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Integrative Model for Quantitative Evaluation of Selection Telecommunication Tower Site

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Abstract

This paper analyzes the weight of impact factors on selection the antenna places for mobile telecommunication system in Jordan. The new technique plays a lead role in divided area and selects the place of antennas' sites. The main objective of this research is to minimize the antenna numbers in order to reduce the cost. Research follows flowcharting categories and stages as: The first stage aim to classify the effective factors on the: signal radius, better position of antenna from candidate points, reserved area, and non-preferring position. The second stage focuses on finding the effective weight of these factors on the decision. The third stage suggest the new proposed approach by implement the MCLP and P-center problems in linear function. The last stage has the pseudo code for the proposed approach, where the proposed approach provides the solution that helps the planners in telecommunication industry and in related government agencies make informed position of the antennas.

Keywords: *wireless telecommunication, tower site, antenna, covering area*

1. Introduction

Nowadays, wireless telecommunications systems represent the core of communication among network nods that are used by individuals organizations [1]. For that, telecommunication companies compete to offer the better efficient services through covering most of the service area [2]. The wireless telecommunication tower represents a bridge between two-way communication systems [1] which is built in a selected geographic point. As we note, the distribution of sites of telecommunication towers is one of the Maximum Coverage Location Problems (MCLP) which aims at: Maximizing the coverage area, minimizing the uncovered area, as well as minimizing the used facilities [3]. To achieve the goals, many factors are mixed to select the point [4] taking into consideration that a wrong selection may cause problems either on the long or short term. Consequently, this poses budget challenges as it represents the highest capital expenditure [2].

The complexity of such decision comes from the multidimensional, multi resources and types of data [2]. Therefore, finding the balance point between reduced expenses and the provision of better services under some constraints in planning stage point [4] cause a huge pressure to the decision maker. In such cases, the methodology, model, and technique are required to solve problem. Many of the solutions proposed in published works of scholars combine effective factors and data in one container with specific process.

The process and factors are represented in one of the selection models which we can classify into a mathematical model or Maximal Covering Location Problem (MCLP) model and p-median model. These models are selected and used by engineers of the telecommunication companies to improve the outcome depending on problem type, and proved to be mostly successful. This paper suggested a linear function that depends on the weight of each collected and classified factor [5]. The factor weight comes from the distributed survey to experts in three main telecommunications companies in Jordan; namely, Orang, Zain, and Umniah. The rest of this paper will be classified as follows; section 2 has the background of selection telecommunication Tower Site, effective factors, models and techniques used in covering area.

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2. Lliterature Rreview
2.1. An overview of selection tower site
Telecommunication systems represent the core of communication among people and organizations. For that, telecommunication companies compete to offer the better efficient services through covering most the targeted area for their services [6]. Currently, telecommunication companies prefer to provide most services through wireless communication that require building a tower in each sub area. The telecommunication tower represents a bridge between two-way communication systems: users and the communication center point using radio frequency propagation that is charged by data between the two points [7]. Building towers represents one of the budget challenges. Therefore, companies must find the best balance point through maintaining less expenses with the provision of good services under some constraints such as minimizing the number of antenna in order to reduce the cost to avoid financial challenges [4],[8].

2.2. Effective factors
Referring to [5], the effective factors of selecting telecommunication towers sites are classified into one of four categories (the technology factors, the geographical and demographical factors, the regulation and policy factors , the data and experiences factors).

2.3. Models for maximum covering area of networking
The telecommunication tower site problem is one of the coverage problems [9]. Many models, techniques, and computer systems are proposed to solve the covering area problem and reach a maximum coverage area with minimum facilities. Research on site selection defines two categories for solution techniques of location problems: p-median problems to find the best location of facilities P among demanded covering problems [10]. Location problems are generally solved using one of three basic spaces: continuous spaces (spatial), discrete spaces, and network spaces [11]. The goal of these models and their derived models is to seek the locations of facilities on the demand area to serve the maximum number of customers with a fixed number of facilities or to determine how to maximize covering with the lowest number of resources [12].

