HYBRID MODEL FOR MAKING DECISION METHODS IN WIRELESS SENSOR NETWORKS THROUGH NEURO-FUZZY INFERENCE SYSTEM

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Dedication

To my Husband and Family in Colombia. Thanks for loving and supporting me during this long trip.

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by

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Abstract

Considering the complexity and multiple alternatives for technology decisions in Wireless Sensor Networks (WSNs), a multicriteria selection method (MCDM) is an appropriate approach for choosing the best option in technical projects. Purely quantitative decision-making procedures have currently been created based on client requirements and recommendations from industry professionals in many domains. In this context, implementation and operational costs could be increasing due to technical problems and additional processes. In order to prevent future difficulties and obtain a more accurate technology selection, a new method was being developed to involve qualitative and quantitative parameters taken from real scenarios and technical literature review and optimized with a Neuro-Fuzzy Inference Systems using Mamdani Approach (NFIS) design. This dissertation provides a detailed description of the Multicriteria Decision methods as AHP, ANP, Vikor, and others. In addition, the process to generate data for NFIS systems, and the Hybrid methodology designed, including the economic analysis, are explained.

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Chapter 1: Introduction

1.1 Problem Definition

The demand of wireless sensor network (WSN) technology is expanding across all industries due to new services and applications for the operational requirements into the companies. For example, temperature, humidity, and presence readings have been requesting for oil and gas, health, food, and geology sectors. Several types of technologies could be applied for taking the measurements, but some factors need to be evaluated for selecting the appropriate technology, such as location, infrastructure, economic, technical, regulatory, and social aspects[1]. Table 1. Describes the parameters involved in each criterion for the evaluation.

Table 1. Criteria for Technology Evaluation[2], [3]

Factors	**Parameters involved**
Environmental/Geographical aspects	Type of location (plain, mountainous), Geometric form of the locality, weather parameters, Variety of flora and fauna
Technical	Channel capacity, reliability, percentage of packet lost, flexibility, scalability, bandwidth, data rate, type of data.
Infrastructure	Presence of electricity, buildings, cellular and microwave reception.
Social	Solvency and social structure of communities, size of population
Regulatory	Rights of way, licensing, spectrum availability
Economic	Investment, operational costs, ROI (return of investment)

Decision models, called Multicriteria Decision Making methods (MCDM), have been used to obtain the best technical solution for different applications based on theoretical parameters, technical standards, and expert opinions becoming the solution in a pure qualitative decision. Some

MCDM adopted for wireless sensor networks decision process are AHP [4], ANP[5], Vikor [6], parametric model [3], and others will be explained in detailed on chapter 2.

Therefore, some problems could be raised in the implementation and operation process such as high costs or low communication quality because real scenarios and parameters are not taking under consideration during the decision process. To avoid this situation, an exhaustive quantitative and risk study is needed to obtain the best result in the technology selection guaranteeing high quality and performance for different applications.

1.2 Research Question

Due to the lack of a quantitative study because there is not a simulation method for real cases where input parameters are combined to generate an exhaustive analysis of the technology factors, the question for this project is: Can a multi-criteria decision model provide an effective and reliable solution about the technology to be used in a given application, including real and specific parameters corresponding to technical, economic, social, regulatory, environmental factors, and risk evaluation?

1.3 Proposed Work

In this research, we are proposing a novel multicriteria decision method to provide an effective and reliable solution about the technology to be used in a given application, including real and specific parameters corresponding to technical, economic, social, regulatory, and environmental aspects and risk evaluation is designed, simulated and compared with AHP methodology.

The new methodology, called Hybrid Decision Model for Selecting Wireless Sensor Networks Technologies, is divided in two sections according to Figure 1. On the first stage, customer requirements are collected, and real scenario is simulated via Netsim® (Network simulator) to

generate data for stage 2. Also, an Analytic Hierarchy Process (AHP) model is executed to make the comparison between the two models. For the second stage, a Neuro-Fuzzy inference system based on Mamdani approach is developed to optimize the Multicriteria decision method proposed. Data generated in stage 1 is used to train the inference system and economic and environmental risk analysis is running to obtain the final result using decision trees.

