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A MULTI-CRITERIA DECISION SUPPORT SYSTEM FOR SELECTING CELL PHONE SERVICES

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Bachelor of Engineering, Tong Ji University, 1997

A Research Project
Submitted to the School of Graduate Studies
of the University of Lethbridge
in Partial Fulfilment of the
Requirement for the Degree

MASTER OF SCIENCE IN MANAGEMENT

Faculty of Management
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LETHBRIDGE, ALBERTA, CANADA

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A MULTI-CRITERIA DECISION SUPPORT SYSTEM FOR SELECTING CELL PHONE SERVICES

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Abstract

An increasing number of companies now provide cell phones for their employees. However, these organizations find selecting cell phone services to be complex with literally hundreds of rate plans, coverage areas and other factors to consider.

A cell phone service vendor selection decision support system is designed and developed to determine the most cost-effective vendor and plans. Current business plans including pooling plans, designed for business users in the local market are incorporated into this system. A Search Decision Rule (SDR)-based algorithm, written in VB.NET, determines the most cost-effective vendor and plans. Critical non-cost factors which affect the selection process are determined from a survey conducted in the local community. Finally, an Analytic Hierarchy Process (AHP)-based decision model is adopted to facilitate this decision-making process.

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List of Abbreviations

AHP……… Analytic Hierarchy Process
DBMS……. Database Management System
DM………. Decision Maker
DSS………. Decision Support Systems
MCDM…... Multiple Criteria Decision Making
MCDSS….. Multiple Criteria Decision Support System
SDR……… Search Decision Rule

1. Introduction

According to the Canadian Wireless Telecommunications Association (CWTA, 2006a), more than half of all Canadians are cell phone customers and 47 per cent of all phone connections in Canada are wireless. An increasing number of companies now provide cell phones for their employees (Allianceone, 2006a). In Massachusetts, over 10 per cent of cell phone bills are paid by employers (Cummings & Smith, 2005).

Many Canadian organizations understand that the use of cell phones improve productivity and efficiency. However, without the help of specialized tools, these organizations find selecting their cell phone services to be complex with literally hundreds of rate plans, coverage areas and other factors to consider.

This paper presents a Multiple Criteria Decision Support System (MCDSS) to aid decision makers (DMs) in selecting the most appropriate cell phone vendor and plans. In order to improve decision-making quality, we propose a method that integrates a cost-oriented Decision Support System (DSS) with an Analytic Hierarchy Process (AHP) model to address both cost and non-cost factors. A case example is provided to illustrate how this integrated methodology can select cell phone services.

1.1. Cell Phone Service Industry

There were six Canadian cell phone service vendors in 2005. The three main vendors, accounting for over 92% of all the Canadian cell phone subscribers in 2005, are Bell Wireless Alliance (including Bell Mobility, NorthernTel Mobility, Fido Wireless, etc.), Rogers Wireless, and TELUS Mobility (CWTA, 2006b). The other three are Aliant Mobility, MTS Mobility, and SaskTel Mobility. In the province of Alberta, where this study was undertaken, cell phone services are mainly provided by Bell Mobility and Fido Wireless (Bell Wireless Alliance), Rogers Wireless, and TELUS Mobility.

Cell phone service vendors provide wireless communication services under different rate plans. Cell phone plans can be defined by three main elements: cost, minute, and additional option. Costs are comprised of fixed costs, variable costs, and related taxes. Fixed costs include service fees (e.g., a monthly 911 emergency service fee and a monthly system access fee) and a monthly basic rate. Variable costs are mainly additional minutes charges.

Canadian cell phone service vendors usually divide calling minutes into three major categories: local, long distance within Canada and from Canada to the U.S., and long distance from the U.S. to Canada. In each category, the minutes can be classified as weekday, evening, and weekend. Each vendor develops its plans by manipulating these time slots and offering related free minutes and charge rates for additional minutes.

Additional options are features that customers can select according to their usage patterns. For example, Fido (2006) offers 'additional minute options,' 'expanded network option,' 'Fido to Fido anywhere in Canada option,' etc. If a Fido user has many calls from and/or to Fido subscribers, he or she can select 'Fido to Fido anywhere in Canada option' to reduce the service cost.

