated areas. And provide telecommunication services at affordable prices rural inhabitants have little financial opportunity to subscribe Internet packages.

Another policy implication is lack of skilled people in rural area of Pakistan which needs to provide training for them to take an active part in development programs. Government of Pakistan and telecommunication service providers must educate the inhabitants of rural areas about sustainability of the applications and skills about maintenance of the technology infrastructure, because the maintenance decision making standard has low priority score in the overall ranking list. So there is a need to educate and provide opportunities to inhabitants of remote area for better performance and reliable infrastructure.

From the IT experts results it is noticed that security has low priority weight in the overall ranking of decision making standard list. Although, rural areas of Pakistan expose security to an increased level of theft of copper wires, telecommunication equipments and damaging of property. But these low proprieties do not mean that these decision making standards are not important in the deployment of telecommunication infrastructure for the rural areas. Thus the government should implement and activate some policies to educate the community on the importance of telecommunications infrastructure for their wellbeing in order to develop the security of the infrastructure and reduce the theft and damages of properties.

5.3 Limitations and Future Work

There are some limitations concerns to this study. First, this study achieved large issues surrounding access technologies for supplying Internet connectivity for the formulation of telecommunication policy, but it does not give an understanding into the climate and the ease of installation factors about the rural areas. Second, data were obtained from a small number of participants in the survey, which limits the scope and coverage of the goal. There is a need to obtain a larger sample size so there should be involved many participants from different organization who are aware of the problems of rural areas.

From this study many prospective areas for further research can be acknowledged, this study was concerned with Pakistan’s rural telecommunications infrastructure selection, and in rural areas of Pakistan, there is a big issue of power supply so a possible research initiative encountered in the distribution of electricity supply to rural communities. The second most important concern about rural communities is the need of education and training with respect to the use, installation, maintenance and protecting the telecommunications infrastructure. Therefore further research should consider on how to conduct such rural community education, training and involvement into the evaluation of issues.

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Appendixes

Annex 1 – Survey Questionnaire

Survey on Policy for Internet adoption and usage in the rural areas of PAKISTAN

This survey is carrying out with the cooperation of IT Policy Program of Seoul National University, South Korea, in order to study consumer preference structure of Internet penetration in rural areas of Pakistan.

With diverse criteria for technology assessment and different alternatives available nowadays, the selection procedure becomes complicated. This questionnaire attempts to raise the question of 'how best can telecommunications infrastructure providers select the most appropriate backbone infrastructure technology, competent of deploying internet penetration in rural areas of Pakistan?

This questionnaire includes pair-wise comparison questions addressed to telecommunications experts, to seek their judgments representing the relative influence of pre-identified selection factors (Criteria), on three telecommunication infrastructure technologies (alternatives).

All your response to this survey will be confidential and used only for academic research purpose.

If you have any comments, suggestions or questions about this survey, kindly contact us via e-mail at gulbacha@snu.ac.kr or star_ibrar@hotmail.com.

Thank you very much for your time and cooperation!

Important Notice - Please spend a few minutes to understand the attributes with their description in the box carefully before answering the questions.

Attributes	Description
Infrastructure	- Infrastructure contributes to the evaluation of backbone technologies. - Sharing of the existing public infrastructure assets such as radio towers, electricity clamps, public buildings, etc, are cost effective to cover remote areas.
Coverage	- How the proposed system is able to cover wider rural areas. - End-users located within the area covered by signals can have access to the internet.
Reliability	- Unreliable service will not encourage the rural population. The networks need safeguard and security against breakdown. Provide consistent speed and service.
Security	- Network Security and Information Security. - Protection of software and network architecture from threats (Hackers).
(Bandwidth) Speed & Services	- Bandwidth is relevant for both voice and data communication. - Bandwidth is directly related to the efficiency and effective performance of the link (speed & services)
Maintenance	In most rural areas main supply of electricity does not exist which lags behind telecommunication development. (low fault liability, no-site repair work etc). A suitable system should be capable of reconfiguring circuits to maintain better services.
Contents & Development (by Govt)	- Rural community is suffering from multi-dimensional problems mainly due to unavailability of information and lack of communication, Education, Agriculture information & technique, Healthcare etc. Through ICT development, rural community can get maximum benefits to improve their education, knowledge, health, agricultural skills, earnings and living standard.
Community of Interest	Rural communities have strong interests at their immediate geographical and administrative area so therefore their communication needs have to be taken into consideration when planning rural telecommunications networks.
Govt Support	Modest (limited) support from state and federal agencies will continue the creative utilization of existing services and facilities to give new life to the rural communities.
Spectrum Licensing	- Service delivery concern was to some extent due to the license restriction on telecommunication companies. In many countries spectrum is licensed through auction and there is a high price to pay for some frequencies.
Supporting Policies	- Most countries have explicit policy goal of promoting universal access to certain Infrastructure utilities. Including telecommunications, electricity, and piped water and sewerage at affordable prices.
Fixed Cost	Investment required for deploying the access technology (Purchase, Deployment and Central Office etc)
Variable Cost	Cost of Maintenance, Administration, Training, Testing and up-gradation etc (Depend on number of users)
Subsidy	- Government might wish to subsidize poor or rural consumers for political reasons or as part of a development strategy. - New methods (Reforms) are necessary to raise subsidies and to ensure access by the poor people.

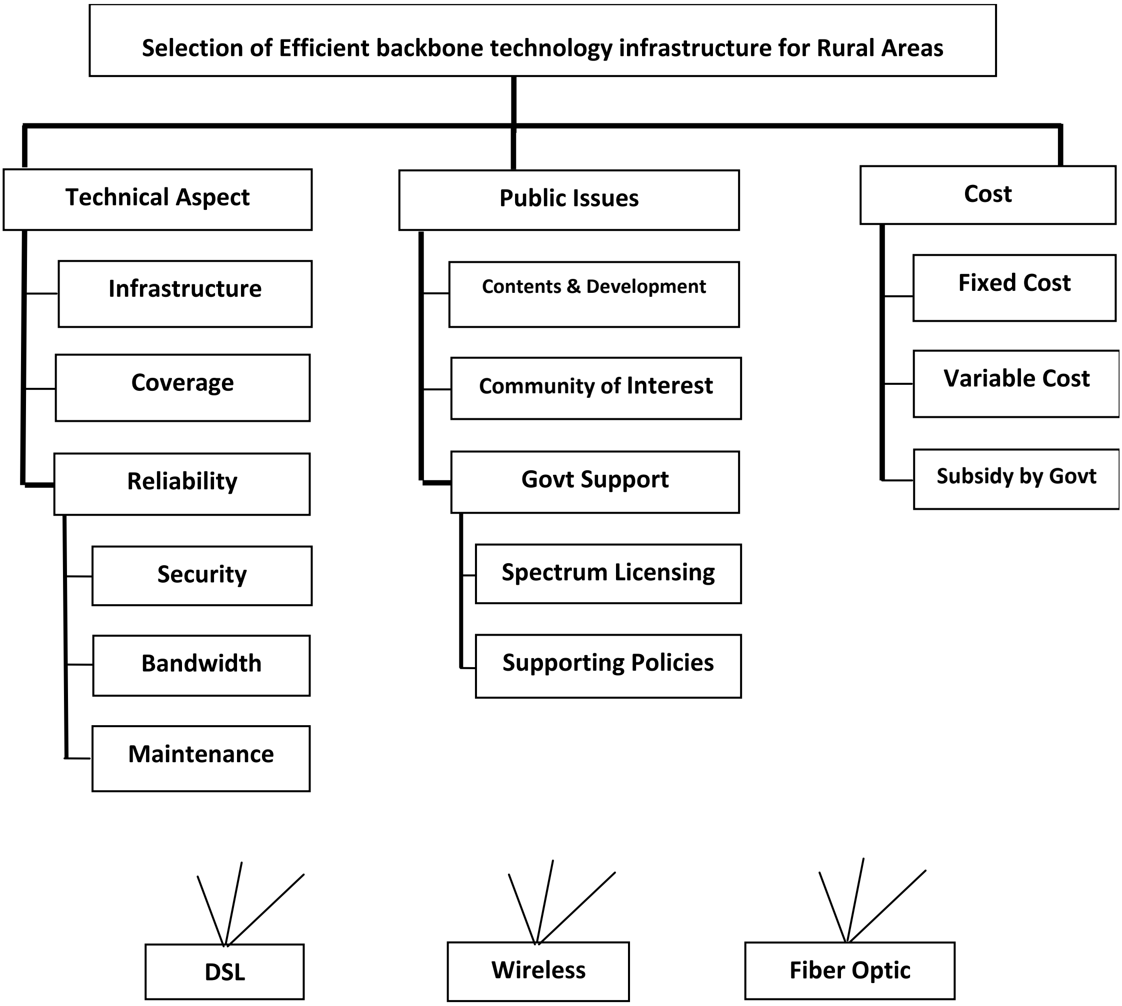

Figure 3.1: AHP Model for Selection of Backbone Technology in rural areas

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(Part - A) Pair-wise comparisons with respect to Criteria

Pair-wise comparisons for backbone telecommunications infrastructure for internet connection in rural areas of Pakistan

1	Equally Important	3	Slightly more Important
5	Strongly more Important	7	Very Strongly Important
9	Extremely more Important	2,4,6,8	Intermediate values

Underline or color the relative weighting of your chosen factor according to the scale shown in the above table.

Example

Technical Aspects	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Public Issues

Level - 1 Pair-wise Comparison

What is the more important efficient factor which influences on each other, when selecting a potential backbone technology infrastructure for internet connection in rural areas of Pakistan?

Underline or color the relative weighting of your chosen factor according to the scale shown in the above table.

Technical Aspects	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Public Issues
Technical Aspects	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cost
Public Issues	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cost

Level - 2 Pair-wise Comparison

1	Equally Important	3	Slightly more Important
5	Strongly more Important	7	Very Strongly Important
9	Extremely more Important	2,4,6,8	Intermediate values

What is the more important *"**Technical factor**"* which influences on each other, when selecting a potential backbone technology infrastructure for internet connection in rural areas of Pakistan?

Underline or color the relative weighting of your chosen factor according to the scale shown in the above table.

Infrastructure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Coverage
Infrastructure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Reliability
Coverage	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Reliability

What is the more important ***"Public Issue factor"*** which influences on each other, when selecting a potential backbone technology infrastructure for internet connection in rural areas of Pakistan?

Underline or color the relative weighting of your chosen factor according to the scale shown in the above table.

Content & Development	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Community of Interest
Content & Development	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Govt Support
Community of Interest	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Govt Support

What is the more important ***"Financial factor"*** which influences on each other, when selecting a potential backbone technology infrastructure for internet connection in rural areas of Pakistan?

Underline or color the relative weighting of your chosen factor according to the scale shown in the above table.

Fixed Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Variable Cost
Fixed Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Subsidy (Govt)
Variable Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Subsidy (Govt)

Level - 3 Pair-wise Comparison

1	Equally Important	3	Slightly more Important
5	Strongly more Important	7	Very Strongly Important
9	Extremely more Important	2,4,6,8	Intermediate values

What is the more important ***"Reliable factor"*** which influences on each other, when selecting a potential backbone technology infrastructure for internet connection in rural areas of Pakistan?

Underline or color the relative weighting of your chosen factor according to the scale shown in the above table.

Security	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Bandwidth (speed & service)
Security	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Maintenance
Bandwidth (speed & service)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Maintenance

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What is the more important ***"Govt support factor"*** which influences on each other, when selecting a potential backbone technology infrastructure for internet connection in rural areas of Pakistan?

Underline or color the relative weighting of your chosen factor according to the scale shown in the above table.

Spectrum Licensing	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supporting Policies

(Part – B) Selection of Telecommunications Backbone Technology in Rural Area of Pakistan.

Instruction: For each pair of technologies given below, please fill in the relative assessment of their pair-wise comparisons, as shown in the example: **Underline or color** the relative weighting of your chosen factor according to the scale shown in below table.

1	Equal Importance	3	Slightly more Importance
5	Strongly more Important	7	Very Strongly Importance
9	Extremely more Importance	2,4,6,8	Intermediate values

Example: Which of the two technologies you believe is more important within rural environments of **Pakistan**?

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	**7**	8	9	Wireless
DSL	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	Fiber Optic

For each pair of technologies given below please **Underline or color** the relative weighting of the technology providing more importance relative to the technology providing less importance. These Pair-wise comparisons questions are for *Technical Aspect, Public Issues and Cost Criteria*.

1	Equal Importance	3	Slightly more Importance
5	Strongly more Important	7	Very Strongly Importance
9	Extremely more Importance	2,4,6,8	Intermediate values

Infrastructure: It refers to the Sharing of the existing public infrastructure assets such as power sources, accessible roads and transport in rural areas of Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

<u>Coverage</u>: It refers to the coverage range from the proposed technology to be deployed in rural areas Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

<u>Security</u>: It refers to the protection of information and network infrastructure technology equipment and cables from threats or Hackers in rural areas of Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

<u>Bandwidth</u>: It refers to what extend the technology will increase and enhance the speed of transport and improve the potential of new services in rural areas of Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

<u>Maintenance</u>: It refers to the maintenance and user friendliness of the infrastructure equipment that needs to be deployed in rural areas of Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Content & Development: It refers that from what one can get maximum benefits and to improve their education, knowledge, health, agricultural skills, earnings and living standard.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Community of Interest: It refers to the collaborative fulfillment of community of interest requirement in rural areas of Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Spectrum Licensing: It refers to the license restriction on telecommunication companies and which satisfy the licensing requirement.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Supporting Policies: It refers to the explicit policy goal of promoting universal access in rural areas.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Fixed Cost: It refers to Capital investment required for deploying the Internet access technology such as Purchases, Deployment and Central Office etc

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Variable Cost: It refers to Cost of Maintenance, Administration, Training, Testing and up-gradation etc

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Subsidy: It refers to the new methods (Reforms) which are necessary to raise subsidies and to ensure access by the poor people of rural resident of Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Part C - 1 (Respondent Demographic and general Information)

Name	
Gender	
Age	
Organization	
Position	
Working Experience (Years)	
Email ID	
Contact No.	

Part C - 2 (Professional background Information)

The aim of this survey questionnaire is to obtain information about the planning and designing phase of rural telecommunication infrastructure within Pakistan.
(Please choose/write the best option(s) according to your preference)

1. What is your Job status?

   ① Public Employee ② Private Employee

   ③ Semi-Government ④ Others…………………

2. What education level do you have?

① Diploma ② Bachelor ③ Masters

④ Doctorate

3. In the planning and design of a rural telecommunications infrastructure in Pakistan, what considerations are given to the following aspects: *(Choose more than one option if applicable)*

① Technological ② Social ③ Economical

④ Regulatory ⑤ Political ⑥ Other………

4. What benefits are expected from Pakistan's rural telecommunications infrastructure?
(Choose more than one option if applicable)

① Economic ② Social ③ Agricultural Info

④ Educational ⑤ Health ⑥ Other ………

5. Consultations take place with whom, during the planning and designing phase of rural telecommunication infrastructure in Pakistan?

① Government ② Private ③ Other………

6. Job Description: …...

7. If you feel any other factors which are not listed in this survey and are relevant to influencing the backbone technology in rural areas of Pakistan, please feel free to suggest and indicate why they are relevant?

…………………………………………………………………………………

…………………………………………………………………………

Thank you very much for your time, participation and cooperation

Annex II - AHP Inconsistency of each respondent

(Total 38 respondents)

S. NO	Group 1: Government Employees		Group 2: Private Employees		Group 3: Semi-government Employees	
	Respondent no	Inconsistency	Respondent no	Inconsistency	Respondent no	Inconsistency
1	P2	0.05	P3	0.03	P4	0.06
2	P3	0.03	P4	0.04	P6	0.03
3	P5	0.07	P6	0.07	P7	0.04
4	P6	0.04	P7	0.03	P8	0.03
5	P7	0.03	P8	0.04	P9	0.03
6	P8	0.05	P9	0.04		
7	P9	0.04	P10	0.09		
8	P10	0.07	P11	0.04		
9	P11	0.04	P12	0.03		
10	P12	0.04	P13	0.05		
11	P13	0.01	P14	0.04		
12	P14	0.04	P16	0.03		
13	P15	0.04	P17	0.06		
14	P16	0.09	P18	0.09		
15	P17	0.03	P20	0.03		
16	P18	0.04	P21	0.05		
17			P22	0.07		

초록

파키스탄 시골지역의 인터넷 연결을 위한 효율적인 침투 정책 :

계층분석과정 접근

이브라

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ICT 정책 및 계획 수립에서 인터넷 사용자들의 선호도를 이해하는 것은 유용하다. 통신인프라는 지리적 경계의 한계와 외부경제 및 사회개발을 위한 기본요소로 인식되고 있다. 도시지역을 넘어, 통신기술 인프라는 사회적인 이익과 성장, 연결과 경쟁에서 필수적이다. 개발도상국의 시골지역의 경우 더욱 중요하다.

이 논문은 파키스탄 시골지역에서 인터넷 연결과 관련된 관점들을 제시한다. 이 연구의 목적은 구체적으로 종합시험과 파키스탄 시골지역에 있어서 최적의 통신기술 인프라 선택에 관한 것이다. 문헌조사는 분석 의사 결정 프로세스에 특히 초점을 맞춘

다기준의사결정모형 (MCDM) 분야의 지식과 이해를 위해 실시하였다. 연구결과, 계층분석과정 (AHP) 가 이러한 복잡한 문제를 모델링 할 수 있는 강력한 결정방법이라는 것을 발견하였다. AHP 는 통신기술에서 대안기술 평가를 위해 사용된다. 방법은 계층구조에서 설명된 서비스의 품질에 영향을 주는 여러 요인 간의 쌍대비교에 기초한다.

이 연구는 통신인프라 데모 제공과 파키스탄 시골지역에서의 기술선택과 결정이 어떻게 이루어질 수 있는지 학계와 전문가 및 정책 입안자에게 귀중한 통찰력을 제공할 것이다.

키워드: AHP 계층분석과정, 인터넷 관통, 통신 인프라, MCDM 다기준의사결정모형, 기술 선택, 파키스탄 시골지역.

학 번: 2012-23986

Master's Thesis in Engineering

Efficient Penetration Policy for Internet Connection in Pakistan Rural Areas

- An Analytical Hierarchy Process Approach -

February 2016

IBRAR

Technology Management, Economics and Policy Program

College of Engineering

Seoul National University

Abstract

Efficient Penetration Policy for Internet Connection in Pakistan Rural Areas: An Analytical Hierarchy Process Approach

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Understanding the preferences of Internet users is useful for ICT (information and communication technology) policy and planning. Infrastructure of telecommunication is recognized as the key and fundamental factor for economic and social development outside the limits of geographical boundaries. Beyond Urban communities, Telecommunication technology infrastructure is a necessity for social benefits, growth, connection and competition, more in the rural communities in developing countries.

