ANALYTIC HIERARCHY PROCESS MODEL FOR THE SELECTION OF OPTIMAL INTERNET ACCESS TECHNOLOGIES IN RURAL PAKISTAN

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ABSTRACT

Information and telecommunication technologies are considered significant for the economic and social development of isolated and remote areas. Internet technologies create links between urban and rural areas that can overcome the barrier of distance that typically hinders development. In rural areas of Pakistan, Internet penetration is low due to high cost, lack of manageable infrastructure, public issues and many other factors that disturb sustainable Internet provision; however, the choice of access to technology in rural areas is a complex process. In this paper, we used the Analytic Hierarchy Process (AHP) method, which is a powerful multi-criteria decision-making (MCDM) approach and is a structured procedure for organizing and analyzing complex decisions. Furthermore, we proposed an AHP model for the selection of an ideal Internet access technology, which would facilitate access to Internet services to the 61% of the population who live in Pakistan's rural areas. Data were collected from 38 respondents, from both academia and the telecom sector IT professionals. The relative weights of each factor and technology alternative were synthesized with Expert Choice 2000. This paper

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can provide comprehensive recommendations to telecommunication policymakers for Internet deployment and the selection of optimal Internet access technology in rural Pakistan.

Keywords: access technology selection; multi-criteria decision-making (MCDM); Analytical Hierarchy Process (AHP); Internet penetration; rural Pakistan

1. Introduction

In the modern information technological revolution, the Internet plays a vital role. Telecommunications that enable the Internet are a link between urban and rural areas that can overcome the hurdle of distance, which interrupts development. Despite the rapid worldwide diffusion of the Internet, there has been a big gap between developing and developed countries – rich and poor regions – in terms of the number of Internet users because of a limitation of telecommunications infrastructure. The same telecommunication services should be offered to both rural and urban areas such as telephone, data transmission, video transmission, and other services, both for individuals (private subscribers) and for the public communities (ITU Group 7, 2000). In a developing country, telecommunications planning in rural areas is a difficult procedure and characterized by a multitude of difficult problems because these rural areas are technologically poor and need special consideration (Andrew et al., 2005). Therefore, the planning and provision of Internet services to rural areas requires more time and involves a substantial use of manpower from many Internet service providers that would be responsible for providing transmission bandwidth to rural inhabitants, including wireless, fiber cables, undersea cables, and satellite, when compared to urban centers. This makes choosing the optimal Internet access technology in rural areas more complicated from the perspective of Internet service providers. It also requires other decision-making processes and attributes that can take into account the environment of rural areas that has different characteristics than urban areas (Andrew et al., 2003).

According to the Pakistan census (2017) report, the total population of Pakistan is 21 million, out of which 61% live in rural areas. To ensure a digital balance between urban and rural areas, the Universal Service Fund (USF) of the government of Pakistan is playing an important role in providing for universal access to broadband services and promoting telecommunication services in un-served and under-served areas throughout the country (Telecommunications Policy, 2015). Currently, communication satellite systems facilitate access to telecommunication services in rural Pakistan. After the government of Pakistan issued 3G/4G licenses in 2014, the USF redesigned the Next Generation Broadband for Sustainable Development (NG-BSD) Program to provide telecom (Internet) services to the unserved areas across Pakistan. Vakataki et al. (2017) highlighted that only 7% of households in rural areas had Internet access compared to 18% of households in the urban areas of Pakistan in 2016. The gap between urban and rural areas has been reduced in terms of household Internet access between 2012 and 2016, as shown in Figure 1. Yasir (2017) stated that in rural Pakistan internet penetration is limited because of many factors such as high cost to the consumers from Internet service providers, cultural hurdles, lack of sustainable infrastructure, and the low literacy rate in the country.

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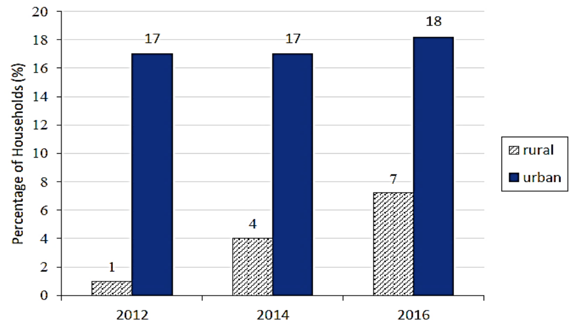

Figure 1 Household Internet access in Pakistan (Vakataki et al. 2017)

A new approach is needed to increase the low Internet access rate that is based on the existing satellite system. Considering the environment and constraints in rural Pakistan, it is necessary to re-select a suitable Internet access technology in order to reach a higher Internet access rate. So far, however, there has been no suitable decision model. Therefore, this study suggests the AHP model for the selection of an optimal Internet access technology within the various constraints to provide access to the central telecommunications network and enlarge connectivity to rural Pakistan.