In addition, some vendors (Rogers and TELUS) offer business pooling plans, which allow a certain number of users to share minutes each month on one bill. With account pooling, the monthly plan rates of members on the same account are combined so that unused free local or long distance minutes can be used by those members who have exceeded their monthly plan minutes. Current information on cell phone plans can be found on the vendors' official websites (see Appendix A). This study is based on ninety plans, with their rates downloaded on February 2, 2006.

1.2. Research Problem

Organizational spending on wireless telecom services is increasing dramatically. The industry-analyst firm Yankee Group estimates that businesses now spend a quarter of their telecommunications budgets on cell phone expenses (Allianceone, 2006b). In order to improve productivity and efficiency, companies look for the best cell phone plans for their employees. However a large number of plans make it difficult to determine which the best is.

Because of this complexity, a large portion of the revenue of a cell phone service provider comes from customers being on the wrong rate plans. In Canada, most companies are actually spending 20-50 per cent more than they need to for the same service (Allianceone, 2006b). A common strategy followed by companies to eliminate higher fees is to purchase very high minute plans, to ensure that employees will not exceed their fixed costs. This approach, however, results in under-spent minutes and over-spent dollars. For these companies, determining the most cost-effective plan is complex because:

1) There might be a large number of employees.
2) Each employee has a different calling pattern which varies from month to month.
3) Different vendors provide many different cell phone plans.

For example, suppose a DM needs to determine the most cost-effective plans for 500 employees from among 90 different plans. This task will require 45,000 (500*90) calculations.

Minimum cost, however, cannot guarantee customer satisfaction because there are a number of non-cost factors that significantly affect a user's experience with a vendor. Cell phone service customers are shifting their attention from cost to other factors (Cummings & Smith, 2005). Billing accuracy, vendor reputation, and service quality are also important in measuring the performance of a cell phone service vendor (Cummings & Smith, 2005; Mao, Srite, Thatcher, & Yaprak, 2005; Navarro, 2005; Totten, Lipscomb, Cook, & Lesch, 2005; Woo & Fock, 1999). How to handle these non-cost factors becomes another challenge in this selection process.

This study addresses the following questions:

1. How can organizations determine the most cost-effective cell phone service vendor and plans?
2. How can organizations integrate non-cost factors into the decision process to improve the decision making?

2. Review of Decision Support Systems and the Analytic Hierarchy Process

2.1. Decision Support Systems

Decision Support Systems (DSS) were defined by Scott Morton (1971) as "interactive computer-based systems, which help decision makers utilize data and models to solve unstructured problems." Keen and Scott Morton (1978) defined a DSS as a computer-based support system for management DMs who deal with semi-structured problems. A DSS couples the intellectual resources of individuals with the capabilities of a computer to improve the quality of decisions.

Since then, DSS have been developed in a variety of fields (Eom & Lee, 1990). Generally, DSS 1) support DMs rather than replacing them, 2) utilize data and models, 3) solve problems with varying degrees of structure, and 4) focus on the effectiveness rather than the efficiency of decision processes (Eom, Lee, Kim, & Somarajan, 1998).

A popular conceptual framework for DSS evolved from work at the IBM Research Laboratory in San Jose, California, during the late 1970s. This framework was first articulated by Sprague (1980) and developed later by Sprague and Carlson (1982). Sprague and Watson (1989) depicted the component parts of a DSS as dialogue, data, and model. In this conceptualization, the dialogue between the user and the system provides some data that support the system, and models provide the necessary analysis capability.

2.2. DSS Components

2.2.1. Dialogue

Dialogues allow commands, requests, and data to be entered into the DSS and results and information to be generated. A well-designed dialogue should provide a user-friendly interface that allows users to avail themselves of the full potential of the system.

Bennett (1977) defined dialogue components to include the knowledge base, the action language, and the presentation language. The knowledge base includes what the user knows about the decision and about how to use the DSS.