This study shows appearance of Internet connection in rural areas of Pakistan, and specifically the aim of this research is concerned with a comprehensive examination and analytical procedures on the selection of optimal telecommunications technology infrastructure in Pakistan's rural areas.

Literature review was accomplished to investigate the knowledge and understanding in the areas of Multi-Criteria Decision-Making (MCDM) approaches, with particular focus on the analytical decision processes. The findings show that the Analytic Hierarchy Process (AHP) is a powerful decision method which is capable of modeling such a complex problem. An Analytic Hierarchy Process (AHP) method is presented that can be used for the evaluation of alternate technologies in telecommunications. The method is based on pair-wise judgment between various factors that affect the quality of service in a described hierarchical formation.

This research will provide valuable insights for the policy makers from both academics and professionals, on Telecommunications infrastructure providing demonstration and how such rural technology selection decisions can be made within Pakistan's rural areas.

Keywords: Analytical Hierarchy Process (AHP), Internet penetration, telecommunication infrastructure, multicriteria decision making (MCDM), technology selection, rural Pakistan.

Student Number: 2012-23986

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Chapter 1. Introduction

1.1 Overview

In the modern information technology revolution the Internet plays an indispensable role. It is the fastest diffusing ICT to date. For instance, Internet access spread to 50 million users in the world in only 4 years compared to the television and the radio, which took 38 years and 13 years, respectively, to reach the same user access level (ITU, 1999). Another more attractive phenomenon is the number of countries linked to the global network. From over 20 in 1990, there were more than 200 nations linked to the Internet by July 1999 (ITU, 1999). Despite rapid word-wide diffusion of the internet, there has been a great disparity between developing and developed countries – rich and poor regions – in terms of the number of Internet hosts and internet users (Manandhar, S, P. 2012). This rapid technological change was driven by the demands of information access. Telecommunications technology became a tool for the delivery of information, affecting all sectors from business to education, from healthcare to entertainment. Telecommunications is an important element in any country's strategy for reconstruction and development as it suggests information links between urban and rural areas that can vanquish distance hurdles which interrupt development. In urban areas there is dynamic competition for long distance, wireless telephone, and broadband internet access. However, in rural areas, even basic telephone services may become difficult or impossible to maintain for many of their inhabitants. Such areas are technologically poor and need special consideration and efforts if they are to actively participate in the information age.

Rural communities need better services to compensate for their geographical isolation and cost of being far from the cities. Developments in telecommunications technologies make it possible to supply services in rural areas at reasonable prices, which were earlier not possible. The planning and development of telecommunication infrastructure in rural areas and risky environment require longer time involving a substantial number of manpower from many suppliers as compare to urban centers, but an infrastructure provider is responsible for providing transmission bandwidth for them, these include: Wireless, Fiber cables, undersea cables, satellite, etc.

There are several studies of International Telecommunications Union (ITU, 1989 and ITU-D, 1997) which identified the need to investigate various issues related to the deployment of telecommunication services to settlements of rural communities as a problem requiring urgent action. These studies have also shown that telecommunications, particularly in rural areas need access to the main Telecommunication network, which can facilitate many development activities, such as agriculture, industry, social, education, health care, etc. which are unevenly distributed in such areas.

Nowadays there are various criteria available for technology assessment and a different alternatives, the selection procedure becomes complicated. There are many of choices of technologies available in the market to be applied to rural areas, depending on the nearby conditions of the concerned areas. However, the selection and deployment of such rural technologies are characterized by complex issues that are not only technological but are complex due to the complexity of interactions among the different elements affecting the process (Andrew and Petkov, 2003). In general, the telecommunication backbone is a key problem for the rural areas information infrastructure.

1.2 Research motivation and objectives

This study is about telecommunications technology infrastructure in rural areas of Pakistan, to promote fundamental factors of modern services, non-existence of such proper telecommunication infrastructure will delay the delivery of such services. There is necessity to provide access to the central telecommunications network and enlarge connectivity to Pakistan's rural areas, by the choice of appropriate telecommunications infrastructure technology that will provide the required e-services within various constraints. The backbone network offers the long-haul signal transmission from the country's central telecommunication centre to the remote access network of the particular area. This network may be wireless or wire-line (copper wires), including analogue and digital transmission technology through fiber optic, wireless or satellite transmission media. But the deployment of telecommunication technologies infrastructure in rural areas is critical because of the presence of many associated problems, cost affordability and the correct choice of telecommunication technologies. For this problem there is a need of methodology that can help telecommunication infrastructure providers to understand better that how to reach to successful investing decisions in available different rural technologies and the need of account for technical, social and economic elements.

Furthermore, according to (Andrew and Petkov, 2003 and Nepal, 2005) the deployment of rural telecommunication services and infrastructures in developing countries is considered by many researchers as a difficult system of people and technology which are co-dependent on other systems or subsystems and characterized by multiple stakeholders. These issues initiated the need to think the selection process from several point of views to discover methodologies that will facilitate contribution and engagement, which contain improvement of the difficulties by the needed rural communities.

This study mainly addressing the questions of how can the telecommunications service providers establish the backbone network model for the rural areas of Pakistan? and how to select the most suitable backbone infrastructure technology for the rural areas of Pakistan? But there are complexities which are involved with the consideration of a set of criteria such as technical aspects, public issues and cost attributes. Taking these attributes into consideration, the problem of selecting the most appropriate telecommunications infrastructure technology for rural areas Pakistan is to be addressed in this study by using a multi-criteria approach, with particular focus on the analytical hierarchy process (AHP).

This study, thus, aims to provide a comprehensive examination regarding rural telecommunications infrastructure selection by conducting an analytical decision analysis within the context of Pakistan. Based on the motivation, background and objective of this research the main aim will be pursued through the following objectives:

1. To examine and analyze the issues and challenges involved in the selection of rural telecommunications technologies in Pakistan.
2. To explore and analyze suitable MCDM (Multi Criteria Decision Making) methods particularly the Analytic Hierarchy Process (AHP) that can be applied to choose the most appropriate telecommunications technologies for Pakistan's rural areas.
3. To formulate AHP decision model for selecting potential technology options concerning rural telecommunications infrastructure for Pakistan.
4. To propose strategy for improvement of decision processes related to Pakistan's rural telecommunications infrastructure selection.

And it is assumed that the conducted research and investigation can be modified to integrate the unique needs of other rural areas with similar characteristics.

1.3 Structure of the Thesis

This study is structured into five chapters and a brief description of the remainder is summarized as follow: Chapter one introduced the overall overview and information for the telecommunication infrastructure in rural areas, and specifically for Pakistan's rural areas. This chapter also included the background information about the problem of the selection of suitable backbone infrastructure, objectives, motivation and structure of the thesis.

The second chapter covers a review of the related work by exploring the attributes affecting the selection and deployment of rural telecommunications infrastructure in a Pakistani scenario. It also covers the importance of the application of telecommunication services in rural area. This chapter investigates deep analysis of rural situation and the requirement of telecommunication to growth and development, economic and social well-being. It also includes various factors faced by policy makers of rural infrastructure, and in particular, factors that influence the selection of rural telecommunications technologies. It presents an explanation of the activities that were used as means to consolidate the final list of selection criteria.

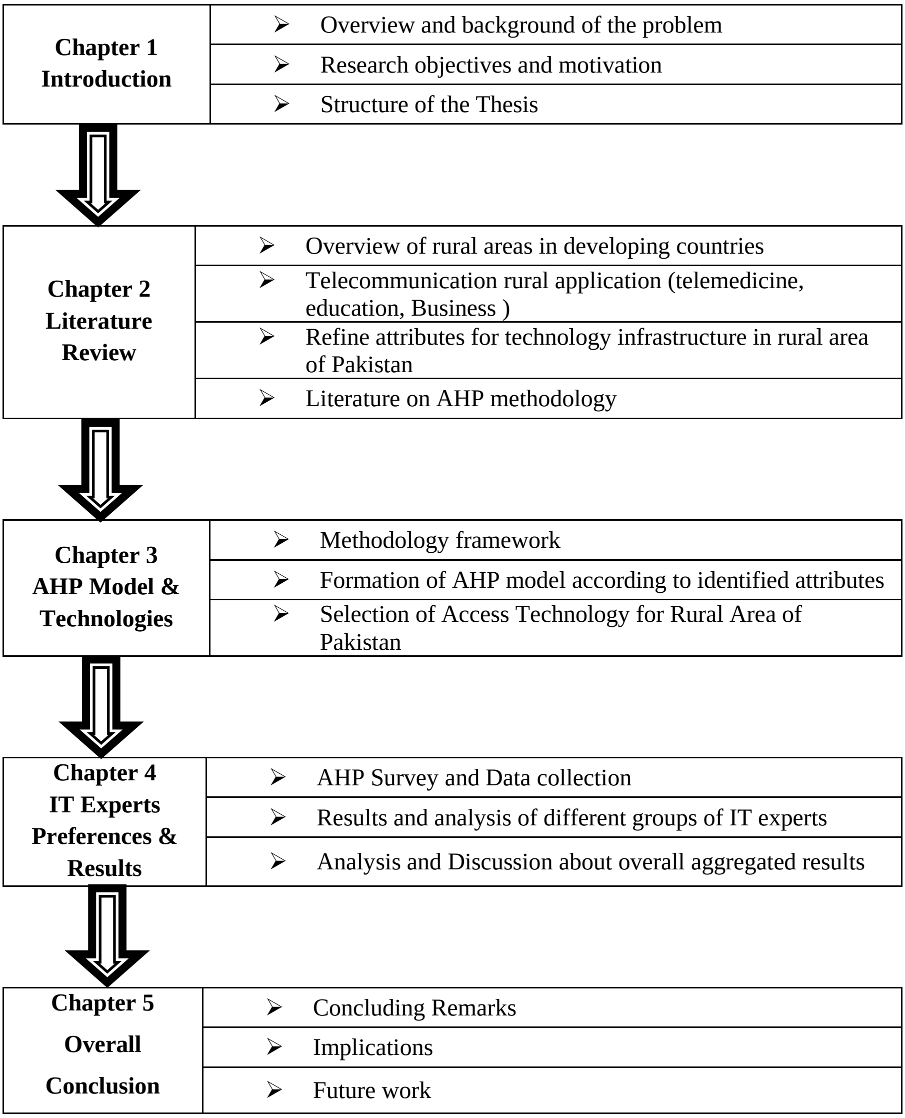

Figure 1.1: Structure of Thesis

Chapter three briefly introduced the AHP model and access technologies which is the fundamental methodology of the proposed approach. The Analytical Hierarchy Process (AHP) has been widely applied to a range of decision problems with diverse and sophisticated solution. So this chapter describes the structuring of AHP model for the selection of telecommunication backbone infrastructure and different media access technologies available for Pakistan's rural areas.

Chapter four covers the collection of data and AHP analysis phase. For pair-wise comparisons of the identified attributes the AHP survey questionnaire was developed. Data was collected from planners of rural areas infrastructure and from different IT experts, government employees, Private employees, and technical staff, and data was analyzed using pair-wise comparison of the elements on a qualitative scale. So, chapter four describes the AHP survey, data collection and synthesizes of results, in detail related to the selection of technology infrastructure for Pakistan rural area case.

Chapter five concludes the overall objective of the research. It also discusses the implication of the findings, recommendation and suggestion for the future work.

Chapter 2. Literature Review on Rural Telecommunication

To find optimal connectivity access technology, it was needed to assess the technologies that could possibly be deployed in rural areas. From a technical point of view rural telecommunications systems should satisfy certain technical conditions, in order to be economically attractive. Proper decisions need to be made to ensure the provision of the most proficient network and most helpful system within numerous constraints (ITU-D, 1997). This chapter includes various factors that generally faced by policy makers of rural infrastructure, and in particular, factors that affect the selection of rural telecommunications technologies. It presents an explanation of the activities that were used as means to merge the final catalog of selection criteria.

This chapter investigates into deep analysis of rural situation and the requirement of telecommunication to growth and development, economic and social well-being. The summary is presented in the end of this chapter.

2.1 Characteristics of Rural Areas in Developing Countries

The population of rural areas is more in percentage and they are living with poor and low life standard. Majority of them are jobless and uneducated. Unluckily, if someone gains an education, they struggle to shift to urban areas for better jobs. If government thinks only about the education of rural people so that is not enough. There is requirement to develop their lives within their current locations; similarly they love to live there with their own resources. Therefore, there is requirement for horizontal co-ordination among Government sectors and vertical co-ordination between local leaderships and national policy-makers to make sure a united response to consider rural community and to support rural development.

Rural areas have distinctive characteristics that need appropriate technology to help the area. According to (ITU-D Group 7, 2000), in 2000 more than half the world's population lived in rural areas. Rural areas are described by one of the following features (Kawasumi, 2000):

- Challenging obstacles, such as mountains, lakes, rivers, deserts and long distances between settlement areas, which cause costly construction of wired telecommunication networks.

- Hard climatic conditions that make massive demands on certain components of telecommunications equipment (e.g., the remote switch and antenna), accordingly adding to the costs of maintenance and installation.
- Absence or lack of public facilities, such as usable water, regular transport, reliable and consistent electricity supply, access roads, and an existing communication infrastructure.
- Underdeveloped social framework, such as for education, health, small business and lack of most government services.
- Low level of economic activities with few jobs opportunities; the existing economic system may be based mainly on agriculture, fishing or handicrafts.
- Low per-capita incomes, as low-paying work precede to low family incomes. Ultimately, there is low demand for communication services.
- High illiteracy rates and low educational levels. Thus, there is insufficiency of technical personnel and that may become difficult or impossible to maintain for many of their inhabitants.

To provide a basic network infrastructure the above characteristics make rural areas a hard environment for Telecommunication Company. To understand rural problems and issues in developing countries, it is essential to investigate the demographic characteristics, benefits and challenges of rural environments. Furthermore, among these problems the most serious are lack of necessary funds and work opportunities, and as a result insufficiency of such cultural resources and opportunities for professional advancement faced, youths are likely to move to urban areas, which can provide higher education and career opportunities. The divide between rural and urban communities is increasing annually in terms of job opportunities, economy, education, health care, public service and public safety (Hudson, 1999).

2.2 Telecommunication in Rural Areas

“Telecommunications in rural areas should be offer the same services as offered in urban areas such as telephone, data transmission, video transmission and other services, both for individuals (private subscribers) and for the public communities” (ITU-D, 1997). In a developing country rural Telecommunications planning is a difficult procedure; The Planning of rural telecommunications services is characterized by a multitude of difficult problems (Andrewa, Rahoo, and Nepal, 2005). Aside from the provision of some infrastructure for the provision of services, the provision of proper telecommunications infrastructure is neglected in several rural areas in developing countries. It is the disadvantage of rural areas that they do not receive the technology as quickly as urban areas do. Rural communities are not benefiting from the quality of life and economic opportunities that new technologies bring because of the unavailability of telecommunication infrastructure. Therefore for developing countries it is a great challenge to provide and ensure the relevant telecommunication services and applications, such as telephone service, telemedicine, internet, e-learning etc. These services will promote the rural development and also the resulting advantages of economics, agriculture, cultural and social development are extended effectively and efficiently. The aim focus of this study is on the provision of telecommunication infrastructure for rural areas of Pakistan. Another study from (ITU-D, 2006) stated that "Planning of rural telecommunication infrastructure should first consider the development of rural areas as an essential part of a coordinated evolution in a given country".

According to (ITU, 2010) repot it stated that in most developing countries the rural telecommunication services are growing but still in need of improvement, statistics from (ITU, 2010) indicate about telephony services and internet access as follow

- Almost 90% of the world population is subscribed by mobile cellular network.
- 50% population of the world lives in rural areas and 75% of rural population subscribed by mobile cellular networks.
- Africa showed the lowest coverage; where over 50% population of the rural area is covered by a mobile cellular network. And in

Africa the biggest increase recorded in rural mobile subscription between 2000 and 2008.

- In developed countries 95% of rural areas are covered by a mobile cellular network signal. In which few have internet access and more than half of rural households have a telephone technology.
- In developing countries rural inhabitants rely more on mobile technology than on fixed telephony, mobile penetration rates are reaching over 50%, while fixed telephone penetration in rural households often below 5%.
- In developing countries over 80% of people still do not have access to the Internet and from world's population 26% was reported online at the end of 2009.
- Almost 60% of inhabitants in developed countries had Internet access as compared to 12% of inhabitants in developing countries. This showed very low internet penetration.

Despite government legislations, in developing countries rural areas remain far behind than urban in advanced telecommunication development. Theoretically it is simple for the governments to confirm development, but it is very hard to implement policies and strategies to encourage it. By the shift to an information economy, rural areas are being strongly affected. (Hudson, 1999). The provision of telecommunication indicates rural development and is therefore considered an essential infrastructure element, but development of rural culture and environment is not justified by installing telecommunications networks, equipment and computers. Many studies from around the world investigate and conclude positive relationship between in economic improvement and access to telecommunication capabilities. As we discussed above that telecommunication is a development tool but sometimes telecommunication has been ignored by planners and they put telecommunication in a low rank with other public utilities like roads, water, and power supply, although telecommunication is a key element of conveyance of information. Telecommunications is essential but not enough for rural development because of the lack of different utilities and facilities which are closely related with the need for improvement of rural telecommunications. In order for local telecommunication to be successful, there is a necessity for a basic level of literacy and training.

The Information technology literacy in rural areas is very low and the understanding of technologies and computers are neglected. Computer literacy and training should be the purpose for the people residing in rural areas, and the use of localized software solutions would be useful in providing support for their understanding. The majority of opinions are that providing connectivity to residents of rural areas can be an innovative way to empower the economy, community and individuals.

2.2.1 Telecommunication rural applications

Telecommunications have been verified to be the rapid medium to access services. The new applications being introduced by telecommunication companies are being created to meet rural requirements and are often connected to development efforts. Suchlike applications include telemedicine, distance education, and community and business development (ITU-D Group 7, 2000).

i. Telemedicine:

Telemedicine has been explained as the utilization of electronic information and communications to provide and support healthcare when distances split the members (Field, 2002). To consult a specialist physician, the people of rural areas have no choice but to travel to big cities, spend money and hard time on transportation. Most of the times, due to bad conditions of roads and traffic, the patients are unable to consult the concerned physician on the day of appointment.

In many developed countries it is an initiative for the delivery of medicine at a distance, using communications and information technologies. This approach provides a wide range of benefits to individuals such as monitoring and diagnosis of patient through multimedia communication connections between urban and remote rural facilities (health centers, hospital etc) which may develop home health care services for rural inhabitants. Telemedicine connections can develop the quality of rural health care by this mean.