In this paper, we developed an Analytic Hierarchy Process (AHP) model, using the multi-criteria decision-making (MCDM) approach. The goal of the decision problem is the selection of the optimum Internet access technology to provide quality Internet services to rural areas of Pakistan. Chemane et al. (2005), Malladi and Min (2005), and Andrew et al. (2005) have used the MCDM based model and the AHP model to select Internet access technologies that are suitable for a specific region. The AHP model provides priority weights for the Internet access technologies, and the Internet access technology with the highest priority weight is then selected for the rural areas of Pakistan from among the different available technologies (such as DSL, cable modem, and wireless).

This study is organized into five sections; section one gives an overview of the telecommunication services in Pakistan's rural areas. Section two reviews related work by exploring the attributes that affect the selection and deployment of Internet access technology for rural areas of Pakistan. Section three introduces the different Internet access technologies that are available in Pakistan and develops an AHP model for the selection of access technologies. Data collection and the Analytical Hierarchy Process (AHP) analysis will be covered in section four, and section five discusses the conclusions, study limitations, and suggestions for future work.

2. Attributes for access technology selection in rural areas

Proper decisions need to be made in order to ensure the provision of Internet services with the most helpful system within numerous constraints (ITU-D, 1997). According to Saaty (1990), the most important and creative issue in making a decision is the adoption of the factors that are relevant to that decision. Saaty (2005) stated that a cluster gives room for one to think about a criteria grouping that has a common set of attributes. The AHP model involves a cluster of elements that are connected to one another by their need. Previous studies have shown that each telecommunication service provider has its own criteria, sub-criteria, and alternatives for the particular problem. Malladi and Min (2005) and Douligeris and Pereira (1994) investigated cost, quality, and speed attributes and used multi-criteria decision making (MCDM) methods, particularly the Analytic Hierarchy Process (AHP), for the selection of access technology in rural areas. Chemane et al. (2005) and Andrew et al. (2005) explored several criteria concerning financial and technical aspects and stated that the selection of the most appropriate Internet access technology is a challenging and complex process. Pakistan's rural areas need a list of possible criteria when selecting access technologies. To combine the final list of the selection criteria the following activities were used:

- This study conducted a literature survey of previous studies on similar problems, including Douligeris and Pereira (1994), Chemane et al. (2005), Malladi and Min (2005), Chasia (1976), and Andrew et al. (2005) that were used as secondary sources to strengthen the list of criteria that includes the most important factors for the problem.
- Interactions with IT professionals both from the telecom sector and from academia, who were contacted through e-mail to give their feedback on the preliminary list of attributes, using a five-point Likert-type scale. The preliminary list of attributes can be observed in Table 1.

Table 1
Preliminary list of attributes

Attributes		
Infrastructure		Contents & Development
Fairness		Public Issues
Technical Aspect		Community of Interest
Coverage		Government Support
Climatic conditions		Spectrum Licensing
Reliability		Supporting Policies
Flexibility		Cost
Security		Fixed Cost
Speed & Services (Bandwidth)		Return on investment
Geographical Coverage		Variable Cost
Response Time		Terrain factors
Maintenance		Subsidy

Using the above-mentioned activities and the results obtained from the respondents on the preliminary list, the weakest attributes (Fairness, Climate conditions, Flexibility, Geographical Coverage, Response Time, Return on investment, and Terrain factors) were dropped from the list for further analysis using the cut-off value method, and a consolidated list of 17 attributes (Table 2) that have straightforward effects on the objective of the selection of optimum Internet access technologies for rural Pakistan was

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finalized. The AHP model was grouped into three strategic criteria, namely technical aspects, public issues, and cost. Each criteria cluster only includes those attributes that are comparable by orders of magnitude. Further, 14 sub-criteria attributes (infrastructure, coverage, reliability, security, bandwidth, maintenance, contents & development, community of interest, government support, spectrum licensing, supporting policies, fixed cost, variable cost, and subsidy by government) were grouped according to their respective criteria (technical aspects, public issues, and cost).