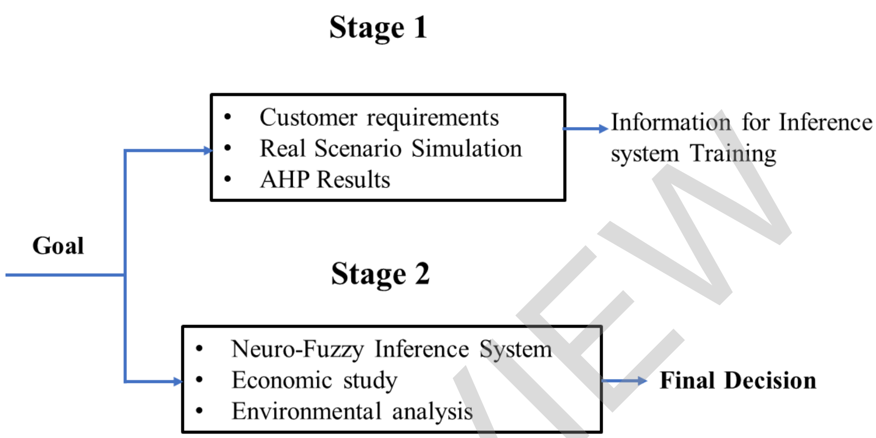


Figure 1. Methodology Hybrid Decision Model for selecting Wireless Sensor Networks Technologies

The dissertation is organized as follows:

Chapter 2 introduces the concept of Multicriteria decision methods. This is followed by the description of present decision methods used on wireless sensor networks and wireless communications, AHP, ANP, Vikor, Parametric model, Hub structure model and Business Canvas model for decision process. Chapter 3 describes the stage 1 of the model, includes the characterization of scenarios, parametric model features and results from the NetSim simulations.

Chapter 4 explains the stage 2 of the multicriteria decision model, Neuro-Fuzzy inference system with Mandami approach, economic decision tree and risk evaluation. Chapter 5 analyses

the scenarios results for stage 2 and the comparison with AHP. Chapter 6 includes the conclusions related to the results and future work.

Chapter 2. Literature Review: Multicriteria Decision Methods and WSN

2.1 Multicriteria Decision Methods

Multiple criteria decision making (MCDM) refers to all methods for helping people or processes to make decisions in the presence of multiple conflicting factors. Decision problems are frequently in real life and different contexts [7]. For example, to buy a house involves different parameters such as price, location, neighborhood, years of built, materials, and others. A young woman can choose her life partner based on intelligence, studies, money, looks, etc. Those situations are classified in personal or familiar context. For business situations, A human resource person can characterize the employees by studies, years of experience, salaries, area of experience, etc. In academic situations, the annual budget can be assigned to each department according to number of enrolled undergraduate/graduate students, number of faculty and staff, research projects and others. For our specific case, we are using the MCDM methodology to obtain the appropriate technology in wireless sensor network according to the application and customer requirements. Some multicriteria methods used for selecting wireless sensor networks technologies will be explained in the next section. Those methods are Analytic Hierarchy Processes (AHP), Analytic Network Process (ANP), Vikor, Parametric Model and Business canvas model addressed for technology selection.

2.1.1 Classification of MCDM Models

The literature review indicates that considerable studies have been conducted by academics in the telecommunication fields to create the optimum communication selection model for every scenario where parameterized and organized criteria such as geographic, technical, and

socioeconomic elements are taken under consideration. These models can be classified as comparison models and weighted models [1].

2.2.1.1 Weighted Models

Figure 2 illustrates a basic procedure for weighted strategies. The first step is to establish the objective in accordance with customer specifications. Then, based on the expert opinions and theoretical concepts, evaluation elements are established and examined. In the third step, numerical weights are given to each parameter depending on the evaluation of the client's benefits, and a mathematical model is employed to determine the final decision. The Analytic Hierarchy Process (AHP), the Analytic Network Process (ANP), the Parametric Model, and the Vikor Process are weighted model types, [8] , [9].

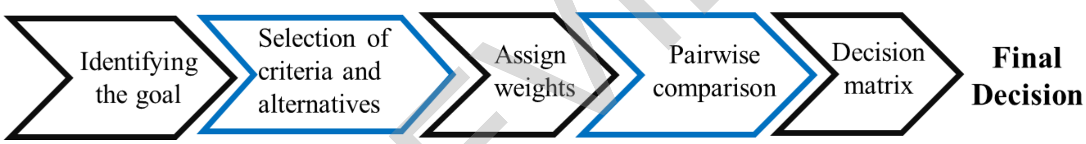


Figure 2. Basic Process for Weighted Methods

2.2.1.1.1 Analytic Hierarchy Process (AHP)

The objective of the AHP, developed by Saaty in 1980 [4], is to build a hierarchy process in which a collection of assessment parameters and alternatives are considered. Figure 3 shows the process. The first step is to clearly define the goal according to the requirements of the study. The second level is selecting the criterion parameters to satisfy the goal demands [10], and the third level involves the determination of the possible alternative results based on the criteria in level 2.