There are some challenges which are linked with the utilization of telemedicine systems which include lack of physician interest, high telecommunication costs and failure to build evaluation into the design process. Experience has verified that important telemedicine applications contain training and in-service coaching of remotely situated health care staff. And for real time application of telemedicine a high speed of bandwidth will be required.

ii. Distance education:

Distance education is utilized in a broad range of purposes such as colleges and universities use it to increase the number of students who have approach to higher education; companies use it to upgrade their employees skills; individuals use it for their own professional advancement to boost their career opportunities; governments use it to provide on-the-job training to teachers or other employees to boost the quality of traditional primary and secondary schooling, and to convey instruction to rural areas that might not be served. The delivery of distance education through technology (satellite or internet) may provide an ideal way for rural schools to provide best education to their students available anywhere and anytime. Technology is an important contributor to the transformation of distance education, although the use of technology for distance education is not new television and radio has been used effectively. New technologies offer options to expand educational opportunity and improve quality, but inappropriate decisions whether to use technology or what type of technology to use can be costly and can delay the benefit of a distance education.

Utilizing video and voice capabilities need high bandwidth to deliver services to rural areas, which is a technical challenge. Rural and remote inhabitants can enjoy and get benefits from using telecommunication technologies which has the potential of new educational and training possibilities. Distance education programs need flawless management and financial planning to ensure sustainability.

iii. Community and Business Development

A big improvement is being made in business development and rural community through the introduction of telephony, Tele-centers, e-mail, and radio broadcasts. The successes of business development and community applications were found to depend on the availability of relevant content and local language support (ITU-D Group 7, 2000). In many developing countries rural communities access telecommunication through community centers, schools, coffee shops or available Internet café etc. Therefore, such centers allow emigrants to keep contacts with the friends and family that they have left behind in the villages, promoting profitable revenues from long distance calling charges.

These centers may also provides facilities of printing, scanning, composing etc which creates jobs opportunities and provides platform for small business in such rural and remote areas.

2.3 Attributes for deploying Rural Telecommunication Infrastructure

The selection and deployment of rural telecommunications technology is a complicated process. And the problem is defined for the selection of appropriate technology for rural areas based on criteria, so there is a need to consider technical, economical and public issues before deciding on a specific rural telecommunications technology. The most important and creative issue in making a decision is to adopt the factors that are relevant for that decision" (Saaty, 1990). Previous studies showed that each telecommunication infrastructure supplier have its own criteria, sub-criteria and alternatives for the particular problem. Several pieces of research have been undertaken concerning the selection of telecommunications infrastructure technology which is designed to extend e-services applications to rural areas. Without sufficient knowledge about particular rural area it is impossible to deploy a telecommunication infrastructure. Introducing advance telecommunication services to rural area and getting the people to adopting and having used to, take a lot time.

(Sasidhar and Min, 2005; Douligeris and Pereira, 1994) investigated cost, quality, and speed attributes and use Multi Criteria Decision Making (MCDM) methods particularly the Analytic Hierarchy Process (AHP) for selection of telecommunications network. (Chemane et al, 2005) explored several criteria with respect to financial and technical aspects and stated that selection of most appropriate Internet access technology is a challenging and complex process. With the use of broadband internet access, developed countries are enjoying the advantages of the technological transforms but developing countries have issues of selecting inappropriate choice of access technology, Low adoption of ICT and high cost of access to technologies.

(Andrew, P.Rahoo and T.Nepal, 2005) stated that the planning of rural telecommunication services is characterized by a great number of complex issues like uncertainty, multiple conflict objectives and security of physical technology infrastructure. AHP model is utilized for providing suitable solutions in the selection of telecommunication technologies for rural areas. And 51 sub criteria were categorized into 5 first level categories e.g. “Service Standard”, “Cost”, “Environmental issues”, “Social and demographic issues” and “Regulatory and technical standards”. For the deployment of telecommunication infrastructure it is a complicated challenge to provide affordable and accessible advance services to rural inhabitants who have low financial resources. To provide efficient and optimal telecommunication technology require different expertise in different disciplines which involves in designing, constructing equipment installing, testing, monitoring and managing further activities for consistent accessibility. Before designing and planning a telecommunication infrastructure in a rural area, it is highly recommended that the needs of the area and the infrastructure must be economical.

After discussion and conclusion from different studies on different issues that may affect the provision of telecommunication services in the rural areas, Pakistan rural areas need a list of possible criteria when selecting telecommunication technologies. Initially a list of 20 criteria (cost, technical aspect, public issues, regulatory, environmental issues, fixed cost, variable cost, subsidy, security, reliability, coverage, maintenance, flexibility, bandwidth, contents and development, community of interest, licensing issues, spectrum availability, parallel infrastructure and climate condition) was produced that affecting the choice of rural telecommunication technologies for the Pakistan rural areas. There were some attributes which were not suggested and the list was further revised and the criteria reduced to **17** different attributes (technical aspect, public issues, cost, Infrastructure, coverage, reliability, security, bandwidth, maintenance, contents & development, community of interest, government support, spectrum availability, supporting policies, fixed cost, variable cost and subsidy). With the main goal of this research being ‘Selection of efficient backbone technology infrastructure for rural areas of Pakistan’ the **17** criteria were categorized into **3** first level categories; ‘Technical Aspect’, ‘Public

Issues', and 'Cost'. We will talk in detail about all these attributes and grouped them together according to their perspective criteria.

2.3.1 Attributes for Technical Aspect

The process of establishing an integrated telecommunication infrastructure and selecting the most optimal backbone technology in rural areas of Pakistan was the primary objective of this study. The results of this study may be useful to other developing countries. Telecommunications infrastructure has shaped societies in various ways in order to provide basic Advance services, but in rural areas economic characteristics make is complicated to provide telecommunication services of a satisfactory prices and quality. In developing countries rural transportation systems are often not well managed and small, therefore most of the rural communities may not be reachable at all by road and technical staff availability on site is rare. And infrastructure maintenance became very costly. Similarly, many rural areas are not linked to national power grids, and so operators have to provide their own energy, (Gasmi and Virto, 2005).

Following are some technical attributes that may affect the choice of optimal technologies for access to rural areas that will provide the most efficient network. However, technical attributes can also be classified into attributes such as infrastructure, coverage, reliability, security, bandwidth (speed and service) and maintenance as explained below.

i. ***Infrastructure:*** To encourage rural development parallel infrastructure is needed which support rural telecommunication. Consumers of Telecommunications appeal for high quality of services from their providers, therefore Telecommunication Company should provide the best infrastructure with the provision of best quality with low prices (Douligeris and Pereira, 1994). Lack of optimal infrastructure has been predicted to double or triple the cost of supplying the services to rural areas; therefore government should consider some reforms for example price, interconnection agreement, cost allocation mechanisms in term of their impact on affordability and infrastructure (Gasmi and Virto, 2005).

ii. ***Coverage:*** Network coverage (geographically) is one of the successful attribute within a rural or remote area of a country. The penetration level will be more when the coverage is more. End-users based within the area covered by signals can have access to the internet (Chemane et al, 2005). According to Pakistan Telecommunication Authority (PTA, 2009) Broadband is a developing technology rather than a well-established industry in Pakistan, consequently its penetration is at very low level. Presently, Pakistan remains at 0.26 % in terms of broadband penetration. Lack of local content, low literacy rate and focus on big cities by operators rather than rural areas are the reasons for low penetration.

iii. ***Reliability:*** Rural telecommunication infrastructure must be highly reliable and the most important need for a rural communication system is to provide the best and reliable services. Many network technologies such as satellite and wireless may be affected by weather because of bad quality of transmission. Reliability belongs to consistent service and speed. The inhabitants of rural areas will not encourage unreliable telephone and other access technologies to arrange their social and economic affairs. Reliability is more important than maintenance, to provide consistent speed & service and provide safeguard against breakdown (Henry Chasia 1976; Sasidhar and Min 2005).

iv. ***Security:*** Protection of rural telecommunication networks from theft is a big problem also security must be considered risk to values and information utility. Every user connecting to the Internet who is using available access technologies has security needs, specific information and concerns (Sasidhar and Min, 2005; Douligeris and Pereira, 1994; Chemane et al. 2005). Security in general based on the software and the architecture of network.

v. ***Bandwidth:*** Bandwidth belongs to the capacity of data transferring through the access technology. High bandwidth channels are referred to as broadband, which typically means higher speed at which one can upload and download information (ITU, 1997). The transmission medium comprises of coax cable, twisted wire pairs, fiber optic cable, radio medium links, and wireless satellite transmission systems. High bandwidth channels are referred to as broadband which means higher speed at which one can upload and download information. (Chemane et al. 2005, Sasidhar and Min 2005). Bandwidth is directly associated to the effective performance and efficiency of the transmission connection (speed & service).

vi. Maintenance: It is very important in terms of efficiency and economic success. Mostly rural areas main power supply does not exist which lags behind telecommunication development. Power supply is required for the operations of telecommunications equipments. The instability of power supply in rural areas is dangerous situation, because exchange cannot occur for long hours. In most rural areas cables are laying by the road side when there is a fault occurs it is difficult to send expert to repair them on time. The requisite skills and necessary supplies may not exist in the immediate locality. Telecommunications networks, however, should be considered part of the basic infrastructure like roads, water mains, and electrical power grids which are justified on the basis of their importance to economic development and quality of life. (Hudson 1989, Henry Chasia 1976).

2.3.2 Attributes for Public Issues

Information and Communication Technology brings revolution in today's life style which brings together people from different environments and they may learn from one another. New changes needed for the interest of local community there should be more and more innovations for the development of public and social issues. The attributes to public issues including contents & development, community of Interest, government support, spectrum licensing and supporting policies.

i. ***Content and development:*** Because of unavailability of information & lack of communication, rural community is facing many problems like in Education, Healthcare, Agriculture information & other techniques etc. Through Information and Communication Technology (ICT) development, rural community can obtain ultimate benefits to improve their education, health, knowledge, agricultural skills, living standard and earnings (Kashif Sattar 2007, Herselman, 2003). Main complications in developing the infrastructure of rural areas are low priority given by the government and lack of interest of private sectors. The government must think about the 70% of Pakistan rural community, to provide them good manpower, up-to-date information and latest contents in less time for the better development.

ii. ***Community of interest:*** **(**Hudson, 2006; Andrew, P.Rahoo and T.Nepal, 2005) Rural communities have strong interests at their immediate geographical and administrative area so therefore their communication needs have to be taken into attention when planning rural telecommunications networks. For a successful telecommunication infrastructure relevant contents according to the community interest are considered. Social and economic changes are transforming rural and regional communities. There are many ways to attract rural community towards development by new employment, new jobs opportunities, and new ways of social interaction among communities.

iii. ***Government Support:*** Humble support from government and other federal departments will continue the creative use of existing services and facilities to provide new life to the rural communities (Nazem, S. M. 1996). Governments provide directly or indirectly telecommunication services to improved rural communities such as governments utilize communication technology and knowledge for administrative development, provide assistance to different departments, national agriculture research centers and other rural stakeholders. To observe the needs of rural communities, governments involve in telecommunication service for rural improvement.

iv. ***Spectrum Licensing:*** In many countries spectrum is licensed through auction and there is a high price to pay for some frequencies. Service delivery concern was to some extent due to the license restriction on telecommunication companies. Technology has been dramatically developed, spectrum resource is scarce and limited, which means spectrum resource should use as efficiently as possible (Andrew, P.Rahoo and T.Nepal, 2005). The radio spectrum is divided into various bands, which are used, by a wide variety of services like emergency, mobile phones, commercial radio and television, terrestrial microwaves, and satellites. In some cases only fixed telecommunications technology could be utilized to deploy voice services to rural communities.

v. ***Supporting Policies:*** Many countries have clear policy of promoting access to Infrastructure utilities, Including piped water, electricity, telecommunications and sewerage at affordable prices. (Clark, G. & Wallsten, J. 2002). In the telecommunications sector, various countries have clearly expressed their policies of promoting general access and supporting policies to telecommunication services. For the development of rural community rural collaborators promote Internet strategy and agricultural growth, access to use a communication for development, access to support telecommunication policies and to support local Internet service providers in rural areas. Also, to assist collaborators in supporting for Internet service provision and to policy advancement of existing Internet services to rural inhabitants.

2.3.3 Attributes for Cost

The selection of rural telecommunication technologies is greatly affected by the economics and "economics is the dynamic force following the innovation of technological clarifications to the problem of access to telecommunications services in those areas" (Gasmi and Virto, 2005). In developing countries, rural areas have some economic aspects that make it hard to provide a suitable telecommunication infrastructure. ICT and specially Internet is considered key driver for social and economic welfare development. Internet reduces isolation and eliminates hurdles of rural living by affordable prices. Internet penetration is low due to lack of infrastructure, skills and low-income communities in rural areas.

i. ***Fixed Cost:*** Fixed financing needed for the deployment of Internet access technology such as Purchasing, Deployment and Central Office etc (Andrew, P.Rahoo and T.Nepal 2005, Chemane et al. 2005, Sasidhar and Min 2005). Fixed costs are fixed they are one-time expenses, and investment needed for deploying of Internet access technology.

ii. ***Variable Cost:*** Variable cost refers to maintenance, administration, training, testing and up-gradation etc (Andrew, P.Rahoo and T.Nepal 2005, Sasidhar and Min 2005, Chemane et al. 2005). *Cost* capability is an important attribute of the selected technology because of the deficiency of finances for rural telecommunications. There should be relax and acceptable policy for variable cost.

Table 2.1: Attributes for rural telecommunications infrastructure

Criteria	Attributes	Related Literature
Technical Aspect	Infrastructure	Douligeris and Pereira (1994); Gasmi and Virto (2005); Clark G & Wallstern (2002).
	Coverage	Chemane et al. (2005).
	Reliability	Henry Chasia (1976); Sasidhar and Min (2005).
	Security	Douligeris and Pereira (1994); Sasidhar and Min (2005); Chemane et al. (2005).
	Speed & Services (Bandwidth)	ITU (1997); Sasidhar and Min (2005); Chemane et al. (2005).
	Maintenance	Hudson (1989); Henry Chasia (1976).
Public Issues	Contents & Development (by Govt)	Kashif Sattar (2007); Herselman, (2003).
	Community of Interest	Hudson (2006); Andrew, P.Rahoo and T.Nepal (2005).
	Govt Support	SM Nazem (1996).
	Spectrum Licensing	Andrew, P.Rahoo and T.Nepal (2005).
	Supporting Policies	Clark G & Wallstern (2002).
Cost	Fixed Cost	Sasidhar and Min (2005); Chemane et al. (2005); Andrew, P.Rahoo and T.Nepal (2005).
	Variable Cost	Sasidhar and Min (2005); Chemane et al. (2005); Andrew, P.Rahoo and T.Nepal (2005).
	Subsidy	Clark G & Wallstern (2002).

iii. ***Subsidy:*** For political reasons Government might wish to subsidize the deprived and rural customers, or as part of a development policy. New methods (Reforms) are necessary to raise subsidies and to ensure access by the poor people. When subsidies are introduced by Government, then they are repeatedly expanded to cover more and more parts of the population (Clark G & Wallstern, 2002).

2.4 Related Literature on Methodology

Based on the review of the previous literature, one can identify multi-criteria decision making (MCDM) as a suitable approach to understand and analyze the complexity in a rural telecommunications systems. In particular, the AHP technique is to be considered as applicable potential method for rural telecommunication infrastructure. In this study methodology part is presented in two sections. The first part briefly reveals an introduction of Analytical Hierarchy Process (AHP), previous literature and various aspects related to the AHP method. The second part reviews various studies with regard to Applications of the AHP in telecommunications.

2.4.1 Analytical Hierarchy Process (AHP)

The AHP was first presented and developed by Thomas Saaty in the early 70’s. AHP is a multi-criteria decision making (MCDM) method which decomposes a complex problem into a hierarchy consisting of specific elements. AHP technique is usually used to model substantial decision making process which is based on multiple attributes (Saaty, 1994). Additionally, AHP follows the natural attitude of human thinking. This technique explores the difficult problems based on their dealing effects. Analytical hierarchy process (AHP) is a favorite way to a Multi-Criteria Decision Making method (MCDM) and helps policy/decision makers to handle difficult problems with several contradictory criteria like location or selection of investment and projects position (Ishizaka and Labib, 2011). The AHP derives proportion scale priorities for attributes and by making paired judgments of attributes on a general criterion. "It is used for a complex decision-making problem by distribution of a complex, unstructured condition into its elements; organizing these elements into a hierarchical order; assigning values to judgments on the relative importance of each element; and synthesizing the judgments to decide the priority of elements" (Liao, 1998). Pair-wise observations allow the decision maker to focus on the observation of two items and then identify a preference on each decisive factor and for each decision alternative.

The basic objective of MCDM is to help decision makers to gain knowledge about the problem, state their judgments about the criteria preferences and importance relating to alternatives, tackles other contributors' judgment, recognize the final alternatives' standards, and use them in the problem solving actions. The AHP decision making process begins by forming the problem into a hierarchy. This hierarchical design helps simplify the description of the problem and brings it into a precondition that is easily understandable. At each level of hierarchy, importances of the concerned elements are calculated mathematically. Thereafter, the decision of the final objective is concluded seeing the importance of criteria and alternatives.

According to (Ishizaka and Labib, 2011), AHP method is based on four steps that include solving a decision problem e.g. problem designing, weight of importance estimation, weights of importance aggregation and analysis. The four steps utilized by AHP method and its development can be sum up as follows:

i. Structuring the decision problem

Decision making is an influential part of the design of a hierarchy to show a decision problem, because there is no set procedure for identifying the objectives, criteria and making hierarchy. When creating hierarchies one should contain related aspects to show the problem such as the issues, environment close to the problem, or attributes that may share the solution, and the participants who are associated with the problem. To elaborate the design of a hierarchy there are some suggestions such as to identify criteria and sub-criteria to fulfill the overall goal of the problem, to identify relevant factors and policies and to identify available options for the problem (Ishizaka and Labib, 2011; Saaty and Vargas, 1994).

A four-level hierarchy is shown in Figure 2.1, in which a decision problem is break down into a series of hierarchies. Each level of the hierarchy contains of a set of factors which is further decomposed into another set of sub-elements with respect to the next level. The final level consist decision alternatives which are relative to the problem.