Maximal Covering Location Problem (MCLP) was proposed in [10] to developed the Greedy Adding and the Greedy Adding with Substitution algorithms as heuristic procedures to solve the problem. In addition, p-center problem (PCP) to seek the location of p facilities in the demand area [13]. In addition, Location Set Covering Problem (LSCP), [14]. Maximum Survival Location Problem (MSLP), [15], Double Standard Model (DSM) [16], Maximum Expected Covering Location Problem (MEXCLP) [17], Maximum Availability Location Problem (MALP) model [18], hypercube queuing model [19], dynamic allocation models [20], gradual covering models, and cooperative covering models [21].

To solve large problems, the researchers in [22] suggested a new solution using a cluster relaxation technique for large-scale problems. With complexity of the selection tower site problem and growth of the information technologies, computer systems have become a more powerful tool to improve the quality of solutions, such as simulation techniques: TIMEXCLP approach [23], BARTSIM, and CPLEX 10.0, genetic algorithm (GA) [24], Automatic Vehicle Location (AVL) [25], smart antenna (SA) [26]. In addition, GIS is used to determin and analyze the data to find the best place for facilities, as per these studies: [27] built a geo-referenced model using GIS for determining location, to enhance the public health care programs [28]. Suggested creating an optimization model using genetic algorithm to build an expert system for cereals land suitability evaluation based on soft computing [29].

The system has the ability to improve itself when real input data are available presented a solution of MCLP using modeling to formulate a fuzzy goal programming [3]. suggested a new system named SHERLOCK for solving Location-Based Services (LBSs) problems using heterogeneous knowledge source that comes from different resources and different shapes [30]. Genetic algorithm was used by Arakaki and Lorena to solve real problems [12]. Proposed a deterministic approach to the synthesis of linear arrays having the least possible number of elements while radiating shaped beams lying in completely arbitrary power masks [31]. There approach takes joint advantage from compressive sensing, from the multiplicity of power patterns lying in a given mask, and from the multiplicity of field solutions corresponding to each of these power patterns.

2.4 An overview of telecommunication industry in Jordan

Jordan is one of the developing countries located in the Middle East/ western Asia. The area of Jordan is 89‹287 Km2 with a population of around 9 million citizens, distributed over 12 governorates, each of which has various towns and villages. Most of urban areas are located in the capital, the northern regions of the country, the middle region, Jordan valley, with less population in the southern regions. Jordan's topography is distinguished by mountainous areas, deep valley's, plains and is bordered by four countries. All this poses a real challenge to the telecommunications system (Department of statistics/Jordan, 2016).

Three main players in telecommunication technology have licenses to provide the telecomm nation services in Jordan (Orange, Zain, Umniah) (Telecommunications Regulatory Commission report, 2016). Zain-Jordan published in its annually report 2015 that it reached the peak to provide 4G service to its customers spending about 52 million dollars to establish. To cover most areas of Jordan and to serve the population everywhere, Zain's network has 2,672 sites/ towers (Zain-Jordan, 2016). Orange (Jordan Telecom Group) market share of mobile services ranges between 30-35'% in 2015 (orange-Jordan report, 2015). It covers most Jordan through over 1700 sites. Umniah was established in 2005 and was granted the third GSM license. Its market share has increased eversince, and its services have expanded to cover most areas in Jordan (Umniah , 2015).

3. Methodology

In order to achieve the objectives of the research which tackles one of the problems in real life, with the aim of enhancing applied theories in management and the use of logical methodology and systematic methods to collect data and to solve problems. Hence, this research utilizes a mix of qualitative and quantitative methods to extract and validate knowledge. The used methodology consists of a number of steps which include problem identification and definition, proposing the approach to address the research problem, carrying out a user study to capture data needed to implement the approach.