2.1 Attributes for technical aspects

Rural areas in developing countries have a lack of technical assistance and equipment repair facilities due to a lack of experienced manpower. From a technical point of view (ITU-D, 1997), it is recommended that rural telecommunications systems satisfy certain conditions and proper decisions need to be made to ensure the provision of an effective system and efficient network. Gasmi and Recuero (2005) stated that in developing countries rural transportation systems are not often well managed, and most are not reachable at all by roads, and the presence of on-site technical staff is rare. Therefore, the sub-classification of the technical aspects attributes includes infrastructure, coverage, reliability, security, bandwidth (speed and service) and maintenance.

2.2 Attributes for public issues

Sattar (2007) stated that through telecommunications development, rural communities can obtain the ability to improve their education, health, knowledge, agricultural skills, living standard, and earning. Andrew et al. (2005) highlighted that rural communities have a strong interest in their geographical and administrative setups; therefore, their needs have to be taken into account when planning rural telecommunications networks. Hudson (2013) highlighted that in the interest of the local community, there should be more and more innovations for the development of public and social issues. The attributes for public issues include contents and development, community of interest, government support, spectrum licensing, and supporting policies.

2.3 Attributes for cost

Chemane et al. (2005) stated that rural areas of developing countries have some economic aspects that make it hard to provide a suitable telecommunication infrastructure. ICT and especially the Internet is considered a key driver for social and economic development. Andrew et al. (2005) analyzed that in developing countries Internet penetration is low due to lack of infrastructure, skills, and low-income communities in rural areas. Internet services can reduce isolation and would eliminate the hurdles of rural living at affordable prices. According to a report from International Monetary Fund (IMF, 2018), Pakistan is among the top eight countries where the majority of the population cannot access or afford the internet. The attributes under the cost criteria are rather self-explanatory. These are fixed cost which covers the expenses for purchasing, deployment, and recovery cost, etc. Variable cost refers to maintenance, administration, training, testing, and up-gradation, etc. The government might wish to subsidize the rural consumers who have been deprived. New methods (reforms) for neutral financing mechanisms, like subsidy auctions and universal service funds must continuously be revisited so that they can truly benefit rural consumers. (Clark & Wallstern, 2002). Table 2 summarizes the final list of attributes (criteria and sub-criteria) with descriptions for the AHP model.

Table 2
List of criteria and sub-criteria for AHP model

Criteria	Sub-criteria	Description	Related Literature
Technical Aspect	Infrastructure	- The combination of technologies and systems to make efficient transmissions possible. - It contributes to the evaluation of backbone technologies.	Douligeris (1994); Gasmi (2005); Clark (2002)
	Coverage	- How the proposed system can cover wider rural areas. - End-users located within the area can have access to the internet.	Chemane et al. (2005)
	Reliability	- Unreliable service will not encourage the rural population. - The networks need safeguards and security against breakdown. - Provide consistent speed and service.	Chasia (1976); Malladi & Min (2005)
	Security	- Protecting telecommunications networks from vandalism/theft - The security of physical infrastructure refers to the protection of the equipment and cables installed.	Douligeris (1994); Chemane (2005); Malladi & Min (2005)
	Speed & Services (Bandwidth)	- Bandwidth is relevant for both voice and data communication. - Bandwidth is directly related to the effective performance of the link (speed & services)	ITU (1997); Malladi & Min (2005); Chemane et al. (2005)
	Maintenance	- In most rural areas the main supply of electricity does not exist which lags behind telecommunication development and maintenance (Low fault liability, no-site repair work, etc.). - The system must be capable of maintaining better services.	Hudson (1989); Chasia (1976)
Public Issues	Contents & Development (by government)	- Through ICT development, rural communities can get maximum benefits to improve their education, knowledge, health, agricultural skills, earnings, and living standard.	Sattar (2007); Herselman, (2003)
	Community of Interest	- Rural communities have a strong interest in their immediate geographical and administrative area. This needs to be considered when planning rural telecommunications networks.	Hudson (2006); Andrew et al. (2005)
	Government Support	- Modest (limited) support from the government will continue the creative use of the existing services and facilities to give new life to the rural communities.	SM Nazem (1996)
	Spectrum Licensing	- Service delivery was a concern with the license restriction on telecommunication companies. - In many countries spectrum is licensed through auctions and there is a high price to pay for some frequencies.	Andrew et al. (2005)
	Supporting Policies	- Most countries have an explicit policy goal of promoting universal access to certain infrastructure utilities including telecommunications, electricity, etc. at affordable prices.	Clark & Wallstern (2002)
Cost	Fixed Cost	- Investment required for deploying the access technology (purchase, deployment and central office, etc.)	Andrew et al. (2005); Chemane et al. (2005);
	Variable Cost	- Cost of maintenance, administration, training, and up-gradation, etc. (depends on the number of users)	Andrew et al. (2005); Chemane et al. (2005);
	Subsidy	- The government supports 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 poor people.	Clark & Wallstern (2002)