The action language serves to direct the system's actions. The actions that the user can take to control the DSS can be described in a variety of ways, depending on the system's design. For example, some DSS use an input-output form approach. The user is provided an input form and enters the required data. After all the data are input, the DSS performs the analysis and presents the results.

The presentation language provides alternative presentations of the system's responses. The output is often presented on the screen, internalized by the DM, and discarded.

2.2.2. Data

Data play an important role in a DSS. Data can be either stored in the DSS and accessed by the user or inputted manually to the models for processing. The capability of a DSS is constrained by the availability and the accuracy of the data. Data can be categorized as external data (data outside organizations) and internal data (data inside organizations).

Typically, data can be obtained in two ways. One way is to have the database management system (DBMS) extract the transaction data, summarize them, and make the results available to the DSS. The other option is to extract the data but have the summarization done externally via a computerized process or manual processing (Sprague & Watson, 1989).

In addition, other internal data may be needed such as subjective estimates from managers. These data are seldom available from normal data processing activities but are sometimes crucial in decision making.

2.2.3. Models

Models provide the analysis capabilities for a DSS and can be classified as optimization or descriptive (Sprague & Watson, 1989). An optimization model seeks to identify points of maximization or minimization. It is usually utilized in a profit or revenue maximization or cost minimization scenario. On the other hand, descriptive models serve to describe the behavior of a system, but do not suggest optimizing conditions.

Models can also be classified as strategic, tactical, and operational (Sprague & Watson, 1989), covering a wide variety of issues from company objectives planning (strategic), to worker requirements planning (tactical), to credit scoring and production scheduling (operational). In addition to strategic, tactical, and operational models, the model base includes model-building blocks and subroutines. These tools can be adopted separately for ad hoc decision support and might range from a designed subroutine for solving a specific problem to a packaged set of programs for exploring a generic class of problems (Sprague & Watson, 1989).

2.3. Methods Applied in DSS Development

The tools chosen for developing a particular DSS are affected by the structuredness of the decision. Decisions can be defined as structured, semi-structured, and unstructured. A semi-structured decision is the one in which some aspects of the decision-making activity can be programmed, whereas others cannot.

This proposed study is concerned with a semi-structured decision-making problem because the cost analysis involves a routine and repetitive process that can be programmed, while the non-cost analysis is more abstract. Based on this characteristic, three approaches, complete enumeration, algorithmic, and analytic, are combined in developing the DSS.

2.3.1. Complete Enumeration Approach

A complete enumeration approach collects and evaluates all feasible options in order to determine the optimal result (Sauter, 1997). The disadvantage of this approach is that, in some cases, it is not always an efficient way to solve the problem. However, this approach works well in addressing small-sized problems (Alexouda, 2005; Balakrishnan & Jacob, 1995; Berman, Wang, & Sapna, 2005; Dobson & Nambimadom, 2001; Sharp, Muhlemann, Price, Andrews, & Afferson, 1990).

2.3.2. Algorithmic Modelling Approach

The algorithmic model uses a set of computational procedures that can define the characteristics of a problem and efficiently use stored information to obtain the result. In this study, a search algorithm is needed to find the most cost-effective vendor and plans.

The Direct Search Algorithm was first proposed by Hooke and Jeeves (1961) and many subsequent search algorithms (golden-section direct search, direct tabu search, genetic algorithm, etc.) are derived from it. Based on this technique, Taubert (1968) proposed a Search Decision Rule (SDR) in an aggregation scheduling problem. SDR is a pattern search algorithm that tries to find the minimum cost combination of various workforce levels and production rates (Russell & Taylor, 2000). In his paper, Taubert mentioned that one could perform a "logic search" and solve the problem by manipulating the logic associated with the statement of the problem. He also suggested that search techniques could not only be applied in the context of the aggregate scheduling problem, but could also find widespread use in many other areas of management science. Many studies have used search techniques to address a variety of operational problems (Brandao, 2006; Mak, Wong, & Huang, 1999; Scheuerer, 2006; Yagiura, Kishida, & Ibarahi, 2006; Zhang, Chen, & Ye, 2005).