The processing level is the sub-level between the second and third level. In this sub-level,

the result of the evaluation of criteria is a weight in accordance with the "Saaty decision score table" presented in [9],[10].

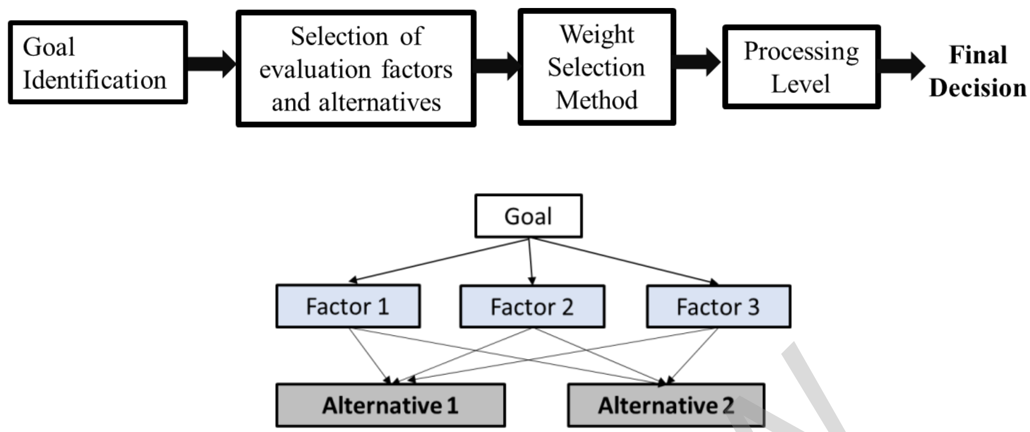


Figure 3. Analytic Hierarchy Process (AHP) [1]

The processing level is the sub-level between the second and third level. In this sub-level, the result of the evaluation of criteria is a weight in accordance with the "Saaty decision score table" presented in [9],[10]. This level involves two steps. The comparison between two evaluation parameters and alternatives to generate the dominance coefficient result (a_{ij}) and a square matrix n x n (pairwise comparisons) refer to the first step [11]. This is an estimate of the first element's ((*i*) predominance over the second element (*j*). Table 2. is used to choose the coefficients (a_{ij}). In the second step of processing level, all the dominance coefficients and matrices from level 1 are synthesized, and the final decision is taken according to the higher weight. In conclusion, the optimal choice is the one that accomplishes the best value between several criteria [4].

AHP is frequently used in many industries such as communications, transportation, administration, and medical to make difficult decisions. For example, in Hong Kong, for vendor selection of telecommunication system, in Nigerian Mobile Telecommunication for subscriber

retention, in addressing consumers' preferences in Telecommunication Operators in Bangladesh, and so on [9], [12], [13].

Table 2. Saaty Decision Score table [4]

Scale	Numerical Rating	Reciprocal
Equal importance	1	1
Equal to moderate importance	2	1/2
Moderate importance	3	1/3
Moderate to strong importance	4	1/4
Strong importance	5	1/5
Strong to very strong importance	6	1/6
Very strong importance	7	1/7
Very strong importance to the extreme importance	8	1/8
Extreme importance	9	1/9

2.2.1.1.2 Analytic Network Process (ANP)

The analytic network process (ANP) is defined in [5] as an extension of the AHP approach in which networks are used instead of hierarchies to show the parameters dependence and the interaction between the alternatives and criteria. The ANP model consist of two parts. In the first part, factors are identified and grouped into the clusters with similar characteristics' parameters groups or clusters. The second part consists on the feedback of the clusters' influence concerning to each other. Also, the presence of feedback, as seen in Figure 4, denotes the reciprocal outer dependency of the criteria in two distinct groups. Similar to the AHP, the ANP process is built on the expertise and experience of specialists, reasoning, and soliciting management inputs in order to get organized communication and structure, while also considering qualitative decision considerations [14]. In addition, the ANP methodology is analogous to AHP, Figure 5 shows the process.