3. Access technologies and AHP model

3.1 Selection of access technology for rural areas of Pakistan

According to the latest telecom indicators (November 2019) from Pakistan Telecommunication Authority (PTA)'s website, the total number of broadband subscribers by technologies is 71 million. Currently, wired and wireless technologies are accessible as a backbone connection for Internet connectivity in remote areas of Pakistan. PTA’s (November 2019) updates further stated that total broadband penetration is 36.18%, of which 35.02% is mobile broadband penetration and 1.16% is fixed broadband penetration. In Pakistan, broadband technologies are DSL, EvDO (Enhanced Voice-Data Optimized), WiMax (Worldwide Interoperability for Microwave Access), HFC (Hybrid fiber-coaxial), FTTH (Fiber To The Home), mobile broadband, and 3G/4G/LTE (fixed). For this study, three relevant access technologies (DSL, fiber optic, and wireless) have been chosen as the decision alternatives. From PTA’s (November 2019) updates, Figure 2 shows annual broadband subscribers growth by technology in Pakistan.

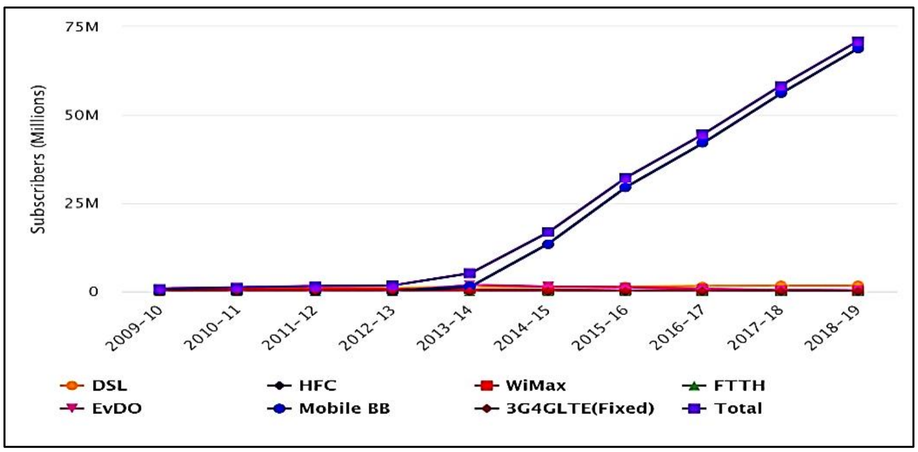

Figure 2 Annual broadband subscribers by technology in Pakistan (PTA, Nov 2019)

PTCL (Pakistan Telecommunication Corporation Limited) offers and delivers both EvDO and DSL technologies to the majority of broadband subscribers in the country with roughly a 65% market share in terms of subscribers (Umer & Harris, 2017). However, Figure 2 shows that the fixed broadband penetration in Pakistan remains very low over the past five years due to the dominance of the mobile platform. Table 3 briefly compares the advantages and disadvantages of the selected backbone Internet access technologies for rural Pakistan.

Table 3
Selected technology alternatives for Pakistan's rural areas

Technology		Advantages	Disadvantages
DSL	DSL (digital subscriber line) The way a computer connects to the Internet at high speeds using telephone lines.	Coverage	High cost
		Ease of deployment	Limited bandwidth
		Efficient	Latency
Fiber Optic	FTTH (Fiber To The Home) the installation and use of optical fiber from a central point.	High flexibility	Most difficult to deploy
		High reliability	Long rollout time
		High speed	High cost
Wireless	WiMAX, Mobile BB, and Ev-DO (Enhanced Voice-Data Optimized) wireless transmission of data through radio signals.	Low-cost equipment	Less bandwidth
		High reliability	Low reach/line of sight
		Fast deployment	Licensing constraints