2.3.3. Analytical Modelling Approach

The analytical modelling approach breaks the whole problem into its parts, and examines the parts to determine their nature, proportion, function, and inter-relationship (Sauter, 1997). It usually involves the development of mathematical models (e.g., deterministic model, stochastic model, etc.) and solving them using numerical or analytical methods based algorithms or heuristics. The AHP is an example of a multi-criteria decision-making model.

2.4. Multiple Criteria Decision Making and Multiple Criteria Decision Support Systems

Since Charnes and Cooper (1961) developed goal programming and Keeney and Raiffa (1976) developed the theory and methods for multi-attribute utility assessment, Multiple Criteria Decision Making (MCDM) has been one of the most active and interdisciplinary fields of research in management science and operations research. A general definition of MCDM is solving decision problems that involve multiple, and sometimes conflicting, criteria or objectives. In its most basic form, MCDM assumes that a DM must choose among a set of alternatives whose objective function values or attributes are known with certainty. Many problems in MCDM are formulated as multiple objective linear, integer, or non-linear mathematical programming problems, and many of the procedures proposed for their solution are interactive (Dyer, Fishburn, Steuer, Wallenius, & Zionts, 1992).

A DSS designed to help structure and solve a MCDM problem is known as a Multiple Criteria Decision Support System (MCDSS). It allows DMs to analyze multiple criteria and to incorporate the DM's preferences over these criteria into the analysis. A MCDSS seeks to support the modelling and structuring of decision problems, often making use of advanced visualization capabilities.

2.5. Analytic Hierarchy Process

Since its invention (Saaty, 1980), the AHP has been a popular tool for DMs and researchers. The AHP is a MCDM technique which permits the inclusion of subjective factors in arriving at a recommended decision. Because the AHP can handle both quantitative and qualitative criteria in the course of decision making, a large number of

DSS (Vaidya & Kumar, 2006; Vargas, 1990) have been developed using the AHP on a wide variety of themes.

Yurimoto and Masui (1995) designed a DSS using AHP for overseas plant location in European countries. They identified location factors in the selection of countries and sites, modelled the selection process using the AHP, and then developed a DSS reflecting the preferences of DMs.

Tam and Tummala (2001) used the AHP for selecting a vendor for a telecommunication system. Both quantitative and qualitative factors are taken into consideration. This method enables DMs to examine the strengths and weaknesses of alternative vendors by comparing them with appropriate criteria and subcriteria. This significantly reduces the time and effort in decision making.

Kengpol (2004) developed a MCDSS model that can accommodate investment evaluation models and criteria in making a decision on a new distribution center. The MCDSS model is the combination of two models: transportation model which obtains the cost of transportation and capital investment model which optimizes various costs of new distribution centers. After that, the AHP is employed to develop an approach to aggregate quantitative and qualitative criteria.

Mahdi and Alreshaid (2005) developed a MCDM methodology to assist DMs in selecting the proper delivery method for their projects. In order to determine which of the various options would most likely produce the best outcome for the owner, the authors examined the compatibility of various project delivery methods using the AHP and concluded that the proper selection of a project delivery method is based on a high degree of technical factors and low construction costs.

Dyer, Forman, and Mustafa (1992) presented an integer programming approach incorporating the AHP for a media selection problem. They found that selecting the best media buy needs to consider not only cost and number of readers, but also the efficiency with which the media reach the target audience. A great advantage of such a computerized DSS is that new plans can be quickly generated to show the significance of changes made in problem specifications.

Some other studies (Dey, 2004; Min, 1992; Tullous & Utecht, 1994) adopted the same approach (combining quantitative and qualitative criteria using the AHP in developing a MCDSS). However, no reported research has been conducted on cell phone service vendor selection.

2.5.1. Basic Concepts of the AHP

The AHP is designed to solve complex problems involving multiple criteria. The purpose of the AHP is to facilitate making choices among a number of alternatives and criteria by formulating priorities. The process requires that the DM provides judgments about the relative importance of each criterion and then specifies a preference for each decision alternative on each criterion. The output of AHP is a prioritized ranking, indicating the overall preference for each of the decision alternatives (Saaty, 1980, 1990).