Step 1: In qualitative research, selecting individuals and groups of experts was made through interviews using Delphi technique and participant-observation to classify the factors into groups and finding the Constance values that effect on radius of signal and the used procedures to solve such a problem depend on [5]. The interviews will be conducted with senior levels of experts (mangers and co-managers) at three departments of the companies: Network department, planning department, and GIS department. The interviews contain two separate sheet answers one for reviewing and ranking the factors and the second for procedures and some related data.

Step 2: Employ the findings by [5] to classify and to figure out the weight of each effective factor for the selection telecommunication tower site. The survey distributed to all the field's employees invited them to participate in the experiments using Likert-type scale with five categories (1-5) as digit (1) signifies the very weak and the digit (5) signifies the very strong. The goal of the survey is to identify the effective factors and their weights in our case study (Jordan).

Step 3: the results of this survey will be utilized as input data to Rising Statistical distribution technique to find the weight of effect of each of the factors.

Step 4: applying a mathematical functions that have ability to represent the relation between the factors group to find the better place for telecommunication tower, such as minimum distance (r_{min}), wave length, antenna coverage area and signal radius shrink. All these math relation will be tackled in section 4.

Step 5: express the finding in step 4 by pseudo code.

4. Findings and results

The service providers' goal is to find the best balance point between offering better services and a lower cost to cover most of the demand area to acquire the highest gain. As we said, the towers represent one of the main company's costs; thus, they must be cautiously selected. Through interviews, the experts classified the factors into four groups: reserved area, constant values, non-preferring area, radius of antenna signal, and site properties.

Table 1 has the reason of reserved area under regulations and policies. Table 2 has the constant values factors which they affect directly on the radius of antenna signal. In detail, the maximum radius of signal antenna cover in free space without barriers and in square angle depends on equation 1, where the Telecommunications Regulatory Commission grants broadcast ranges licenses to the companies to organize the signals between national and international telecommunication companies and to prevent interaction with other broadcasting signals or magnetic fields then, the company selects the range frequency for each service.

Table 1. reserved area under regulations and policies

Protected area	Protect under Laws	Military zone Archeological area Environmental area Wild life areas Health services area Airports area Public area Airplanes routes
	Protect under GOV. Policy	not causes environment damage Monitoring safety gives legislative authority and use the land agree with Gov. Strategic plan
	Company constructions	Visible to the main station Agree for rent by the landlord

Table 2. Constant Values

Less Slope could cover by signal
Population users' number per antenna
probability of users increasing
Type of users
Frequency range
Wavelength
Sight distance and antenna angle
Intersection between cells
Frequency-dispersive wireless channel

$$r_{min} = 2\, d^2 / \lambda \quad (1)$$

Where r_{min} is the minimum distance from the antenna, d is the largest dimension of the antenna, and λ is the wavelength. The wavelength $\lambda = c/f$, where c is the speed of light and f is the frequency. On the other hand, the antenna has specific capacity of call which the number of users and probability of increasing them have directly affect to shrink the signal radius as shown in equation 2 which antenna capacity depends on the used technology type. Moreover, in real life the received signal is affected by some barriers where the radius of signal is shrinking, Table 3 has those factors with the weight for each of them. Moreover, the firm policy determines the percentage of intersection between cells to provide better services. As a result, the radius of antenna signal to cover area depends on technology, the predicted number of users, the effect of barriers and the firm policy. The number of customers, as we said, has directly affected on the radius of antenna coverage area which the equation 2 represent the relation.

$$X = \text{Number of customer} / \text{antenna capacity} \quad (2)$$

If X>=1 then the radius is shrinking otherwise the antenna could cover area under constraints. In addition, the slop areas represent the special case for coverage area which it must be coverage as it. Otherwise, the radius antenna coverage area used the equation 1. Some barriers may cause the bad signal that the Table 3 represents these factors and the weight of their effective. To calculate the effective of those factors to shrink the signal radius we applied the factors weight in equation 3

$$F = n - \sum_{i=1}^{n} ki \quad (3)$$

Where n present the factor number, and k present the summation of weight factors. In suggested method, the experts prefer to start from a most complex area where the radius of antenna signal is smallest. Now the radius will be shrinking of percentage of F on r max. Where R min =r max-(r max*g).