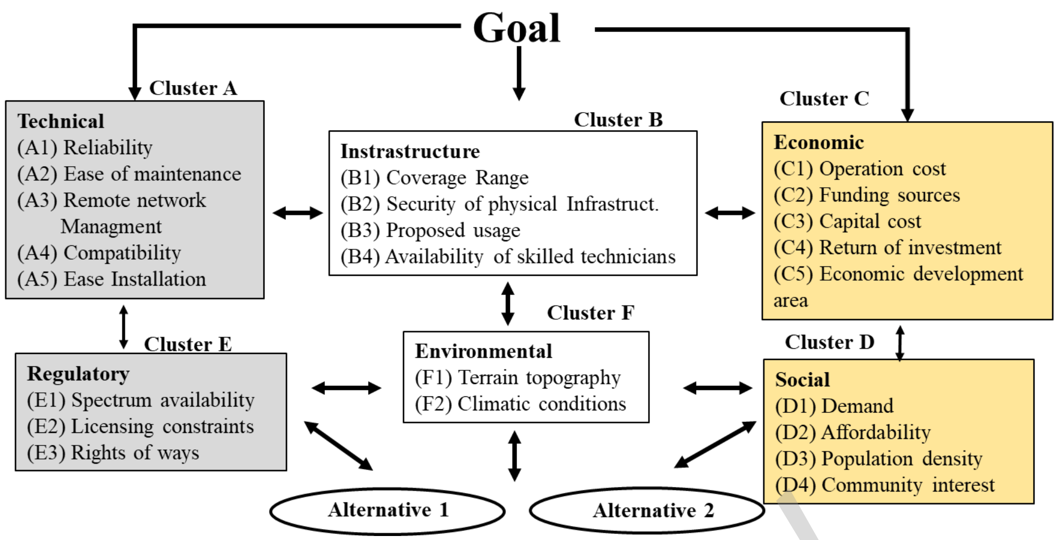


Figure 4. ANP Cluster example

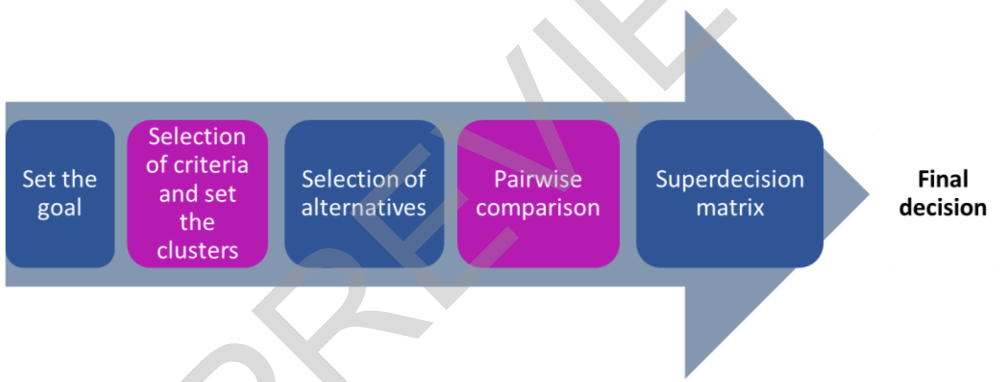


Figure 5. ANP Process

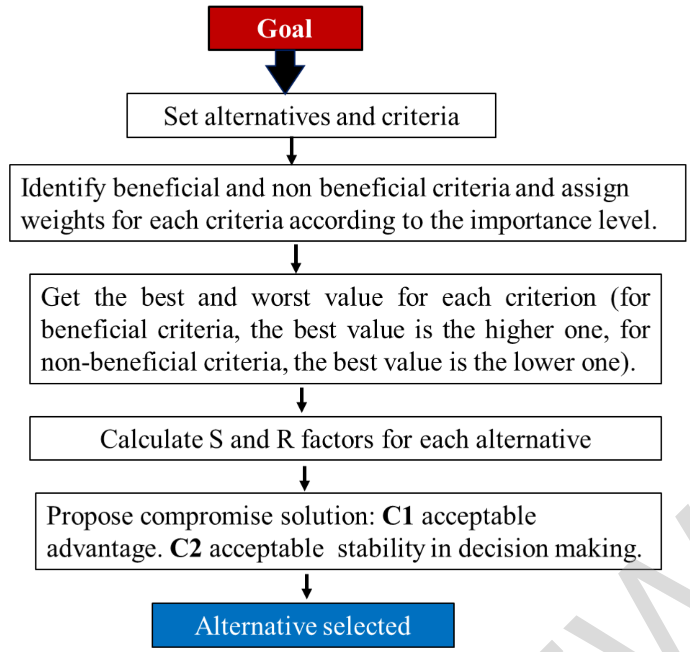
In order to choose a communication technology, the first step of the ANP process is a comprehensive literature review of previous research on comparable difficulties and conversations with telecommunication experts to generate a consolidated list of criteria that includes the most essential variables for the study, [5], [14]. After structuring the problem, the following stage is to examine the influence between criteria. Survey questionnaires are developed to detect the