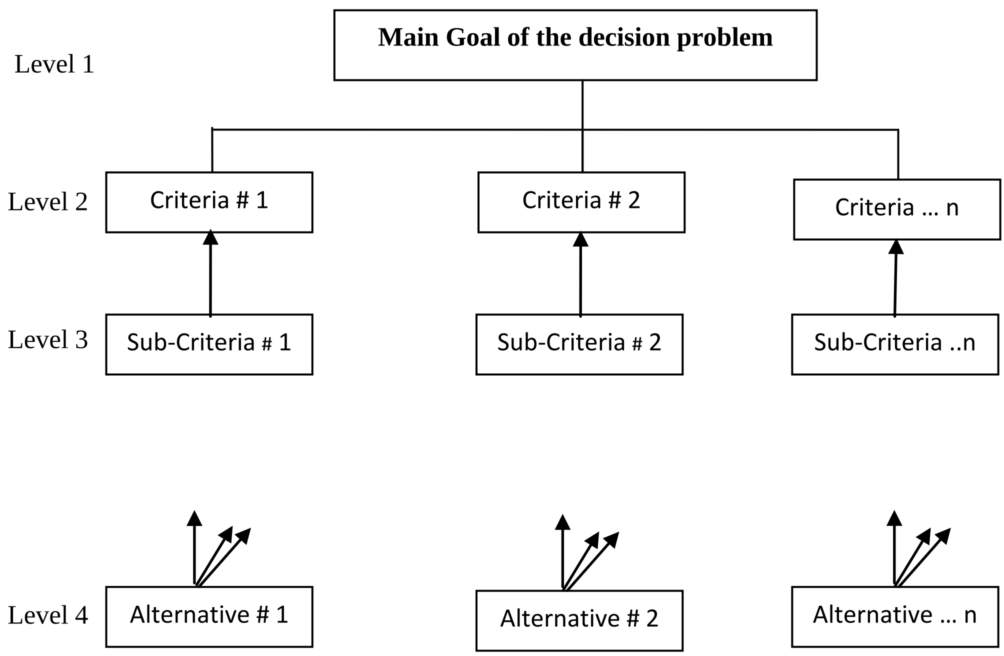

Figure 2.1 Four level Analytic Hierarchy Process (AHP) schema

ii. Pair-wise comparisons

After constructing the hierarchy describing the problem, the second step is the measurement and collection of data which involves conducting pair-wise judgment. Pair-wise judgment is the process of collecting input data of decision elements so that ratio scale priorities can be derived. It is therefore more scientific in deriving ratio scales because AHP uses a unit and estimates multiples of that unit rather than simply assigning numbers by guessing (Saaty, 2005). Judgments are stated in a positive reciprocal matrix (Ishizaka and Labib, 2011). The comparison procedure requires a series of paired judgments where the decision maker will evaluate two elements at a time with respect to objective element. It involves comparing the relative importance, preference of two elements in response to a question. It is only essential to make $n\,(n-1)/\,2$ comparisons to create the full set of pair-wise judgments, where n is the matrix size. For m alternatives and n criteria, there is a need to create and process a $n\ (m\ x\ m)$ matrices (Saaty, 1980).

During this procedure, it is possible to identify which alternatives and attributes are ideal. The data produced are accumulated according to the hierarchical map to its final significance. Additionally, decision attributes on the hierarchical diagram are utilized as a source for composing questions on the questionnaire. Hence, a judgment matrix $\boldsymbol{A}$ is constructed by putting the results of pair-wise comparisons in the position a_{ij} so that $= [a_{ij}]$, i.e. $(n\ x\ n)$ matrix.

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

All entries in this matrix are positive. Where, a_{ij} is the judgment among element i and j. If the matrix is entirely reliable, the transitivity rule (a_{ij} = a_{ik} . a_{jk}) possesses for all judgments. The matrix of pair-wise judgments ($A = [a_{ij}]$) shows the passions of the expert's preference among each pairs of alternatives (A_i versus A_j , for all i, j =1,2,3,……..,n). The pairs of alternatives are generally selected from a given scale$(1 \sim 9)$.

iii. Determination of matrix judgment

Once all pair-wise comparisons are performed at every level and comparison matrices are constructed, a scale of relative priorities is derived from the paired comparisons, which are based in the utilization of the pair-wise as a contribution to form a comparison matrix (Saaty, 1980). Ratio scales (as shown in the table) are the only likely quantities if one wants to aggregate quantities as in a weighted figure (Saaty, 1994).

The judgments are entered using the numbers 1, 3, 5, 7, and 9 which correspond to the verbal judgments. The values of 2, 4, 6 and 8 are intermediate values that can be utilized to indicate compromise values of importance among the five basic assessments.

vi. Synthesizing the relative weights

The ultimate step of the AHP method involves in synthesizing the results to determine the overall outcome considering local priorities across all criteria conclude the global priority (Ishizaka and Labib, 2011). If the Consistency Ratio (CR) is higher than 0.1 then the judgments are considered to be unreliable because they are very close for comfort to unpredictability and the exercise is insignificant or must be repeated. The alternative with the maximum weighted value is to be treated the preferred alternative (Andrew et al., 2005).

Table 2.2: AHP pair-wise comparison scale

Relative importance	Definition	Explanation
1	Equally Important	Two activities donate equally to the objective
3	Slightly more Important	Experience and judgment a little favor one activity over another
5	Strongly more Important	Experience and judgment strongly support one activity over another
7	Very Strongly Important	An activity is supported very strongly over another and its dominance is demonstrated
9	Extremely more Important	The importance of one activity over another is established at the highest possible order
2,4,6,8	Intermediate values	Used to denote a compromise between the priorities listed above

2.4.2 Applications of AHP in Telecommunications

(Douligeris and Pereira, 1994) used the AHP method to choose a telecommunication provider that best satisfy the needs for better service and quality like Fiber distributed data line and distributed dual bus that satisfies customer needs in terms of quality of service and also mentioned that consumers of Telecommunications services insist for a best quality from their providers.

(Sasidhar and Min, 2005) expressed that to select the high-speed access technology in rural communities with different characteristics of performance criteria e.g. high Speed, Low cost and high quality by using AHP model. (Tam and Tummala, 2001) explained application of AHP for the mutual selection of telecommunications system and vendor, and authors emphasized the applicability of the AHP and its possible potential to decrease the time taken in the selection process. Furthermore, (Andrew, P.Rahoo and T.Nepal 2005) summarized that the planning of rural telecommunication services is characterized by a great number of difficult issues like uncertainty, multiple conflict objectives and security of physical technology infrastructure. They also recommended AHP as an efficient technology selection approach for rural area telecommunications that would be regularly improved and updated.

(Chemane et al, 2005) presented that MCDM can help in selecting the optimum Internet access for end users; AHP method was utilized to get relative weights and utilizing pair-wise comparison for cost, link speed, Geographical Coverage and security. and by comparison results Wireless Access technology is the alternative with the maximum value and therefore recommended to be the selected one. “(Manandhar,S, P. 2012) expressed in his study that contents and network effect would provide deeper insight for internet adoption in rural areas, which are not included in his study”. (Henry Chasia, 1976) recommends for future discussions that the choice of technology for rural telecommunication in third world countries, is not a decision among old and modern technologies but it is a decision based on appropriateness of the specified equipment of the socioeconomic situation in rural areas. (Douligeris, C., Pereira, I.J., 1994) noted that in AHP method there are several pair-wise comparisons when multiple respondents are involved, a miscalculated answer will not influence the result so a second round of questionnaires may be provided for updates so that a consistency index close to optimal is achieved. The questionnaires could also include questions related to the degree of risk aversion of the respondent (their expertise, their biases etc).

In sum, this study provide a great contribution to the literature on the telecommunication infrastructure in rural areas from many angles In order to achieve the aim and objectives of this research, a comprehensive analytical decision structure for the selection of rural telecommunication technologies will gradually be developed. There has no study considered the selection of telecommunication infrastructure technology to rural areas of Pakistan.

Chapter 3. Formation of AHP Model and Access Technologies

The process of modeling AHP model is one the mathematical method which is used for solving multi-criteria decision problems. The Analytical Hierarchy Process (AHP) has been widely practiced to a range of decision problems with diverse and sophisticated solution. However, the decision related to rural environment / nature is a complex issue because of the existence of different criteria. Therefore, an optimum way is needed that can make valuable solutions to the problem. This chapter describes the structuring of AHP model for the selection of telecommunication backbone infrastructure and different media access technologies available for Pakistan’s rural areas.

3.1 Methodology Framework

The AHP methodology including the following sections, The First section is based on structuring of the decision problem, Second section related to measuring and data collection, the Third section including the normalized weights and synthesis and the fourth section including results and discussion with finding solution of the problems. The AHP methodology framework of this study covers a hierarchical decision scheme which is constructed by a broad literature review and by dividing the problem into decision elements comprised of the main goal, which is positioned at the top of the hierarchy, criteria and sub-criteria in the middle and then the alternatives at the bottom. Each particular element is pair-wise compared regarding its parent element by means of real data obtained from different fields of IT experts. Each section is explained to illustrate how to develop the AHP model, demonstrate how it could be used to priorities the three adopted technology alternatives, the attributes are described in chapter two, Table 2.1.

3.2 Structuring AHP Model

An AHP model will be structured to show how the model can be useful for a problem in the rural telecommunication environment. Every telecom provider may have their own criteria, but this model is based on attributes and alternatives which are identified from previous literature and from the views of experienced IT experts' (as describe in chapter 2). The model could be extended by policy makers for rural areas or by the company, to support a situation of the area.

To adapt AHP methodology for technology selection for rural area of Pakistan, the problem should be structured in the form of hierarchy. According to AHP methodology, the hierarchical tree should be designed accordingly as the first step of the AHP procedure. The structured hierarchy that was designed for this study is presented; a hierarchy that contains of four levels, and descends from the general to the more particular was developed as shown in Figure 3.1. The top level is the overall goal of the decision, which is the selection of optimum backbone infrastructure technology to provide quality telecommunications services to the rural areas of Pakistan, followed by the decision criteria which impact the goal directly in the second level. The sub-criteria level comes next against the alternatives to be calculated at the lowest level. Three traditional technologies have been chosen (DSL, Wireless and Fiber Optic) as candidate decision alternatives for this study.

The objectives of such a selection task are the enhancement of telecommunications access through the expansion of the connectivity to rural and remote areas, offer telecommunications services that can meet customer requirements, and increase the return on investments. This study expanded on previous literature by adding related attributes that have straightforward effects the objective of selection of optimum backbone infrastructure technology for rural areas of Pakistan. Moreover, both existing attributes in previous literature and the identified attributes for the Pakistan case have been classified into three categories:

(1) Technical Aspect Attributes

(2) Public Issues Attributes

(3) Cost or financial Attributes

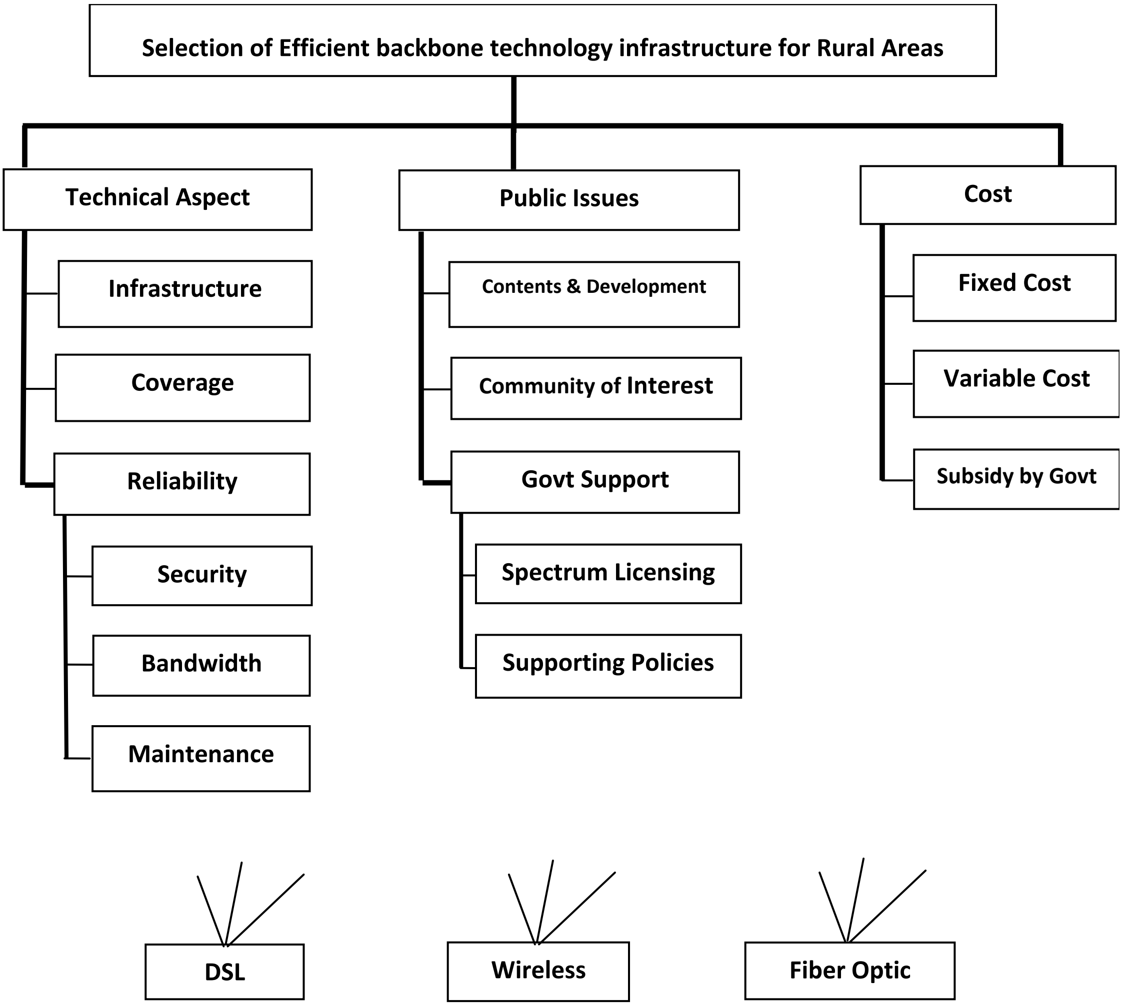

Figure 3.1: AHP Model for Selection of Backbone Technology Infrastructure in rural areas

Third level of the hierarchy contains the sub-criteria which have been classified from the above three categories. The criteria and sub-criteria used in the hierarchy can be determined by using the AHP approach of pair-wise comparison of attributes in each level with respect to every parent attribute placed one level above. The local priorities define a share of a given decision-making element in reaching the goal of the hierarchy at the upper level, where the global priorities of a given level represent each element in reaching the main goal, which is the selection of telecoms backbone technology for rural areas of Pakistan. Local priorities results directly from pair-wise comparisons of the Sub-criteria with respect to the criteria, while global priorities result from the multiplication of criteria and sub-criteria priorities. For instance, a set of global priority weights is produced for each of the sub-criteria by multiplying local weights of the sub-criteria with weights of all the parent elements based above it. Lowest level of the hierarchy is the alternatives which include different technologies for selection. Overall weighting of a technology is generated by adding the global priorities of all attributes in the hierarchy.

3.3 Selection of Access Technology for Rural Area of Pakistan

This section provides a review of telecommunication infrastructure access technologies in the context of how it can be deployed in rural areas of Pakistan. These consist of wired and wireless technologies, which are currently available for the backbone connection for Internet access in a remote/rural area of Pakistan.

Total population of Pakistan is 183 million in which 64% lives in rural areas[1]. The main goal is the technologies that can provide satisfactory telecommunications backbone infrastructure to rural areas. Although, based on the previous literature, it has been found that the uniqueness of rural areas in developing countries makes it useful to discover a technology that will offer the best solution to all areas e.g. (Sasidhar and Min, 2005), identified three technological solutions to offer rural backbone infrastructure that contain two wire-line technologies: Power Line Communication, Fiber Optic Cable and one wireless technologies.

1) Digital subscriber line (DSL) Access Technology

It is a wired access technology that utilizes regular telephone lines to transfer access to businesses and homes. In fact, DSL proposes upload speeds of up to 128 Kbps and download speeds of 1.5 Mbps for single connections. Both analogue voice and data travel over the same piece of copper cable with DSL technology. Voice frequency is from 0 to 4 KHz which is transmitted over low bands, whereas data frequency is from 10 Hz to 1 MHz which is transmitted over higher band. The efficiency of Digital subscriber line (DSL) also depends on the nature of wire (Mervana *et al*., 2001).

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1. http://ansr.io/blog/pakistan-market-trends-2013-online-mobile-social/

2) Cable media Access Technology

It is a wired media access technology which allows communication through a physical medium. For Internet access in Pakistan, these are considered to be the most common media access technologies. When evaluating which media access technology can be used for a network deployment then these factors like cost, broadband, reliability and maintenance are to be considered with observe to user-application requirements.

3) Wireless media access technologies

Wireless access Technology utilized electromagnetic waves to transmit the signal. Where there is a need for mobility or where there is lack of fixed infrastructure, wireless technologies perform a rapidly emerging area for providing Internet connectivity. Wireless technologies can often provide cost-effective solutions and support to the institution mission. When evaluating the deployment of wireless access technology in rural area of Pakistan the Important attributes which to be considered are cost, reliability, Public issues, security, and maintenance.

4) Fiber Optic media Access Technology

Fiber Optic is a glass fiber or plastic designed to convey information using infrared or even noticeable light beam. Thus, Fiber Optic is anti electrical noise, and can transmit large amounts of data. It is possible to modulate 500 to 1000 video signals on a single fiber optics cable because the bandwidth of a fiber optics cable is 100 to 1000 MHz. Fiber Optic cable has drawbacks in terms of system configuration. The cost of Fiber Optic is more than the ordinary wires, which are cheaper alternatives for deploying network in rural areas.

According to PTA (Pakistan Telecommunication Authority) $2012 - 2013\ annual\ report$[2], total broadband users in Pakistan crossed 2.72 million at the end of 2013 as correlated to 2.1 million at the end of 2012 characterizing 30% increase correlated to last year. Figure 3.1 represents the users of the key broadband technologies in Pakistan over the five years (2009 ~ 2013). It is clear from the users that the wireless technologies have developed rapidly since their beginning while development of DSL has been gradually increased. Though, market has been changed over the last fiscal year as WiMAX has gone down and EvDO has taken off.

And report from propakistani indicates that broadband subscriber crossed 3.35 million subscriptions at the end of January 2014[3], and EvDO technology became the largest utilized technology for broadband services in Pakistan[4].