3.2 Analytical Hierarchy Process (AHP) model

For this study, the multi-criteria (MCDM) approach plays an important role in the development of the AHP model for the selection of Internet access technology in rural areas. Saaty's (2008) Analytical Hierarchy Process (AHP) is a mathematical method that is widely used to solve multi-criteria decision problems. Ishizaka and Labib (2011) explained that the AHP methodology includes four steps to solve decision problems (1) constructing a hierarchy describing the problem, (2) constructing matrices for pair-wise comparisons between successive levels, (3) producing priorities, or relative weights, of the elements at each level of the hierarchy, by judgment scale of pair-wise comparisons, and (4) synthesizing the relative weights of the various levels obtained from the third step to produce an overall score of decision alternatives. A linear hierarchy of AHP methodology can be seen in Figure 3.

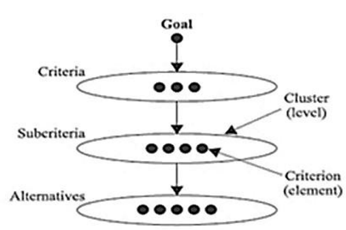

Figure 3 Linear hierarchy

A consistency ratio (CR) ≤ 0.1 (10%) indicates that there is sufficient consistency for the decision. Gasiea et al. (2010) stated that the hierarchical tree of the AHP methodology should be designed accordingly, and contain four levels descending from the general to the more specific. The AHP model of this study is shown in Figure 4, the top level-1 is the overall goal of the decision, which is the selection of an optimum backbone Internet

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access technology to provide quality Internet services to rural Pakistan, followed by the decision criteria, which affect the goal directly in level-2. The sub-criteria are in level-3, and the alternatives to be calculated are at the lowest level-4. Andrew et al. (2005) explained that the alternative with the maximum weighted value is to be treated as the preferred alternative.