relationships between factors and clusters in order to obtain the objective. Finally, an unweighted matrix containing priority and cluster comparisons is constructed.

As a result, a value of zero ("0") is given when there is no association and a value of "1" when there is a link between two criteria. Then, Table 2 is utilized to complete the super-decision matrix and pair comparison, and the final selection is made in accordance with AHP process [15],[16]. The ANP had been used in the telecommunications industry for the evaluation of the Iran mobile communication operator, the service supply chain of Indian Telecommunication, the evaluation of Turkish mobile communication operators, the utilization of ICT (Information and Communication Technology) in Central European enterprises, the selection of rural telecommunications infrastructure technology, and other applications [14].

2.2.1.1.3 Vikor

Vikor (Vlse Kriterijumska Optimizacija Kompromisno Resenje, Serbian name) is an optimized multicriteria selection method with a compromise solution that permits simultaneous evaluation of the proximity to ideal and non-ideal alternative because of basic calculation processes [6],[17]. The fundamental analysis of the Vikor method is presented in Figure 6. The difference between beneficial and non-beneficial elements, as well as the independence of each element, is a critical characteristic of this methodology, [18]. Because Vikor method combines opportunity loss with the minimax regret, this technique is being utilized for prioritizing methods based on decision-making under uncertainty approach.



Note: S is the maximum group utility and R minimum individual regret of the "opponent"

Figure 6. Vikor Model

This model, as AHP, implies specific or conceptual values available for both new and existing projects, such as vendor selection process (VSP), assessing mobile services, evaluating quality service, and others. In certain circumstances, unfortunately, this assumption leads to unrealistic system outputs, [17], [18], [19], [20].

2.2.1.1.4 Parametric Model of a locality

The main purpose of the Parametric model of a locality, presented in [3], is to expand the services already installed to additional regions using the general and administrative factors previously established. This decision model is divided into two levels. The first level, called general parameters level, contains the parameters that describe the entire locality such as weather, location, type of population and others. The administrative parameters level is the second level in which the parameters for the specific area, city or building are included. Each level consists of

dynamic classes, according to Figure 7, where groups of parameters can be added depending on the project requirements.

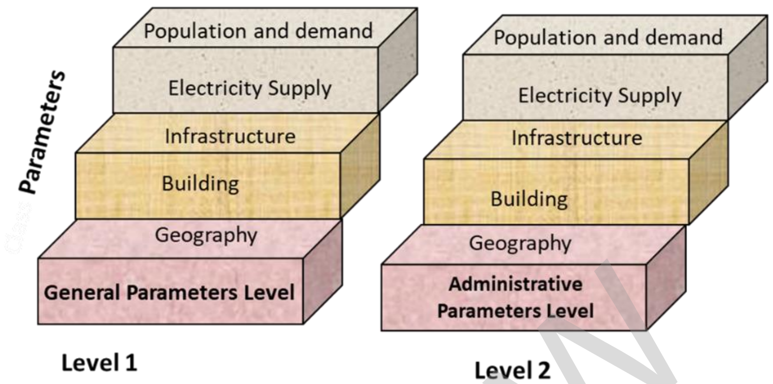


Figure 7. Parametric Model of Locality, levels and classes of parameters.

The functionality of the parametric model of a locality is focused on the imitation of the network construction and operating processes. The objective is to evaluate the implementation and operation costs, and revenues as well as the length of the network construction. Two steps are included in the model functionality according to Figure 8. The first step is the comparison between client demands, locality parameters, and technology considered for the implementation. The second step is the cost calculation and final decision where the "net cash flow indicator" concept identifies the most appropriate technology for the application required. This approach is extensively used by the largest Ukrainian telecommunications provider to build plans for access networks in rural and urban areas, [3].