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2. Pakistan telecommunication authority annual report (2013) [Available online] http://www.pta.gov.pk/annual-reports/annreport2013_1.pdf
3. http://propakistani.pk/2014/04/04/broadband-subscribers-in-pakistan-reach-3-35-million/
4. http://www.ispak.pk/

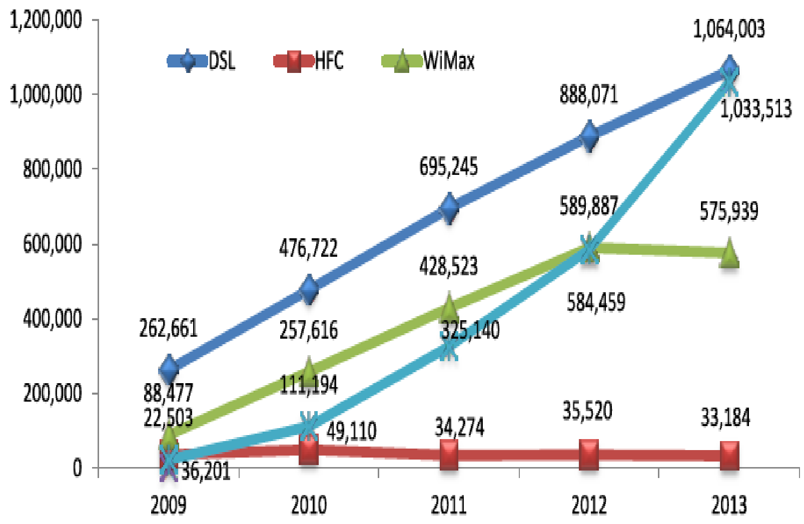

Figure 3.2: Technology wise Broadband subscribers in Pakistan (2009 - 2013)

PTCL (Pakistan Telecommunication Corporation Limited) offers and delivered both (EvDO and DSL) technologies which controls majority of broadband subscribers in the country with roughly 65 % market share in terms of subscribers. In the last three months EvDO technology acquired 256.543 new subscribers. The subscribers of the EvDO technology reach to 1.52 million which account to 45 % of market-share in terms of broadband subscribers. It is evident that wireless technologies are rising rapidly to restore wired systems in various sectors of Pakistan and to make life easier. Wireless networks remain as valuable resources for the rural consumers who cannot afford or do not have the Internet at home.

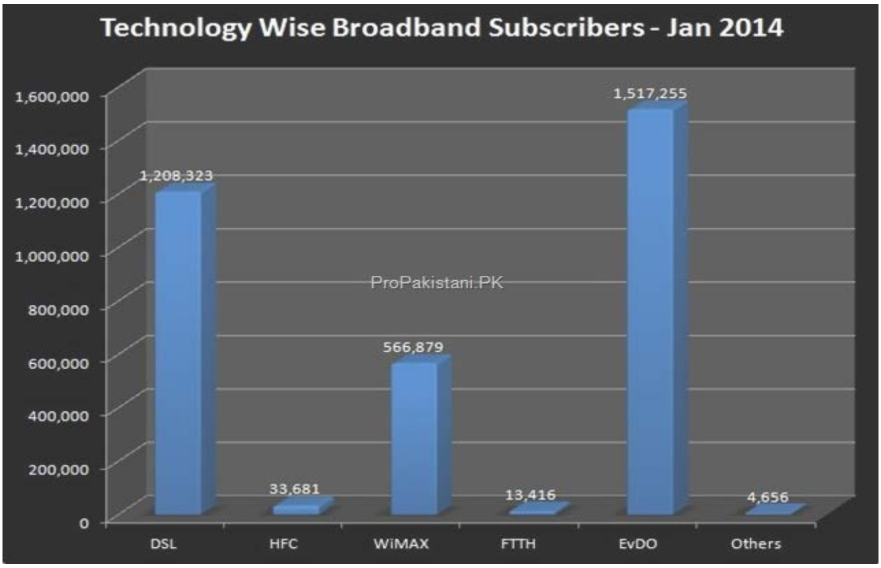

Figure 3.3: Technology Wise Broadband Subscribers Throughout Pakistan

On the bases of responses from participants on feasible infrastructure technologies for rural areas of Pakistan, Most of the respondents are considered very relevant to the subject matter, among these four technology alternatives, three technology alternatives have been selected for this model. Table 3.1 shows a review of access technologies with their main characteristics for rural applications.

Table 3.2 will briefly compare some features of these infrastructural options in terms of advantages and disadvantages of the selected backbone infrastructure technologies for the rural areas of Pakistan.

Table 3.1: Main Technology Alternatives for rural areas of Pakistan

1	**DSL**	DSL is the largest and the fastest growing Broadband service in Pakistan.
2	**Cable**	HFC (Hybrid fiber-coaxial) providing broadband Internet over cable
3	**Wireless**	WiMAX & Ev-DO (Enhanced Voice-Data Optimized) wireless transmission of data through radio signals.
4	**Fiber Optic**	FTTH (Fiber To The Home) the installation and use of optical fiber from a central point.

Table 3.2: Optimum Telecommunication infrastructure for rural areas

Technology	**Advantages**	**Disadvantages**
DSL	Coverage	High cost
	Ease of deployment	Limited bandwidth
	Efficient	Latency
Wireless	Low cost equipment	Less bandwidth
	High reliability	Low reach and line of sight
	Fast deployment	Licensing constraints
Fiber Optic	High flexibility	Most difficult to deploy
	High reliability	Long rollout time
	High speed	High cost

Chapter 4. Configuration & Estimation of Results

After the formation of AHP hierarchy (described in chapter 3), next is the data gathering and analysis phase. The job of addressing a big number of pair-wise questions required in this study would be requiring intensive efforts and extended time. As discussed in Chapter 2, the AHP is depended on four steps: problem modeling (pair-wise comparison design, weights aggregation, and sensitivity analysis). Therefore, the procedure of AHP in this study was to solve a decision problem using these four steps for a particular decision maker (Saaty, 1980). Based on the hierarchy structured, the AHP survey questionnaire was developed. Data was collected from planners of rural areas infrastructure (IT experts, government employees, Private employees, consultants and technical staff) corresponded to the hierarchal structure, and was analyzed using pair-wise judgment of the attributes on a approximate scale. Pair-wise comparison is one of the major strengths of the AHP. It derives precise ratio scale priorities as different from usual ways of assigning weights which can also be hard to justify. Respondents rated the judgment as equal, slightly more important, more important, much more important and absolutely important. This chapter describes the AHP survey and data collection in detail related to the selection of technology infrastructure for Pakistan rural area case.

4.1 Survey and Data

4.1.1 AHP Survey

The AHP survey questionnaire was used to collect the data, the experts were asked to fill the questionnaire in using numbers from the basic scale to represent their judgements: "1 = equal, 3= moderately dominant, 5 = strongly dominant, 7 = very strongly dominant and 9 = extremely dominant" (Saaty, 2001). The questionnaire was designed in three parts. From the hierarchy shown in Figure 3.1(chapter 3), there are **18** sets of pair-wise comparison matrices; the first part contains pair-wise questions for **3** main criteria and **14** sub-criteria with respect to each criterion. The second part contains the pair-wise comparisons of **12** attributes for the alternatives with respect to the selection of telecommunication backbone technology. The last part contains the general demographics of respondents. The respondents were IT experts from different public and private sectors; which assure us that the participants filled the questionnaire carefully not randomly, and gave judgment for comparisons according to their expertise.   According to the pair-wised judgment planned by AHP method, a survey questionnaire for this study was designed with three main parts:

Part A: Pair-wise comparison questions with respect to criteria

The pair-wise comparison matrices were constructed from the hierarchy (shown in Figure 3.1, in chapter 3) which describes each and every criteria and sub-criteria concerned in the hierarchical tree of this study in order to making respondents to know the meaning of each factor comparison. These descriptions and pair-wise comparisons are shown as a table in fourth page of the survey questionnaire. The experts were asked to fill the questionnaire in using numbers from the fundamental scale to represent their judgments.

Part B: Pair-wise comparison questions with respect to sub-criteria and alternatives

In this part the pair-wise judgments are related to the selection of telecommunication backbone technology in rural areas of Pakistan. The pair-wise comparison matrices were constructed from the hierarchy (shown in Figure 3.1, in chapter 3) which describes each and every sub-criteria and alternatives involved in the hierarchical tree of this study in order to making respondents to understand the meaning of each factor comparison and the meaning of alternatives and different criterias and their levels before answering the pair-wise comparison questions. These descriptions and pair-wise comparisons are shown as a table in Sixth page of the survey questionnaire.

Part C: Demographic and general Information

The last part of the survey questionnaire was about the demographic and general information of respondents. The respondents are generally concerned with telecommunication sectors, in which some respondents are particularly dealing with rural telecommunications projects. The respondents' expertise showed from telecoms engineers, consultants and academics. Moreover, the respondents were allowed to remain the demographic part empty in case they think this part is confidential. Descriptions are shown on Ninth page of the survey questionnaire.

4.1.2 Collection of Data

After building the AHP hierarchical structure, next is the pair-wise comparison phase which is one of the major strengths of the AHP. For data collection a survey based instrument is used as a technique for this study. The questionnaire was used to gather the data as shown in Annex (1). Survey questionnaire was sent via email to many IT experts of different sectors, and the experts were asked to fill the questionnaire in using numbers from the basic scale to represent their judgments: "1 = equal, 3= moderately dominant, 5 = strongly dominant, 7 = very strongly dominant and 9 = extremely dominant" (Saaty, 1994). After that, we collected a survey data from **43** respondents. The respondents were from different sectors like planners of rural areas infrastructure, IT experts, government employees, Private employees, consultants and technical staff. Out of **43** respondents, **5** samples were invalid due to the incompletion of answers of the questions or their inconsistency rate is too high. **5** of responses were invalid and had been removed as a result.

The obtained responses effectively reached to **38** responses. The Respondents have been divided by their professional backgrounds into three groups in which each group has a collection of individuals (participants from different organizations). Out of **38** participants, the first group has **16** participants from government sectors, while the second group has **17** participants as private sectors employees and **5** participants are from semi-government organizations. AHP procedure has been used to aggregate information since there is more than one group participates in the decision making process. This procedure follows:

(1) Accumulating the individual judgments for each set of pair-wise comparison into a collective hierarchy.

(2) Synthesize each hierarchy and accumulating the resulting priorities in which the overall inconsistency of each individual is not larger than > 0.1 to guarantee the reliability of the judgments, however the respondent who had a larger inconsistency than 0.1 has been removed and regarded as an invalid response.

(3) Accumulating the individual's resulting priorities in each node in the hierarchy to construct a group decision. The following table 4.1 shows the different groups of participants.

Table 4.1: Participants Grouping

Groups	Group 1 : Government Employees	Group 2 : Private Employees	Group 3 : Semi-government Employees	Total Respondents
No. of Respondents	16	17	5	38

4.1.3 Descriptive statistics

The survey data was collected from IT experts (government employees, Private employees) corresponded to the hierarchal structure, and was analyzed using pair-wise comparison of the decision making standard on a qualitative scale. The survey was conducted via e-mail. The dataset was restricted to IT professionals who are literate.

AHP survey was conducted from **43** respondents in which **5** samples were invalid due to incompletion of answers of the questions or their inconsistency rate was too high and had been removed as a result. Therefore, only **38** acceptable answers were obtained to be eligible to make the AHP survey. Table (4.2) shows the outline of the sample design.

The survey also collected information of the respondent's socio-demographic and professional background such as: gender, age, educational level, occupation, and working experience.

Table 4.2: Sample design

Description	
Participants	Ranging in age from 25 to 60 years and working in different sectors (government, private and semi-government)
Sample size	38 respondents
Survey period	April 2014
Survey mechanism	Via e-mail

The survey answers show that the majority of the 38 respondents were males (89% males and 11% females). This distribution reflects the fact of the Pakistan national statistics forecasting vulnerable employment of male and female in the country. This gender distribution is shown if figure (4.1)

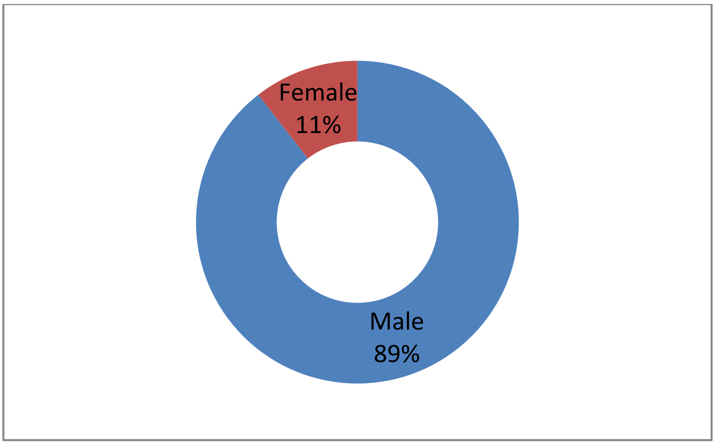

Figure 4.1: Gender Distribution of respondents

Age distribution shows in figure (4.2), a majority number of the 58% respondents were in the ages between 31 and 40, while 8% respondents were between the ages of 25 and 30. 29% of them were between the ages of 41 and 50 and 5% respondents were between 51 to 60 years.

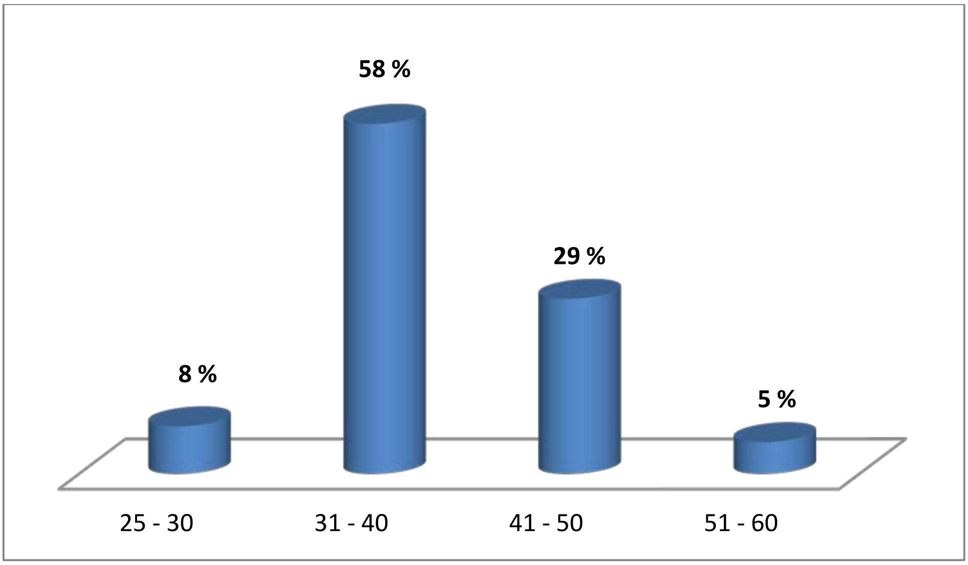

Figure 4.2: Age Distribution of respondents

In terms of education, the results show in figure (4.3) that the majority of the respondents have a master degree, taking 55% out of 38 respondents. And 21% respondents having doctoral degree out of 38 respondents; this indicates that a significant number of respondents are well qualified and experts in their fields. Moreover, the results also have shown that 16% of the respondents have bachelor degree, while 8% have only diploma qualification. As described earlier that participant of this study are generally concerned with telecommunication sectors, in which some participants are particularly dealing with different rural telecommunications projects.

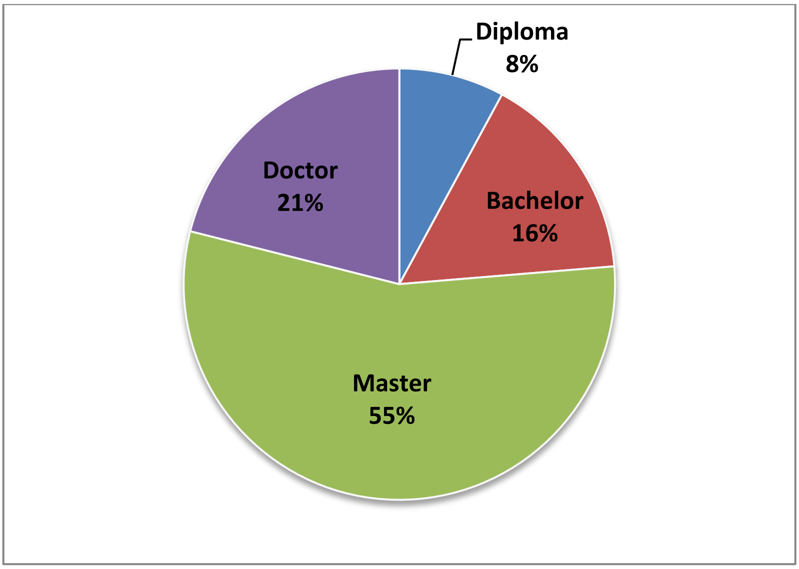

Figure 4.3: Educational Level Distribution of respondents

In terms of job status, the obtained results shows that respondents were from different sectors related to Information technology and telecommunication e.g. government employees, private employees, and semi-government employees. Figure (4.4) shows that out of 38 respondents 42 % are government employees (IT directors, lecturers, assistant professors and professors), 45 % are private employees from different telecom sectors (IT managers, telecom engineers, network engineers, communication engineers, system engineers, network administrators). And 13 % are semi-government employees (communication engineer, IT officer, networks monitoring officer).

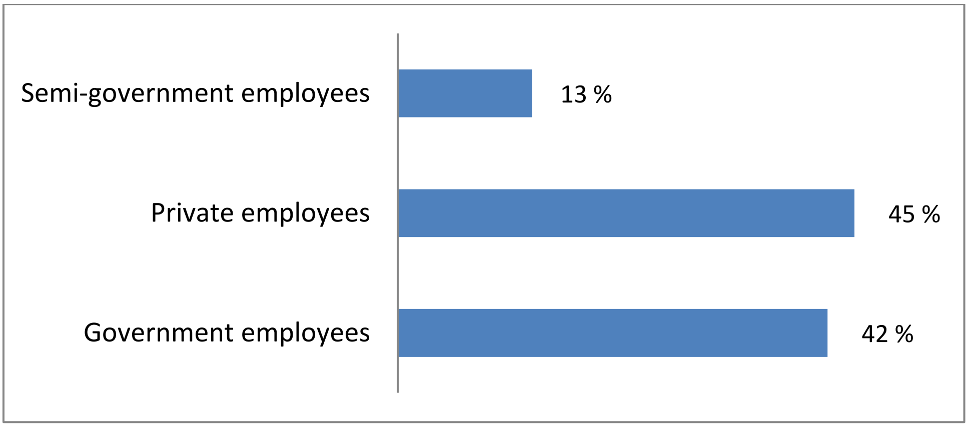

Figure 4.4: Respondents Job Status Distribution

By analyzing the working experience, according to obtained results the majority of respondents have … years experience in their perspective fields of expertise. Figure (4.5) shows the distribution of respondents working experience with different clusters of years.