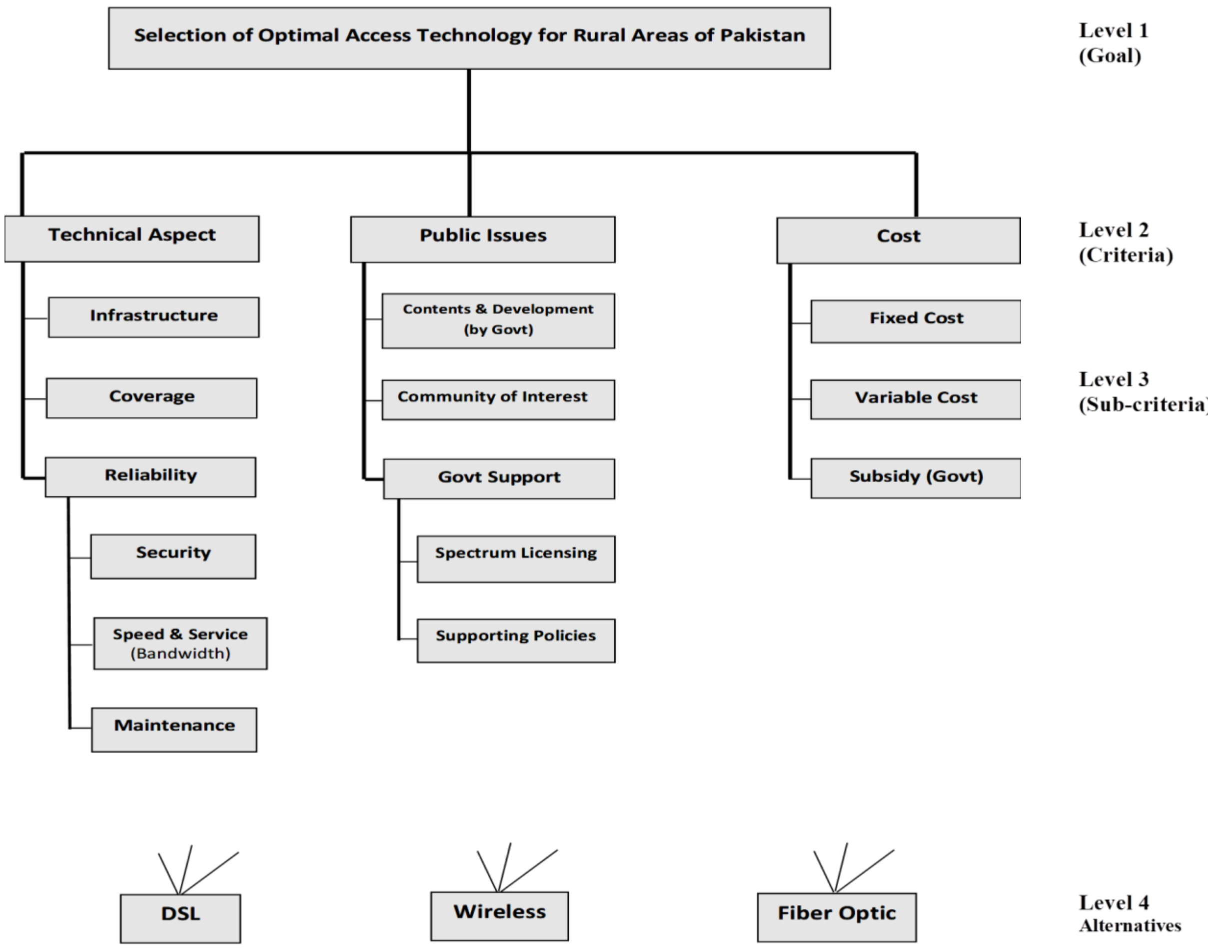

Figure 4 AHP model for the selection of optimal access technology

3.3 Analytical Hierarchy Process (AHP) survey and data collection

The same process that was used to select the attributes selection in section 2 was repeated, and the IT experts were contacted again. The AHP survey questionnaire was sent via email to various IT experts to collect the data and the respondents were from different sectors. The questionnaire was designed in three parts. The first part (Part-A) contained pair-wise comparisons for three main criteria and 14 sub-criteria. The second part (Part-B) contained the pair-wise comparisons of 12 attributes with three alternatives (DSL, fiber optic, and wireless). The last part (Part C) asked about the general demographics of the respondents. According to Saaty and Vargas (1994), the experts were asked how important criterion A is relative to criterion B, and then asked to assign a weight between 1 and 9 to represent their judgments: 1 = equal important, 3= moderately important, 5 = strongly important, 7 = very strongly important and 9 = extremely important. 2, 4, 6 and 8 are intermediate values (when compromise is needed). An example of the technical aspects and public issues attributes can be seen in Figure 5.

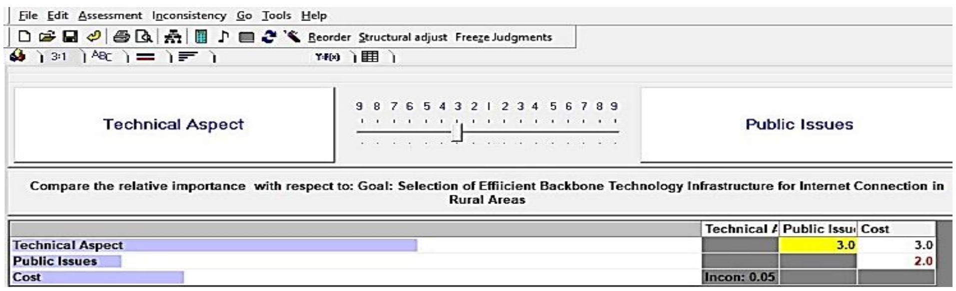

Figure 5 Example of comparison of technical aspects and public issues attributes

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

The pair-wise comparison matrices were constructed from the hierarchy, which describes each criterion and sub-criteria in the hierarchical tree of this study in order to assist the respondent's understanding of the meaning of each factor comparison.

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

Every sub-criteria and alternative that are involved in the hierarchical tree of this study were described to ensure that the respondents understood the meaning of each factor comparison, the meaning of the alternatives, different criteria, and their levels before answering the pair-wise comparison questions.

Part C: Demographics and general information

The last part of the survey questionnaire was about the demographic and professional information of respondents.

3.4 Data collection

After the AHP hierarchical structure was built, the next phase was to perform the pair-wise comparison which is one of the major strengths of the AHP. We collected survey data from 43 respondents. Out of the 43 respondents, five were invalid due to incomplete answers or an inconsistency rate that was too high. These five samples were discarded. Finally, 38 responses were deemed eligible for analysis. The respondents were IT experts from different academia and telecom sectors, and they were government employees, private employees, and semi-government employees. The dataset was restricted to IT experts who had advanced experience and higher qualifications.