Table 3. Coverage Area Factors

Tow er elevation	1
Frequency range	0.9936
Population users' number	0.9888
intersection betw een cells	0.9868
Wavelength	0.9852
Sight distance and antenna angle	0.985
Antenna Type	0.916
Steep terrain	0.9042
Mountainous areas,	0.8824
Slope	0.871
Wind loading	0.8598
Type of users	0.7986
Barriers buildings	0.7774
Probability of users increasing	0.7286
Ability to penetrate most surfaces	0.7032
Forestry	0.6948
Interact w ith electrical pow er	0.6748
Lightning and electromagnetic radiations	0.6636
Barriers of tree,	0.5946
Raining	0.5836
Interact w ith other signal	0.4882
Traffic	0.4836
Foliage movements	0.4236
Birds movement,	0.4162

Referring to P-center problem technique, we should find the best point around the center of each cell to select as antenna place. Therefore, the engineers prefer to find the highest point P in the center of each of the cells to select the candidate site for each cell, and they have a margin of flexibility for the intersection of cells for company policy. But in reality, some barriers may be faced to select the P such as reserved area as reasons appear in Table 4 or non-preferred area under geographical obstacles as classified in Table 5. Mostly, more than one points may appear by scan each cell, therefore, to find the effect of factors on each candidate points of cell we applied the equation 4.

$$WP= \sum_{i=1}^{n} 1 - wi \quad (4)$$

Where 1: represents the candidate point without any barriers. W: represents the barriers weight depending on Table 2. Then, by comparing the result, the highest value is the best point for site. The following pseudo code for dividing the area into cells and selection the best site.

```
Scan /* to find slop /*
Insert to slop file,
Scan /* to find distributed of population using arc-GIS/*
Insert to population file,
Loop,
Find the most complex area /* start from slop area with highest population/*
Calculate the number of antenna needed,
Insert to antenna needed,
End loop;
Loop
Scan /* to find candidate points/*
Insert to candidate points file,
Apply equ 4,
Insert to antenna site,
End loop
```

Table 4. Effective Factors on selection points

Area type	Soil type	0.9176
	Soil erosion, quality of the land	0.902
	Soil moisture	0.2344
	Seismic Loading	0.6242
	Forestry	0.6948
	Wind speed load	0.8598
	ice load	0.6016
	Coastal area	0.5946
	Raining area	0.5822
	Non ability to access site	0.9658
	Lightning and electromagnetic radiations	0.8828
	Drainage area	0.8282
	Bad climate characteristic	0.787
	Electronic power availability	0.7562
Signal Barriers	Interact with other signal	0.3938
	Height of the buildings	0.8952
	Traffic	0.4836
	Birds movement	0.4162
	Foliage movements	0.4236
	Interact with electrical power	0.643
	Tree Barriers	0.5946
Installation Requirements	Visibility to main site	0.9852
	Vehicles availability	0.8178
	Cranes availability	0.7320
	Electronic power motor availability	0.4348
Management Requirements	Site rent price	0.7552
	Management pressure	0.3878
	HR Experience availability	0.8006

Table 5. Non Preferred under Geographical Obstacles

Complex steep terrain	0.9588
Non ability to access site	0.9658
Soil type	0.9176
Soil erosion, quality of the land	0.902
Lightning and electromagnetic radiations	0.8828
Drainage area	0.8282
Climate characteristic	0.787
Ice load	0.6016
Coastal area	0.5946
Seismic Loading	0.6242
Soil moisture	0.2344
Wind speed load	0.6098
Raining area ,	0.5822

5. Conclusion

This research paper reports on the applicability of using qualitative and quantitative approaches to enhance the selection process of a telecommunication tower site, defining a reserved area under regulations and policies, taken in account a constant values and coverage area factors, Table 3 as a sorted values, tower elevation with highest value and bridge movement with lowest, applying selection techniques to find the best points within effective factors, where the results shown in Table 4, Table 5 shows a non preferred under geographical obstacles.

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