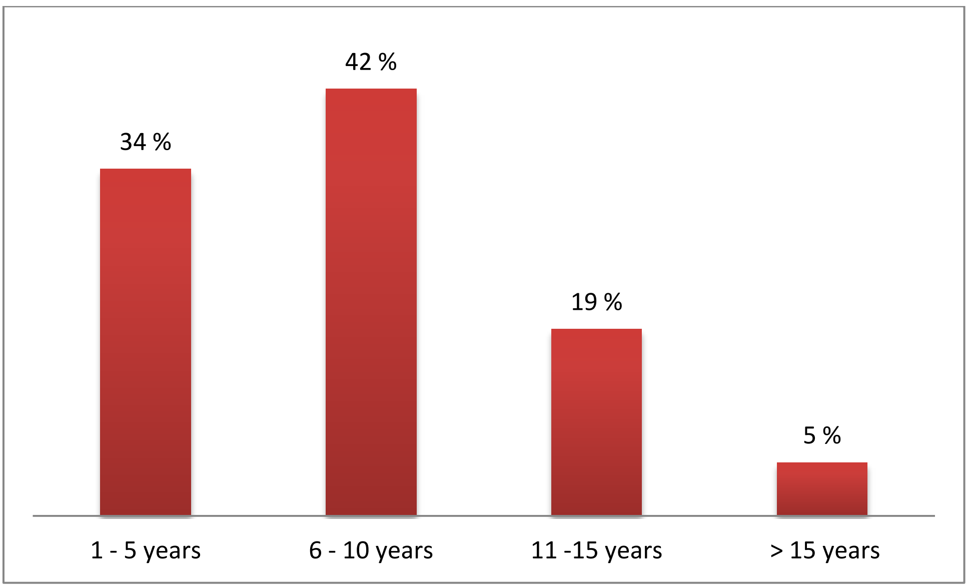

Figure 4.5: Respondent Working Experience

Table (4.3) summarized respondent's demographic profile information.

Table 4.3: Respondents demographics profile

	Category	Frequency	Percentage
Gender	Male	34	89%
	Female	4	11%
Age	25 ~ 30	3	8%
	31 ~ 40	22	58%
	41 ~ 50	11	29%
	51 ~ 60	2	5%
Educational Level	Diploma	3	8%
	Bachelor	6	16%
	Master	21	55%
	Doctor	8	21%
Job Status	Government Employees	16	42%
	Private Employees	17	45%
	Semi-government Employees	5	13%
Working Experience	1 ~ 5 years	13	34%
	6 ~ 10 years	16	42%
	11 ~ 15 years	7	19%
	> 15 years	2	5%

4.2 Results and Analysis

AHP gives mean of break downing the problem into a hierarchy of sub problems which can more easily be understandable and evaluated. This section explains in-depth how this research followed the AHP procedure to get the results.

4.2.1 Prioritizing Identified Attributes

The AHP methodology can be developed in the following steps of the AHP procedure (Saaty, 2008, Ishizaka and Labib, 2011). However, decision making studies made us to involve these following steps.

1. AHP procedure starts with *Setting up the Decision Hierarchy* where the problem is break downed into a hierarchy of goal, criteria, sub-criteria and alternatives. The hierarchy shows the relationship among attributes of one level with the attributes of the level directly below as shown in the hierarchy diagram (See Figure 3.1, chapter 3). In this study, the criteria are the attributes approached in the "identifying the success attributes that contribute to the selection of telecommunication backbone technology in rural areas of Pakistan". According to AHP method, the succeeding attributes of each criterion must depend on associated criterion (Saaty, 2008), the attributes were categorized into three main criterias which are Technical aspects, Public Issues and Cost. Each main criterion has different sub-criterias and at the last level there are alternatives related to the goal.

2. Performing the *Pair-wise Comparisons of attributes*. Pair-wise judgment is the major strengths of the AHP. "Each element in a higher level is used to evaluate the elements in the level directly below with respect to it" (Saaty, 2008). This is utilized to find out the relative importance of the elements involved. And also performing the collectio*n of data regarding the hieratical structure*. However, these steps have been discussed in details in the AHP survey design as presented in the previous section 4.1.
3. *Convert the judgment into weights and consistency.* The AHP transforms comparisons of participants into weights, which are then automatically normalized to sum 1. Many conversion techniques are available, but the AHP use mathematical approach based on Eigen values (Goodwin and Wright, 2004). Because of the complication of this method, computer software called *Expert Choice 2000* is utilized to carry out calculations.

4.2.2 Synthesis – Finding a solution to the problem

Last step of AHP procedure is *synthesizing the Results for* finding a solution to the problem. AHP uses the priorities achieved from the comparison to weight the priorities in the level directly below and keep continue this process for every element. After that for each element in the below level adds its weighted values and achieve its global or overall priority. It continues on this procedure of weighting and adding till the final priority of the decision alternatives at the base level is achieved. Therefore, AHP calculates the local priority related to each criterion. Local priorities are then multiplied by the local priority weight of each attribute with the local weight of its parent attribute, i.e. from which it is connected and aggregated to obtain the global ratings.

4.2.3 Participants Preferences for different groups

From the obtained **38** respondents data now we will take different group's (Academia, Telecom and Job Experience > = 10 years) views and their preferences in different ways: by considering the importance of each attribute in each level utilizing the global importance of each node, or by considering about the relative importance of each attribute within a branch utilizing local importance of each node in the AHP hierarchy. The following are the preferences obtained from each group with different ways according to their expertise and related sector.

A) Preferences of participants from Academia

The Academia group consists of different participants from both (Government employees, Private employees) sectors. Out of **38** participants, the *academia group* has **17** participants, the employees preferences can be viewed in the above mentioned ways. The weights of the local and global importance of each criterion for the academia group were obtained with the AHP technique using the *Expert Choice 2000* software as illustrated in Table 4.4.

According to the group of academia participants, one can observe that the comparison of the criteria with respect to the goal yields that the Cost criterion has the highest priority of **40.10 %,** expressing a certain advantage among others, which indicates more importance in comparison to other Technical aspects and Public Issues attributes. The lowest priorities are for Technical Aspects and Public issues with **30.30 %** and **29.60 %**, respective. Once the global priorities of all sub-criteria are obtained, they were multiplied by the local priority of each alternative with respect to each criterion to obtain the evaluation score (weight) of each alternative (see (2.4.1, iv) in chapter 2). Finally, an overall score for each alternative is obtained by summing each evaluation score row as shown in Table 4.5. The resulting priorities of the alternatives are illustrated in Table 4.5. From the Grand total column, *Wireless* technology is the most preferred alternative and has the highest score in this AHP model with a priority of **0.488**. DSL comes next with a priority of **0.338** and then Fiber Optic technology with **0.174**. The sum of the priorities in this column is equal to one. This complies with the AHP procedure and demonstrates that its steps are applied properly towards the goal of the problem, which is the efficient technology selection for Pakistan rural areas.

Table 4.4: Academia participants Preferences for the criteria & subcriteria

Overall Inconsistency = 0.01

Goal: Selection of backbone technology infrastructure for Rural areas of Pakistan				
Criteria	**Local Priorities**	**Subcriteria (Local Priorities)**	**Subcriteria (Local Priorities)**	**Global Priorities**
Technical Aspect	0.303	Infrastructure (0.108)		0.034
		Coverage (0.496)		0.15
		Reliability (0.396)	Security (0.137)	0.016
			Bandwidth (0.638)	0.077
			Maintenance (0.225)	0.027
Public Issues	0.296	Contents & Development (0.274)		0.081
		Community of Interest (0.130)		0.039
		Government Support (0.596)	Spectrum Licensing (0.378)	0.066
			Supporting Policies (0.622)	0.11
Cost	0.401	Fixed Cost (0.302)		0.12
		Variable Cost (0.224)		0.089
		Subsidy by Government (0.475)		0.191
Grand Total				**1**

Table 4.5: Synthesized priorities for the alternatives from Academia participants

Alternatives	Criteria (Local Priorities)			Grand Total
	Technical Aspect (0.303)	Public Issues (0.296)	Cost (0.401)	
DSL	0.091	0.099	0.148	0.338
Wireless	0.161	0.151	0.176	0.488
Fiber Optic	0.052	0.046	0.076	0.174
Grand Total	0.304	0.296	0.4	**1**

From the above analysis, one can observe that the AHP is capable of structuring the problem and providing a systematic approach to decision making. It allowed for diverse qualitative factors to be examined in a mathematical model, which can help to reduce the time needed to evaluate the alternatives. By using the traditional selection process in such problems, the decision may take months to be reached. As the criteria are defined and the problem is prepared analytically, the AHP allows the decision makers to visualize the strengths and weaknesses of each technology alternative by comparing their scores against each attribute. The obtained final weights in Table 4.5 provide information about the alternatives and the way they are used to satisfy the selected attributes, as well as the importance of these attributes in order to reach the goal of the model. Taking this into consideration, a result where one can affirm which alternative is more preferable from Academia participant's point of view is reached. However, the priority weights of the three technologies are actually quite different from each other and although Wireless achieved the highest score, it is above DSL weights by less than 15 %. And, Fiber Optic weight is 35 % less than DSL.

Table 4.6: Ranking of attributes according to their global priorities for Academia group

Synthesis with respect to efficient policy infrastructure in rural areas

Rank	Subcriteria	Global priorities (%)
1	Subsidy by Government	19.10
2	Coverage	15.00
3	Fixed Cost	12.00
4	Supporting Policies	11.00
5	Variable Cost	8.90
6	Contents & Development	8.10
7	Bandwidth	7.70
8	Spectrum Licensing	6.60
9	Community of Interest	3.90
10	Infrastructure	3.40
11	Maintenance	2.70
12	Security	1.60

In above table 4.6, the sub-criteria are arranged for ranking in a descending order of their global priorities. The table shows that the most important sub-criterion among all is ‘Subsidy by government’ with a priority of 19.10 % followed by ‘Coverage’ with 15 % and ‘Fixed Cost’ with 12 %. The top four attributes comprised a variety of sub-criteria that belong to all criterions. The least important sub-criteria among others considered in the model with priorities of less than 5% are ‘Community of Interest’, ‘Infrastructure’, ‘Maintenance’ and ‘Security’ with 3.90 %, 3.40 %, 2.70 % and 1.60 % respectively.

B) Preferences of participants from Telecom Sectors

The participants of Telecom Sector group are from different Telecom Organizations in Pakistan. Out of **38** participants, the Telecom Sector group has **21** participants; many of them are involved with deployment of Telecommunication infrastructure projects. The employee’s preferences can be viewed in the previous mentioned ways. The weights of the local and global importance of each criterion for the Telecom Sector group were obtained with the AHP technique using the expert choice 2000 software as illustrated in Table 4.7.

According to the Telecom Sectors participants, one can observe that the comparison of the criteria with respect to the goal yields that the *Cost criterion* has the highest priority of **41 %,** expressing a certain advantage among others, which indicates more importance in comparison to other *Technical aspects and Public Issues* attributes. The lowest priorities are for Technical Aspects and Public issues with **40.10 %** and **18.90 %**, respective. Once the global priorities of all sub-criteria are obtained, they were multiplied by the local priority of each alternative with respect to each criterion to obtain the evaluation score (weight) of each alternative (see (2.4.1, iv) in chapter 2). Finally, an overall score for each alternative is obtained by summing each evaluation score row as shown in Table 4.8. The resulting priorities of the alternatives are illustrated in Table 4.8. From the Grand total column, *Wireless* technology is the most preferred alternative and has the highest score in this AHP model with a priority of **0.5**. *DSL* comes next with a priority of **0.321** and then *Fiber Optic* technology with **0.179**. The sum of the priorities in this column is equal to one. This complies with the AHP procedure and demonstrates that its steps are applied properly towards the goal of the problem, which is the efficient technology selection for Pakistan rural areas.

From below analysis, one can observe that the AHP is capable of structuring the problem and providing a systematic approach to decision making. It allowed for diverse qualitative factors to be examined in a mathematical model, which can help to reduce the time needed to evaluate the alternatives. By using the traditional selection process in such problems, the decision may take months to be reached.

Table 4.7: Telecom Sector participants Preferences for the criteria & subcriteria

Overall Inconsistency = 0.01

Goal: Selection of backbone technology infrastructure for Rural areas of Pakistan				
Criteria	**Local Priorities**	**Subcriteria (Local Priorities)**	**Subcriteria (Local Priorities)**	**Global Priorities**
Technical Aspect	0.401	Infrastructure (0.149)		0.059
		Coverage (0.524)		0.211
		Reliability (0.327)	Security (0.135)	0.017
			Bandwidth (0.628)	0.082
			Maintenance (0.237)	0.032
Public Issues	0.189	Contents & Development (0.285)		0.054
		Community of Interest (0.164)		0.031
		Government Support (0.550)	Spectrum Licensing (0.606)	0.063
			Supporting Policies (0.394)	0.042
Cost	0.410	Fixed Cost (0.255)		0.104
		Variable Cost (0.302)		0.123
		Subsidy by Government (0.444)		0.182
Grand Total				**1**

Table 4.8: Synthesized priorities for the alternatives from the group of Telecom Sector participants

Alternatives	Criteria (Local Priorities)			Grand Total
	Technical Aspect (0.401)	Public Issues (0.189)	Cost (0.410)	
DSL	0.124	0.057	0.14	0.321
Wireless	0.211	0.103	0.186	0.5
Fiber Optic	0.066	0.03	0.083	0.179
Grand Total	0.401	0.19	0.409	**1**

As the criteria are defined and the problem is prepared analytically, the AHP allows the decision makers to visualize the weaknesses and strengths of each technology alternative by comparing their scores against each attribute. The obtained final weights in Table 4.8 provide information about the alternatives and the way they are used to satisfy the selected attributes, as well as the importance of these attributes in order to reach the goal of the model. Taking this into consideration, a result where one can affirm which alternative is more preferable from Telecom experts' point of view is reached. However, the priority weights of the three technologies are actually quite different from each other and although Wireless achieved the highest score, it is above DSL weights by less than 20 %. And, Fiber Optic weight is 35 % less than DSL.

Table 4.9: Ranking of attributes according to their global priorities for Telecom Participants

Synthesis with respect to efficient policy infrastructure in rural areas

Rank	Subcriteria	Global priorities (%)
1	Coverage	21.10
2	Subsidy by Government	18.20
3	Variable Cost	12.30
4	Fixed Cost	10.40
5	Bandwidth	8.20
6	Spectrum Licensing	6.30
7	Infrastructure	5.90
8	Contents & Development	5.40
9	Supporting Policies	4.20
10	Maintenance	3.20
11	Community of Interest	3.10
12	Security	1.70

In Table 4.9, the sub-criteria are arranged for ranking in a descending order of their global priorities. The table shows that the most important sub-criterion among all is 'Coverage' with a priority of 21.10 % followed by 'Subsidy by Government' with 18.20 % and 'Variable Cost' with 12.30 %. The top four attributes comprised a variety of sub-criteria that belong to all criterions. The least important sub-criteria among others considered in the model with priorities of less than 5% are ‘Supporting Policies’, ‘Maintenance’, ‘Community of Interest’ and ‘Security’ with 4.20 %, 3.20 %, 3.10 % and 1.70 % respectively.

C) Preferences from participants having Job Experience more than 10 years

In this group we judge and evaluate the preferences of participants who have job experience more than or equal to 10 years from both (government and private) sectors. The participants of this group are from different Organizations in Pakistan. Out of **38** participants, **15** participants have job experience more than or equal to 10 years. The participant’s preferences can be viewed in the previous mentioned ways. The weights of the local and global importance of each criterion for the this group were obtained with the AHP technique using the *Expert Choice 2000* software as illustrated in Table 4.10. According to the participants of this group, one can observe that the comparison of the criteria with respect to the goal yields that the *Cost criterion* has the highest priority of **41.30 %,** expressing a certain advantage among others, which indicates more importance in comparison to other *Technical aspects and Public Issues* attributes. The lowest priorities are for Technical Aspects and Public issues with **32.50 %** and **26.20 %**, respective. Once the global priorities of all sub-criteria are obtained, they were multiplied by the local priority of each alternative with respect to each criterion to obtain the evaluation score (weight) of each alternative (see (2.4.1, iv) in chapter 2).

Table 4.10: Participants have Job experience > = 10 years

Overall Inconsistency = 0.01

Goal: Selection of backbone technology infrastructure for Rural areas of Pakistan				
Criteria	**Local Priorities**	**Subcriteria (Local Priorities)**	**Subcriteria (Local Priorities)**	**Global Priorities**
Technical Aspect	0.325	Infrastructure (0.111)		0.033
		Coverage (0.530)		0.151
		Reliability (0.359)	Security (0.123)	0.016
			Bandwidth (0.677)	0.071
			Maintenance (0.199)	0.024
Public Issues	0.262	Contents & Development (0.273)		0.071
		Community of Interest (0.156)		0.04
		Government Support (0.571)	Spectrum Licensing (0.387)	0.053
			Supporting Policies (0.613)	0.104
Cost	0.413	Fixed Cost (0.306)		0.161
		Variable Cost (0.214)		0.074
		Subsidy by Government (0.480)		0.202
Grand Total				**1**

The resulting priorities of the alternatives are illustrated in Table 4.11. From the Grand total column, *Wireless* technology is the most preferred alternative and has the highest score in this AHP model with a priority of **0.512**. *DSL* comes next with a priority of **0.326** and then *Fiber Optic* technology with **0.162**. The sum of the priorities in this column is equal to one. This complies with the AHP procedure and demonstrates that its steps are applied properly towards the goal of the problem, which is the efficient technology selection for Pakistan rural areas.

Table 4.11: Synthesized priorities for the alternatives from participants - Job Experience > = 10

Alternatives	**Criteria (Local Priorities)**			**Grand Total**
	Technical Aspect (0.325)	**Public Issues (0.262)**	**Cost (0.413)**	
DSL	0.09	0.092	0.144	0.326
Wireless	0.161	0.136	0.215	0.512
Fiber Optic	0.044	0.04	0.078	0.162
Grand Total	0.295	0.268	0.437	**1**

Based on the above analysis, one can observe that the AHP is capable of structuring the problem and providing a systematic approach to decision making. It allowed for diverse qualitative factors to be examined in a mathematical model, which can help to reduce the time needed to evaluate the alternatives. The obtained final weights in Table 4.11 provide information about the alternatives and the way they are used to satisfy the selected attributes, as well as the importance of these attributes in order to reach the goal of the model. Taking this into consideration, a result where one can affirm which alternative is more preferable from the point of view of participants who have job experience more or equal to 10 years. However, the priority weights of the three technologies are quite different from each other and although Wireless achieved the highest score, it is above DSL weights by less than 15 %. And, Fiber Optic weight is 35 % less than DSL.

In Table 4.12, the sub-criteria are arranged for ranking in a descending order of their global priorities. The table shows that the most important sub-criterion among all is ‘Subsidy by Government’ with a priority of 20.20 % followed by ‘Fixed Cost’ with 16.10 % and ‘Coverage’ with 15.10 %. The top four attributes comprised a variety of sub-criteria that belong to all criterions. The least important sub-criteria among others considered in the model with priorities of less than 5% are ‘Community of Interest’, ‘Infrastructure’, ’Maintenance’ and ‘Security’ with 4.00 %, 3.30 %, 2.40 % and 1.60 % respectively.