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4. Results and analysis

This section gives an in-depth description about how this study followed the Analytical Hierarchy Process (AHP) procedure to obtain comprehensive results. The last step of the AHP synthesizes the results to find a solution regarding the selection of an optimal Internet access technology for rural Pakistan. The collected results were then entered in a reciprocal matrix in order to form the corresponding pair-wise comparison judgment matrices. Furthermore, based on the suggestion of Saaty (2001) and Saaty and Vargas (2007) all of the judgments obtained from individual IT experts were aggregated into a representative group judgment by calculating the geometric mean for each pairwise question. The aggregated group judgments were then arranged in corresponding consensus pairwise judgment matrices and finally entered into Expert Choice 2000 to perform the necessary computations and synthesize the results.

The AHP hierarchy reveals the relationship among attributes of one level with the attributes of the level directly below (Saaty, 2008). The AHP uses the priorities score achieved from the comparison to weight the priorities in the level and continues this process for every element from the goal level down to the alternative level. The connecting lines of the goal to every criterion mean that the criteria should be pair-wise compared for their significance with reference to the goal. Likewise, the connecting lines of every criterion to the sub-criteria mean the following are pair-wise compared for their significance with reference to the criterion itself. Lastly, the connecting lines of each sub-criterion to the alternative mean the alternative technologies are pair-wise compared to determine which is significant for that criterion. This pair-wise comparison is utilized to determine the relative significance of the elements that are involved. Subsequently, the AHP derives local priorities directly from pair-wise comparisons of the sub-criteria with respect to the criteria, whereas global priorities are derived from the multiplication of the local priority weight of criteria and sub-criteria priorities. Once the global priorities of all of the sub-criteria were acquired, they were multiplied by the local priority of each alternative with respect to each sub-criterion to obtain the evaluation score (weight) of each alternative. Lastly, in the grand total row an overall score (weight) for each alternative was achieved by summing each evaluation score (weight) in the columns as shown in Table 4. According to the judgments of all (38) of the participants, the global and local priorities of the alternatives with respect to the criteria and sub-criteria are shown in Table 4.

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Table 4
Composite preferences for the criteria & sub-criteria, IR = 0.01

Goal: Selection of optimal Internet access technology for rural areas of Pakistan						
Criteria	**Sub-criteria**	**Sub-criteria**	**Alternatives**			**Global Priorities**
			DSL	**Fiber Optic**	**Wireless**	
Technical Aspect (L: 0.370 G: 0.370)	Coverage (L: 0.506 G: 0.187)		0.051	0.02	0.116	0.187
	Infrastructure (L: 0.129 G: 0.047)		0.013	0.01	0.024	0.047
	Reliability (L: 0.365 G: 0.135)	Bandwidth (L: 0.64 G: 0.09)	0.025	0.021	0.04	0.086
		Maintenance (L: 0.223 G: 0.03)	0.013	0.004	0.013	0.03
		Security (L: 0.140 G: 0.02)	0.009	0.008	0.003	0.02
			0.111	**0.063**	**0.196**	**0.370**
Public Issues (L: .240 G: .240)	Community of Interest (L: 0.142 G: 0.034)		0.013	0.005	0.017	0.035
	Contents & Development (L: 0.283 G: 0.068)		0.021	0.012	0.035	0.068
	Govt. Support (L: 0.574 G: 0.138)	Spectrum Licensing (L: 0.48 G: 0.07)	0.017	0.01	0.039	0.066
		Support Policies (L: 0.52 G: 0.07)	0.025	0.011	0.036	0.072
			0.076	**0.038**	**0.127**	**0.241**
Cost (L: .390 G: .390)	Fixed Cost (L: 0.277 G: 0.108)		0.049	0.026	0.033	0.108
	Subsidy (Govt) (L: 0.459 G: 0.18)		0.056	0.036	0.086	0.178
	Variable Cost (L: 0.264 G: 0.103)		0.034	0.017	0.052	0.103
			0.139	**0.079**	**0.171**	**0.389**
Grand Total			**0.326**	**0.180**	**0.494**	**1**

Furthermore, a sensitivity analysis was conducted to show the robustness of the obtained results. According to the sensitivity analysis of the ranking produced by this AHP model, wireless technology with the highest priority score of *0.494 (49%)* is the most preferred alternative. DSL is next with a priority of *0.326 (33%)*, and then fiber optic technology with *0.180 (18%)*. The sum of the priorities in the grand total row is *one (100%)*. This complies with the AHP procedure and demonstrates that all of the steps of the AHP were applied properly. To verify the consistency of the experts' judgments comparison, Saaty (1980) suggested the adoption of a consistency ratio (CR) to measure how the judgments have been relative to large samples of purely random judgments. In our study, the overall inconsistency ratio (IR) is 0.01 by the AHP for the three access technologies for rural areas in Pakistan, and the consistency ratio (CR) ≤ 0.1 indicates that the AHP properly performed all of the steps to achieve the goal – an acceptable decision.