Table 4.12: Ranking of attributes according to their global priorities for Experienced Participants (Job Experience > = 10 years)
Synthesis with respect to efficient policy infrastructure in rural areas

Rank	Subcriteria	Global priorities (%)
1	Subsidy by Government	20.20
2	Fixed Cost	16.10
3	Coverage	15.10
4	Supporting Policies	10.40
5	Variable Cost	7.40
6	Contents & Development	7.10
7	Bandwidth	7.10
8	Spectrum Licensing	5.30
9	Community of Interest	4.00
10	Infrastructure	3.30
11	Maintenance	2.40
12	Security	1.60

4.2.4. Comparison Perspectives of Groups' Preferences

From the total 38 obtained respondent data now we will examine and compare the attributes and technologies alternatives with different ways and different criteria with respect to the goal of this study. We examine three groups and got different results from each other, several differences existing in the results of each group. Several gaps were found in the Academia group respondents, Telecom sector respondents and from those respondents who have experience more than 10 years. The sum of the global priorities of each group is equal to one. This complies with the AHP procedure and demonstrates that its steps are applied properly towards the goal of the problem, which is the efficient technology selection for Pakistan rural areas. In table 4.13 we can notice the differences between the scores (weights) of the attributes with respect to criteria and sub-criteria of AHP model. And next we will compare technologies alternatives preferences for all discussed groups according to their obtained results.

As represented in the Table 4.13, the order of the importance for the same attributes is observed from the different participants groups, Academia, Telecom sector and experienced participants. In the first level of the hierarchy, all groups' preferences are in similarities in order of importance for all the criteria in the same level, Technical aspect, Public issues and Cost. There are also similarities in order of the importance within the second and third levels of the hierarchy.

Table 4.13: Comparison of Groups' Preferences

Group of Participants from Academia. (Global priorities)	Group of Participants from Telecom Sectors. (Global priorities)	Group of Participants having job experience > = 10 years. (Global priorities)
Level – 1		
Technical Aspect (0.303)	Technical Aspect (0.401)	Technical Aspect (0.325)
Public Issues (0.296)	Public Issues (0.189)	Public Issues (0.262)
Cost (0.401)	Cost (0.410)	Cost (0.413)
Level – 2		
Technical Aspect attributes		
Infrastructure (0.034)	Infrastructure (0.059)	Infrastructure (0.033)
Coverage (0.15)	Coverage (0.211)	Coverage (0.151)
Reliability (0.12)	Reliability (0.131)	Reliability (0.111)
Public Issues attributes		
Contents & Development (0.081)	Contents & Development (0.054)	Contents & Development (0.071)
Community of Interest (0.039)	Community of Interest (0.031)	Community of Interest (0.04)
Government Support (0.176)	Government Support (0.105)	Government Support (0.157)
Cost		
Fixed Cost (0.12)	Fixed Cost (0.104)	Fixed Cost (0.161)

Variable Cost (0.089)	Variable Cost (0.123)	Variable Cost (0.074)
Subsidy by Govt. (0.191)	Subsidy by Govt. (0.182)	Subsidy by Govt. (0.202)
Level – 3		
Reliability attributes		
Security (0.016)	Security (0.017)	Security (0.016)
Bandwidth (0.077)	Bandwidth (0.082)	Bandwidth (0.071)
Maintenance (0.027)	Maintenance (0.032)	Maintenance (0.024)

In level-1, in Telecom sector group the Technical aspect and public issues attributes shows dissimilarities with two other groups. In the level-2, the Technical aspects attributes shows slightly dissimilarity from the groups 2, where group 1 and 3 have similarity in the order of importance of the same attributes. Other attributes of level-2 have almost same similarities. Moreover, in the third level, in reliability attribute the Telecom sector participant's shows slight dissimilarity among the three groups.

Nevertheless, the respondents from different sectors e.g. planners of rural areas infrastructure, IT experts, government employees, Private employees, consultants and technical staff evaluate *'Cost attribute'* as most important in the first level of the hierarchy model, followed by the *'Technical aspect'* and *'Public issues'* attributes, and the same situation can be seen in level-2. The level-3 shows slightly dissimilarities among attributes from all groups. In general, the judgments and preferences from respondents might be justified for the selection of telecommunication backbone technology for rural area of Pakistan, because the inconsistencies in all groups are less than 0.01.

Table 4.14: Groups' Preferences comparison of technology alternatives

Alternatives	Participants from Academia.	Participants from Telecom Sectors.	Participants having job experience > = 10 years.
Wireless	0.488	0.5	0.512
DSL	0.338	0.321	0.326
Fiber Optic	0.174	0.179	0.162

From the above Table 4.14, the order of the importance for the technology alternatives is observed from the different participants groups e.g. Academia, Telecom sector and experienced participants. The obtained final weights in Table 4.15 provide information about the alternatives and the way they are used to satisfy the selected attributes, as well as the importance of these attributes in order to reach the goal of the model. Taking this into consideration, a result where one can affirm which alternative is more preferable from the point of view of participants from the three groups. However, the priority weights of the three technologies are quite different from each other and although Wireless technology achieved the highest score among three groups, followed by DSL and Fiber Optic technologies.

4.2.5. Overall Preferences Results (Combined ALL Groups)

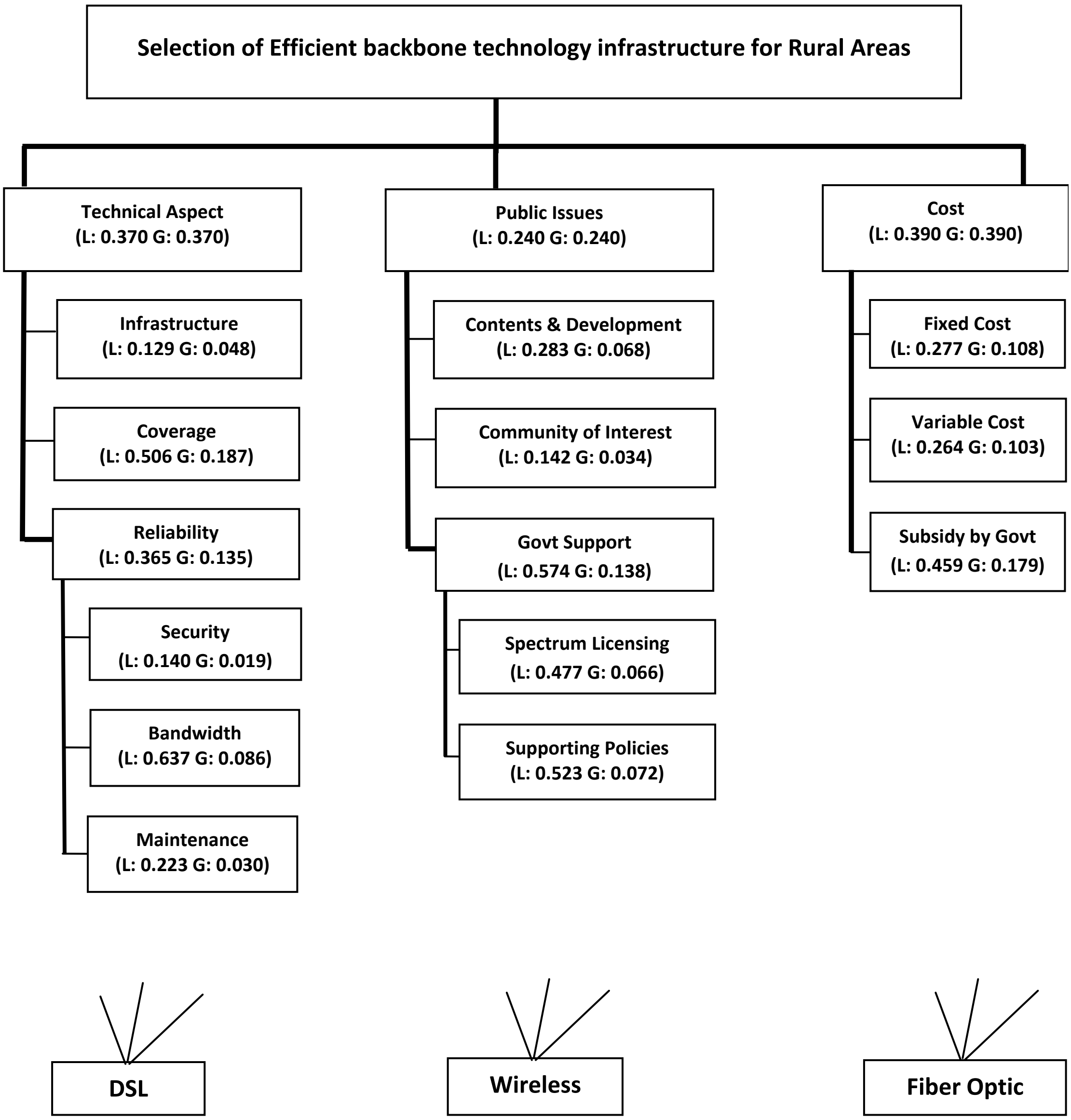

Figure 4.6: All Groups Aggregated Preferences

The overall preferences within each level (branch) are discussed by using the relative local importance of each attribute inside the branches of the hierarchal tree as displayed in the above Figure 4.6.

Table 4.15: Overall Preferences for the criteria & subcriteria – overall Inconsistency = 0.00

Goal: Selection of backbone technology infrastructure for Rural areas of Pakistan				
Criteria	**Local Priorities**	**Subcriteria (Local Priorities)**	**Subcriteria (Local Priorities)**	**Global Priorities**
Technical Aspect	0.370	Infrastructure (0.129)		0.047
		Coverage (0.506)		0.187
		Reliability (0.365)	Security (0.140)	0.02
			Bandwidth (0.637)	0.086
			Maintenance (0.223)	0.03
Public Issues	0.240	Contents & Development (0.283)		0.068
		Community of Interest (0.142)		0.035
		Government Support (0.574)	Spectrum Licensing (0.477)	0.066
			Supporting Policies (0.523)	0.072
Cost	0.390	Fixed Cost (0.277)		0.108
		Variable Cost (0.264)		0.103
		Subsidy by Government (0.459)		0.178
Grand Total				**1**

The weights considering the participants judgment are demonstrated in above Table 4.15 for all 38 participants from both group (government employees & private employees). The overall aggregated weights resulted from aggregating all groups are shown in Figure 4-1. (Overall AHP Model). The global and local priority of each criteria and sub-criteria according to all groups (38 participants) are shown in above Tables 4.15.

4.3 Analysis and Discussion

Once the global priorities of all sub-criteria are obtained, they were multiplied by the local priority of each alternative with respect to each criterion to obtain the evaluation score (weight) of each alternative (see (2.4.1, iv) in chapter 2). Finally, an overall score for each alternative is obtained by summing each evaluation score row as shown in Table 4.16.

The resulting priorities of the alternatives are illustrated in Table 4.16. From the Grand total column, *Wireless* technology is the most preferred alternative and has the highest score in this AHP model with a priority of ***0.494***. *DSL* comes next with a priority of ***0.326*** and then *Fiber Optic* technology with ***0.180***. The sum of the priorities in this column is equal to one. This complies with the AHP procedure and demonstrates that its steps are applied properly.

Table 4.16: Synthesized Final Survey Data

Alternatives	Criteria (Local Priorities)			Grand Total
	Technical Aspect (0.370)	**Public Issues (0.240)**	**Cost (0.390)**	
Wireless	0.196	0.127	0.171	0.494
DSL	0.111	.076	0.139	0.326
Fiber Optic	0.063	0.038	0.079	0.18
Grand Total	0.37	0.241	0.389	**1**

Moreover, from Table 4.15, one can observe that the comparison of the criteria with related to the goal yields that the Cost criterion has the highest priority of **39 %**, expressing a certain advantage among others, which indicates more importance in comparison to other Technical aspects and Public Issues attributes. The lowest priorities are for Technical Aspects and Public issues with **37 %** and **24 %**, respective.

The obtained final weights in Table 4.16 provide information about the alternatives and the way they are used to satisfy the selected attributes, as well as the importance of these attributes in order to reach the goal of the model. Taking this into consideration, a result where one can affirm which alternative is more preferable from telecoms experts' point of view is reached. However, the priority weights of the three technologies are actually quite different from each other and although Wireless achieved the highest score.

Table 4.17: Overall ranking of attributes according to their global priorities

Synthesis with respect to efficient policy infrastructure in rural areas

Rank	Subcriteria	Global priorities (%)
1	Coverage	18.70
2	Subsidy	17.80
3	Fixed cost	10.80
4	Variable Cost	10.30
5	Bandwidth	8.60
6	Supporting Policies	7.20
7	Contents & Development	6.80
8	Spectrum Licensing	6.60
9	Infrastructure	4.70
10	Community of Interest	3.50
11	Maintenance	3. 00
12	Security	2.00

In Table 4.17, the sub-criteria are arranged for ranking in a descending order according to their global priorities. The table shows that the most important sub-criterion among all is ‘Coverage’ with a priority of **18.70 %** followed by ‘Subsidy’ with **17.80 %** and ‘Fixed Cost’ with **10.80 %**. The top four attributes comprised a variety of sub-criteria that belong to all criterion. The least important sub-criteria among others considered in the model with priorities of less than **5%** are ‘Infrastructure’, ‘Community of Interest’, ‘Maintenance’ and ‘Security’ with **4.70 %, 3.50 %, 3 %** and **2%** respectively.

In general, AHP model’s hierarchy is considered the allocation of a goal between the attributes being compared which factor has a superior influence on that goal.

Chapter 5. Conclusion and Policy Implications

5.1 Overall Conclusion

In general, telecommunication plays a vital role to serve a community and especially Telecommunications infrastructure plays an important role in the primary development of the rural area and its inhabitants. In actuality, telecommunication is a very important and essential factor for Pakistan's rural development because Pakistan's 64% population lives in rural areas, and they have insufficient resources to telecommunication services. There are many attributes (economic, social, technical etc) identified for the rural environment which can be considered to achieve e-services from backbone technologies.

The issues surrounding the rural telecommunications infrastructure selection is not only technological but a complex system of other interrelated factors cutting across various aspects of rural areas and their inhabitants. Based on these issues which are associated with the infrastructure technology selection, this research was essential for the rural areas of Pakistan. Because of the complex structure of rural settings there are several factors to be considered. These factors have a big impact on the selection process, related to social, environmental, infrastructure and maintenance concerns. Based on the information and knowledge obtained from IT experts (from different sectors), this study discussed that how the goal was achieved and how to promote the telecommunication services in rural areas of Pakistan.

The previous literature (explained in chapter 2) covered some of the developmental aspects and universal access of rural telecommunications. But still the provision of rural telecommunications infrastructure is regarded as main economical and technology issues in developing countries. Research on this study indicated that the multicriteria (MCDM) approach would play an important role in the development of the AHP model for the selection of rural telecommunication infrastructure.

To obtain the goal of this study, the researcher applied AHP model which is based on the MCDM approach. For the selection of optimum backbone technology the AHP hierarchy was structured based on the identified attribute from the previous literature. Those attributes were considered to be the best solution for the selection of suitable backbone technology and rural development of Pakistan. Moreover, In Pakistan there are different access technologies available which deliver the connectivity of Internet. These contain the wired and wireless access technologies. The wired access technologies contain DSL and Fiber Optic, while the wireless access technologies are WiMAX and EvDO. These technologies were evaluated in terms of their cost, where they can be deployed according to their subscription. Available access technologies were explained in detailed in chapter 3.

The estimation results of the AHP hierarchy expressed in chapter 4 of this study. Data were obtained from IT experts, where IT experts are from different (government, private and semi-government) organizations of Pakistan. The collected data from participants were then combined using the Expert Choice 2000 software. The AHP survey and collection of data was discussed in detailed in chapter 4. The proposed AHP model empowers decision makers to observe the weaknesses and strengths of the problem, by comparing several technology options, with respect to an appropriate gauge for judgment. The total obtained data were classified into different groups (academia, Telecom and experienced participants) to judge the views and expertise of the respondents related to the selection of backbone technology infrastructure. By the comparisons of different groups there were slightly dissimilarities in the obtained results from each group of participants, which are described in chapter four and the obtained synthesis show inconsistency less than 0.1 which mean that their judgments were satisfactory.

After individuals group judgment an overall aggregated results were obtained which shows the priorities (local and global) weights of the attributes according to the preferences. From the grand total weights of the overall results, *Wireless* access technology was the most preferred alternative and has the highest score in this AHP model for the rural areas of Pakistan. However, it is the author understanding that the process of structuring models of any condition is hard and specifically rural areas, and the key to success in this challenge is the identification of the restrictions of any modeling technique utilized and structure shaped. Moreover, there is a limitation of AHP that it is dependent on the decision makers because the weightings obtained are based on the expert's opinion. Hence, the achieved results reveal the preferences of specialists who made the comparisons and therefore, should not be viewed as a goal evaluation of the relative appropriateness of the three technologies as backbone infrastructure in rural areas of Pakistan.

5.2 Key finding and Policy Implications

From the results and analysis there are some important implications which can be described as: In Pakistan' rural areas service cost and coverage of the technologies is the most important factors. The inhabitants of the Pakistan rural community prefer to use the internet stably and smoothly in their own homes with a more suitable bandwidth and specifically in their own local language. Mostly they give preference to Wireless technologies as compared to wired technologies, and wireless networks remain as valuable resources for the rural consumers who cannot afford or do not have the Internet at home. Telecommunication service providers need to focus on providing reliable and fast Internet services, not only in urban areas but also in rural areas of Pakistan, which will energize the market for improved penetration. The priority settings for policies were constructed to derive proper policy implications that help telecommunication service providers and policy makers to successfully establish backbone technology infrastructure in rural areas of Pakistan. For the establishment of new telecommunication infrastructure there is a need of sufficient funding and these deficiencies in funding require policy makers to prioritize technologies that the telecommunication provider has to start with.

The proposed AHP model empowers decision makers to observe the weaknesses and strengths of the problem, by comparing several technology options, with respect to an appropriate judgment for Pakistan's rural telecommunication infrastructure selection. The strengths include sufficient time and money to spend on the selection process, careful evaluation, expertise from different sectors and many criteria considered. While weakness includes that the selection criteria not clearly defined and lengthy selection process. To overcome these weaknesses a systematic structure for the selection of rural telecoms infrastructure is encouraged, by prioritize relevant criteria, and several different elements like technical, social and economic, etc. The formation of the pair-wise comparison matrices in the AHP method is a time consuming and complex task, but the Expert Choice software helped us to efficiently model the problem by clarifying, organizing and presenting it in the way like decision makers think. The Expert Choice software also allowed modification of the model by flexible and easy to learn and use.

For Pakistan's rural areas the telecommunication service providers must provide a suitable technological infrastructure that meets the technology requirements of the area, which is the need and the goal for the provision of effective communication systems to transfer data between individuals, and society. And the government should also give subsidy to telecommunication organizations to support them for the enhancement of networks that interconnect different rural areas. As discussed above that there is a need of training and skills for the people of rural areas to promote the telecommunication services more effectively, for that workshops, training sessions and short term courses should be offered for the maintenance of the telecommunication infrastructure and long term sustainability. There should be a policy from the telecommunication service providers and policy makers for highlighting and improvement the social issues of the rural areas people.