Moreover, Table 4 shows that the comparison of the criteria with respect to the goal yields that the cost criterion has the highest priority of 39% (G, L= 0.390), which indicates it is more important in comparison to the other criteria, technical aspects and public issues with 37% (G, L= 0.370) and 24 % (G, L= 0.240), respectively. Furthermore, the sub-criteria are arranged for ranking in descending order according to their relative importance of the global priorities; it is often good to disclose which of them is the most favored. For example, under the global priorities column (Table 4), the most important attribute is 'coverage' with a priority of 18.70% followed by 'subsidy' with 17.80% and 'fixed cost' with 10.80 %. The least important sub-criteria with priorities of less than 5.0% are 'infrastructure', 'community of interest', 'maintenance' and 'security' with 4.70%, 3.50%, 3.0%, and 2.0%, respectively. In the AHP, a hierarchy considers the distribution of a goal between the attribute being compared and judges which attribute has a higher influence on that goal. The overall ranking showed that some attributes have low priority weights. However, these low priorities do not mean that these decision-making standards are not important in the deployment of a telecommunication infrastructure for the rural areas of Pakistan.

The above analysis demonstrates that the AHP is capable of structuring the problem and giving a systematic method for decision making. The AHP provides decision-makers the opportunity to visualize the weaknesses and the strengths of each technology alternative by comparing their scores against each factor. The obtained weights give information about the alternatives and the way they are used to satisfy the selected attributes. In this regard, a result where one can affirm which alternative technology is more preferable from the IT experts' point of view is made.

5. Conclusion

The issues surrounding Internet access technology selection for rural areas are not only technological, but a complex system of other interrelated factors that cut across various aspects of rural areas and their inhabitants. In Pakistan, there is no clear telecom policy for the connectivity of rural areas to date. There are several key factors to be considered that have a big impact on the selection process, related to social, environmental, infrastructure and maintenance concerns. Based on the information and knowledge obtained from 38 IT experts (from different sectors), this study discussed how to achieve

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the goal and how to promote Internet services to the 61% of the population who live in rural Pakistan.

For the selection of an optimal Internet access technology, a MCDM (multi-criteria decision-making) approach played an important role in the development of the AHP (Analytical Hierarchy Process) model. The AHP hierarchy was structured based on the attributes from previous literature and other identified related attributes. Moreover, in Pakistan, there are different wired and wireless access technologies available that deliver the connectivity of the Internet. This study showed that DSL dominates the fixed broadband market, but its market share has been falling over the past five years due to the dominance of the mobile platform. From the total weights of the overall results, wireless access technology was the most preferred alternative and has the highest score in the AHP model for the rural areas of Pakistan.

There are some important limitations that have been identified by this study. In Pakistan's rural areas, Internet services cost and coverage are the most important factors. The inhabitants of Pakistan's rural communities prefer to use Internet services with a more suitable bandwidth, affordable prices, and specifically in their own local language. Currently, rural Pakistan has access to telephone and Internet services, but they 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 coverage area is insufficient; hence, there is a need to improve coverage and reliability. Additionally, governments should cooperate with the private sector to promote Internet penetration, especially for remote and unserved areas. Another limitation is the lack of skilled people in rural Pakistan. The government of Pakistan and Internet service providers should train and educate rural inhabitants about sustainability and maintenance. The respondent's gave a low priority weight in the overall ranking list of the decision-making standard to security. However, rural areas of Pakistan need to increase security in response to an increased level of theft of copper wires, other Internet deployment equipment and damage to property. These low priorities do not mean that these decision-making standards are not important in the Internet deployment for rural areas. Lastly, data were obtained from a small number of participants in the survey, which limits the scope and coverage of the goal. If responses were obtained from a larger number of participants, then there would be a greater chance of selecting a suitable access technology. This larger sample size should involve participants from many different organizations who are aware of the problems of Pakistan's rural areas.

From this study, many prospective areas for further research can be acknowledged. In rural Pakistan, there is a big issue with power supply, and therefore a possible research initiative could be to study the distribution of the electricity supply to rural communities. The second most important concern for rural communities is the need for education and training about the sustainable use, installation, maintenance, and protection of the telecommunications infrastructure.

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