Policy recommendation for the government and telecommunication service providers in Pakistan toward providing of reliable and fast Internet services to the rural areas of Pakistan. As this study was concerned to successfully establish backbone technology infrastructure in rural areas, the researcher suggests some key components for possible better performance. Currently, the rural areas of Pakistan have telephone and internet services but that are unreliable. This is due to the frequent breaks in the long-haul signal broadcast from the country's main telecommunication point to the remote access network. Information on the area coverage is insufficient; hence, there is a need to reduce downtime on telecommunication services to improve coverage and reliability. Also there is need for telephones to provide better information on demand, increase the capacities and improve the affordability of telecommunication services. Additionally, governments should cooperate with the private sectors to promote Internet penetration especially for remote and isolated areas. And provide telecommunication services at affordable prices rural inhabitants have little financial opportunity to subscribe Internet packages.

Another policy implication is lack of skilled people in rural area of Pakistan which needs to provide training for them to take an active part in development programs. Government of Pakistan and telecommunication service providers must educate the inhabitants of rural areas about sustainability of the applications and skills about maintenance of the technology infrastructure, because the maintenance decision making standard has low priority score in the overall ranking list. So there is a need to educate and provide opportunities to inhabitants of remote area for better performance and reliable infrastructure.

From the IT experts results it is noticed that security has low priority weight in the overall ranking of decision making standard list. Although, rural areas of Pakistan expose security to an increased level of theft of copper wires, telecommunication equipments and damaging of property. But these low proprieties do not mean that these decision making standards are not important in the deployment of telecommunication infrastructure for the rural areas. Thus the government should implement and activate some policies to educate the community on the importance of telecommunications infrastructure for their wellbeing in order to develop the security of the infrastructure and reduce the theft and damages of properties.

5.3 Limitations and Future Work

There are some limitations concerns to this study. First, this study achieved large issues surrounding access technologies for supplying Internet connectivity for the formulation of telecommunication policy, but it does not give an understanding into the climate and the ease of installation factors about the rural areas. Second, data were obtained from a small number of participants in the survey, which limits the scope and coverage of the goal. There is a need to obtain a larger sample size so there should be involved many participants from different organization who are aware of the problems of rural areas.

From this study many prospective areas for further research can be acknowledged, this study was concerned with Pakistan’s rural telecommunications infrastructure selection, and in rural areas of Pakistan, there is a big issue of power supply so a possible research initiative encountered in the distribution of electricity supply to rural communities. The second most important concern about rural communities is the need of education and training with respect to the use, installation, maintenance and protecting the telecommunications infrastructure. Therefore further research should consider on how to conduct such rural community education, training and involvement into the evaluation of issues.

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Appendixes

Annex 1 – Survey Questionnaire

Survey on Policy for Internet adoption and usage in the rural areas of PAKISTAN

This survey is carrying out with the cooperation of IT Policy Program of Seoul National University, South Korea, in order to study consumer preference structure of Internet penetration in rural areas of Pakistan.

With diverse criteria for technology assessment and different alternatives available nowadays, the selection procedure becomes complicated. This questionnaire attempts to raise the question of 'how best can telecommunications infrastructure providers select the most appropriate backbone infrastructure technology, competent of deploying internet penetration in rural areas of Pakistan?

This questionnaire includes pair-wise comparison questions addressed to telecommunications experts, to seek their judgments representing the relative influence of pre-identified selection factors (Criteria), on three telecommunication infrastructure technologies (alternatives).

All your response to this survey will be confidential and used only for academic research purpose.

If you have any comments, suggestions or questions about this survey, kindly contact us via e-mail at gulbacha@snu.ac.kr or star_ibrar@hotmail.com.

Thank you very much for your time and cooperation!

Important Notice - Please spend a few minutes to understand the attributes with their description in the box carefully before answering the questions.

Attributes	Description
Infrastructure	- Infrastructure contributes to the evaluation of backbone technologies. - Sharing of the existing public infrastructure assets such as radio towers, electricity clamps, public buildings, etc, are cost effective to cover remote areas.
Coverage	- How the proposed system is able to cover wider rural areas. - End-users located within the area covered by signals can have access to the internet.
Reliability	- Unreliable service will not encourage the rural population. The networks need safeguard and security against breakdown. Provide consistent speed and service.
Security	- Network Security and Information Security. - Protection of software and network architecture from threats (Hackers).
(Bandwidth) Speed & Services	- Bandwidth is relevant for both voice and data communication. - Bandwidth is directly related to the efficiency and effective performance of the link (speed & services)
Maintenance	In most rural areas main supply of electricity does not exist which lags behind telecommunication development. (low fault liability, no-site repair work etc). A suitable system should be capable of reconfiguring circuits to maintain better services.
Contents & Development (by Govt)	- Rural community is suffering from multi-dimensional problems mainly due to unavailability of information and lack of communication, Education, Agriculture information & technique, Healthcare etc. Through ICT development, rural community can get maximum benefits to improve their education, knowledge, health, agricultural skills, earnings and living standard.
Community of Interest	Rural communities have strong interests at their immediate geographical and administrative area so therefore their communication needs have to be taken into consideration when planning rural telecommunications networks.
Govt Support	Modest (limited) support from state and federal agencies will continue the creative utilization of existing services and facilities to give new life to the rural communities.
Spectrum Licensing	- Service delivery concern was to some extent due to the license restriction on telecommunication companies. In many countries spectrum is licensed through auction and there is a high price to pay for some frequencies.
Supporting Policies	- Most countries have explicit policy goal of promoting universal access to certain Infrastructure utilities. Including telecommunications, electricity, and piped water and sewerage at affordable prices.
Fixed Cost	Investment required for deploying the access technology (Purchase, Deployment and Central Office etc)
Variable Cost	Cost of Maintenance, Administration, Training, Testing and up-gradation etc (Depend on number of users)
Subsidy	- Government might wish to subsidize poor or rural consumers for political reasons or as part of a development strategy. - New methods (Reforms) are necessary to raise subsidies and to ensure access by the poor people.

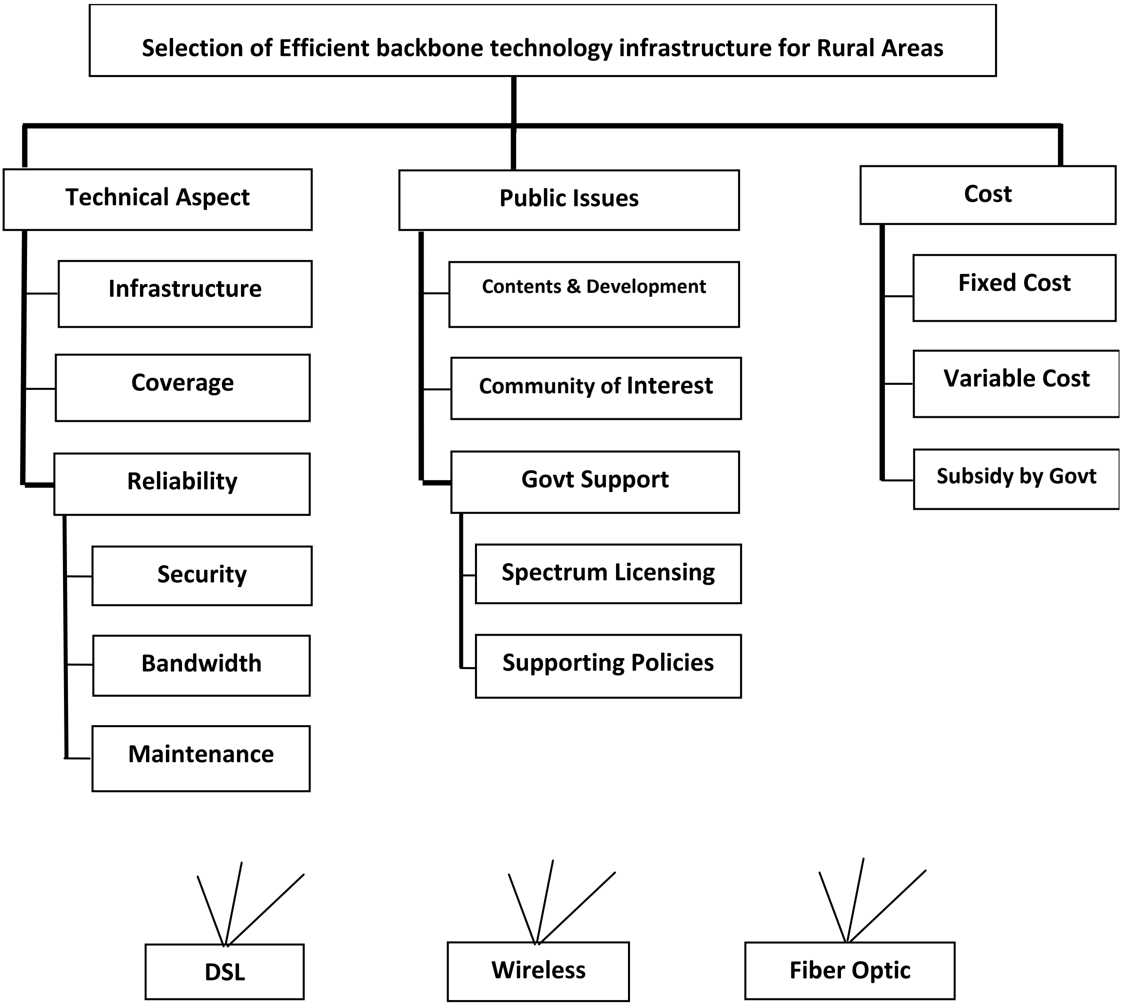

Figure 3.1: AHP Model for Selection of Backbone Technology in rural areas

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(Part - A) Pair-wise comparisons with respect to Criteria

Pair-wise comparisons for backbone telecommunications infrastructure for internet connection in rural areas of Pakistan

1	Equally Important	3	Slightly more Important
5	Strongly more Important	7	Very Strongly Important
9	Extremely more Important	2,4,6,8	Intermediate values

Underline or color the relative weighting of your chosen factor according to the scale shown in the above table.

Example

Technical Aspects	9	8	<u>7</u>	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Public Issues

Level - 1 Pair-wise Comparison

What is the more important efficient factor which influences on each other, when selecting a potential backbone technology infrastructure for internet connection in rural areas of Pakistan?

Underline or color the relative weighting of your chosen factor according to the scale shown in the above table.

Technical Aspects	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Public Issues
Technical Aspects	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cost
Public Issues	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cost

Level - 2 Pair-wise Comparison

1	Equally Important	3	Slightly more Important
5	Strongly more Important	7	Very Strongly Important
9	Extremely more Important	2,4,6,8	Intermediate values

What is the more important "***Technical factor***" which influences on each other, when selecting a potential backbone technology infrastructure for internet connection in rural areas of Pakistan?

<u>Underline or color</u> the relative weighting of your chosen factor according to the scale shown in the above table.

Infrastructure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Coverage
Infrastructure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Reliability
Coverage	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Reliability

What is the more important ***"Public Issue factor"*** which influences on each other, when selecting a potential backbone technology infrastructure for internet connection in rural areas of Pakistan?

<u>Underline or color</u> the relative weighting of your chosen factor according to the scale shown in the above table.

Content & Development	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Community of Interest
Content & Development	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Govt Support
Community of Interest	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Govt Support

What is the more important ***"Financial factor"*** which influences on each other, when selecting a potential backbone technology infrastructure for internet connection in rural areas of Pakistan?

<u>Underline or color</u> the relative weighting of your chosen factor according to the scale shown in the above table.

Fixed Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Variable Cost
Fixed Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Subsidy (Govt)
Variable Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Subsidy (Govt)

Level - 3 Pair-wise Comparison

1	Equally Important	3	Slightly more Important
5	Strongly more Important	7	Very Strongly Important
9	Extremely more Important	2,4,6,8	Intermediate values

What is the more important ***"Reliable factor"*** which influences on each other, when selecting a potential backbone technology infrastructure for internet connection in rural areas of Pakistan?

Underline or color the relative weighting of your chosen factor according to the scale shown in the above table.

Security	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Bandwidth (speed & service)
Security	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Maintenance
Bandwidth (speed & service)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Maintenance

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What is the more important ***"Govt support factor"*** which influences on each other, when selecting a potential backbone technology infrastructure for internet connection in rural areas of Pakistan?

Underline or color the relative weighting of your chosen factor according to the scale shown in the above table.

Spectrum Licensing	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supporting Policies

(Part – B) Selection of Telecommunications Backbone Technology in Rural Area of Pakistan.

Instruction: For each pair of technologies given below, please fill in the relative assessment of their pair-wise comparisons, as shown in the example: **Underline or color** the relative weighting of your chosen factor according to the scale shown in below table.

1	Equal Importance	3	Slightly more Importance
5	Strongly more Important	7	Very Strongly Importance
9	Extremely more Importance	2,4,6,8	Intermediate values

Example: Which of the two technologies you believe is more important within rural environments of **Pakistan**?

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	**7**	8	9	Wireless
DSL	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	Fiber Optic

For each pair of technologies given below please **Underline or color** the relative weighting of the technology providing more importance relative to the technology providing less importance. These Pair-wise comparisons questions are for *Technical Aspect, Public Issues and Cost Criteria*.

1	Equal Importance	3	Slightly more Importance
5	Strongly more Important	7	Very Strongly Importance
9	Extremely more Importance	2,4,6,8	Intermediate values

Infrastructure: It refers to the Sharing of the existing public infrastructure assets such as power sources, accessible roads and transport in rural areas of Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Coverage: It refers to the coverage range from the proposed technology to be deployed in rural areas Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Security: It refers to the protection of information and network infrastructure technology equipment and cables from threats or Hackers in rural areas of Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Bandwidth: It refers to what extend the technology will increase and enhance the speed of transport and improve the potential of new services in rural areas of Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Maintenance: It refers to the maintenance and user friendliness of the infrastructure equipment that needs to be deployed in rural areas of Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Content & Development: It refers that from what one can get maximum benefits and to improve their education, knowledge, health, agricultural skills, earnings and living standard.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Community of Interest: It refers to the collaborative fulfillment of community of interest requirement in rural areas of Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Spectrum Licensing: It refers to the license restriction on telecommunication companies and which satisfy the licensing requirement.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Supporting Policies: It refers to the explicit policy goal of promoting universal access in rural areas.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Fixed Cost: It refers to Capital investment required for deploying the Internet access technology such as Purchases, Deployment and Central Office etc

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Variable Cost: It refers to Cost of Maintenance, Administration, Training, Testing and up-gradation etc

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Subsidy: It refers to the new methods (Reforms) which are necessary to raise subsidies and to ensure access by the poor people of rural resident of Pakistan.

DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wireless
DSL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic
Wireless	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fiber Optic

Part C - 1 (Respondent Demographic and general Information)

Name	
Gender	
Age	
Organization	
Position	
Working Experience (Years)	
Email ID	
Contact No.	

Part C - 2 (Professional background Information)

The aim of this survey questionnaire is to obtain information about the planning and designing phase of rural telecommunication infrastructure within Pakistan.
(Please choose/write the best option(s) according to your preference)

1. What is your Job status?

   ① Public Employee ② Private Employee

   ③ Semi-Government ④ Others…………………

2. What education level do you have?

① Diploma ② Bachelor ③ Masters

④ Doctorate

3. In the planning and design of a rural telecommunications infrastructure in Pakistan, what considerations are given to the following aspects: *(Choose more than one option if applicable)*

① Technological ② Social ③ Economical

④ Regulatory ⑤ Political ⑥ Other………

4. What benefits are expected from Pakistan's rural telecommunications infrastructure?
(Choose more than one option if applicable)

① Economic ② Social ③ Agricultural Info

④ Educational ⑤ Health ⑥ Other ………

5. Consultations take place with whom, during the planning and designing phase of rural telecommunication infrastructure in Pakistan?

① Government ② Private ③ Other………

6. Job Description: …...

7. If you feel any other factors which are not listed in this survey and are relevant to influencing the backbone technology in rural areas of Pakistan, please feel free to suggest and indicate why they are relevant?

…………………………………………………………………………………
……………………………………………………………………

<u>Thank you very much for your time, participation and cooperation</u>

Annex II - AHP Inconsistency of each respondent

(Total 38 respondents)

S. NO	Group 1: Government Employees		Group 2: Private Employees		Group 3: Semi-government Employees	
	Respondent no	Inconsistency	Respondent no	Inconsistency	Respondent no	Inconsistency
1	P2	0.05	P3	0.03	P4	0.06
2	P3	0.03	P4	0.04	P6	0.03
3	P5	0.07	P6	0.07	P7	0.04
4	P6	0.04	P7	0.03	P8	0.03
5	P7	0.03	P8	0.04	P9	0.03
6	P8	0.05	P9	0.04		
7	P9	0.04	P10	0.09		
8	P10	0.07	P11	0.04		
9	P11	0.04	P12	0.03		
10	P12	0.04	P13	0.05		
11	P13	0.01	P14	0.04		
12	P14	0.04	P16	0.03		
13	P15	0.04	P17	0.06		
14	P16	0.09	P18	0.09		
15	P17	0.03	P20	0.03		
16	P18	0.04	P21	0.05		
17			P22	0.07		

초록

파키스탄 시골지역의 인터넷 연결을 위한 효율적인 침투 정책 : 계층분석과정 접근

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ICT 정책 및 계획 수립에서 인터넷 사용자들의 선호도를 이해하는 것은 유용하다. 통신인프라는 지리적 경계의 한계와 외부경제 및 사회개발을 위한 기본요소로 인식되고 있다. 도시지역을 넘어, 통신기술 인프라는 사회적인 이익과 성장, 연결과 경쟁에서 필수적이다. 개발도상국의 시골지역의 경우 더욱 중요하다.

이 논문은 파키스탄 시골지역에서 인터넷 연결과 관련된 관점들을 제시한다. 이 연구의 목적은 구체적으로 종합시험과 파키스탄 시골지역에 있어서 최적의 통신기술 인프라 선택에 관한 것이다. 문헌조사는 분석 의사 결정 프로세스에 특히 초점을 맞춘

다기준의사결정모형 (MCDM) 분야의 지식과 이해를 위해 실시하였다. 연구결과, 계층분석과정 (AHP) 가 이러한 복잡한 문제를 모델링 할 수 있는 강력한 결정방법이라는 것을 발견하였다. AHP 는 통신기술에서 대안기술 평가를 위해 사용된다. 방법은 계층구조에서 설명된 서비스의 품질에 영향을 주는 여러 요인 간의 쌍대비교에 기초한다.

이 연구는 통신인프라 데모 제공과 파키스탄 시골지역에서의 기술선택과 결정이 어떻게 이루어질 수 있는지 학계와 전문가 및 정책 입안자에게 귀중한 통찰력을 제공할 것이다.

키워드: AHP 계층분석과정, 인터넷 관통, 통신 인프라, MCDM 다기준의사결정모형, 기술 선택, 파키스탄 시골지역.

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