The first step in AHP is to develop a hierarchical representation of the problem in terms of overall goal, criteria, and decision alternatives. The top level of the hierarchy shows the overall goal and the bottom level represents decision alternatives. The middle level includes criteria and sub-criteria if needed, depending on the complexity of the problem.

Second, AHP asks the DM to make specific judgments about the relative importance of each criterion in terms of its contribution to the achievement of the overall goal. Also, AHP asks the DM to indicate a relative preference for each decision alternative in terms of how it contributes to each criterion through pairwise comparisons. Following that, the relative priorities for the alternatives and criteria being compared can be determined through the eigenvalue method. Other mathematical techniques for deriving the relative priorities for pairwise ratio judgments are discussed in the literature (Bojan, 2005). This project uses the decision support software Expert Choice™ which implements the eigenvalue method.

Finally, the criterion priorities and the priorities of each decision alternative relative to each criterion are combined to develop an overall priority ranking of the decision alternatives. From this ranking, a DM can determine the best alternative. This will be explained in detail in the following section.

2.5.2. Hierarchical Decision Making through Pairwise Comparisons

A complex problem needs to be decomposed into an appropriate hierarchy with respect to the goal, criteria and subcriteria, and the alternatives. A typical structure of an AHP model is shown in Figure 1 having one level of m criteria and n alternatives. After the establishment of a hierarchy for a specific problem, pairwise comparisons are utilized to establish priority measures for both the criteria and the decision alternatives. The pairwise comparison answers two problems: 1) which of the two objectives (criteria or alternatives) is more important with respect to a higher-level criterion; and 2) how intense are these objectives.

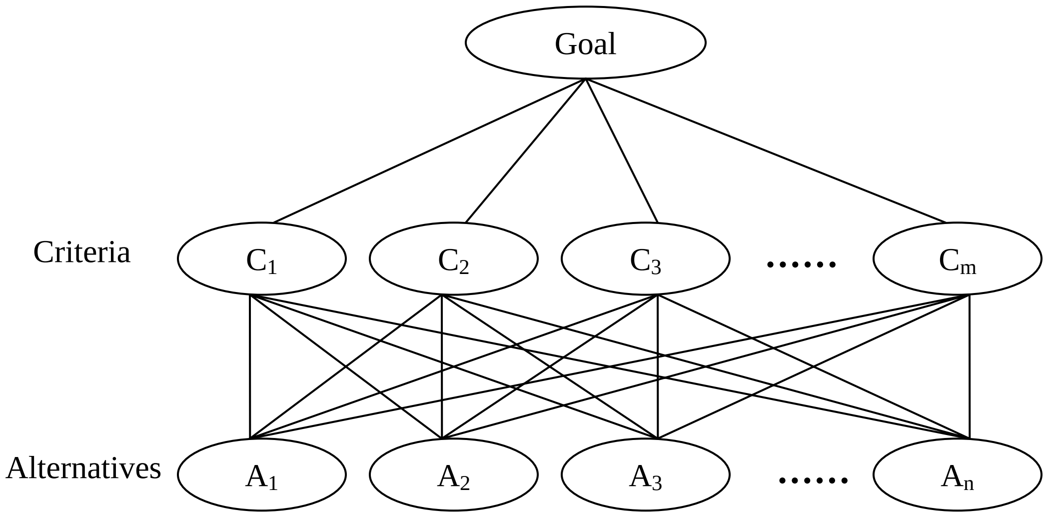


Figure 1. Typical AHP Model

Saaty (1980) developed an underlying scale (see Table 1) with values 1-9 to rate the relative preferences for a pair of items. For example, a DM is asked to state his/her preference between the two criteria (e.g., C_1 and C_2). If he/she strongly prefers criterion C_1, a value of 5 is utilized. A DM also needs to state his/her preference for the two

Table 1. Pairwise Comparison Scale for AHP Preferences

Verbal Judgment of Preference	Numerical Rating
Extremely preferred	9
Very strongly to extremely	8
Very strongly preferred	7
Strongly to very strongly	6
Strongly preferred	5
Moderately to strongly	4
Moderately preferred	3
Equally to moderately	2
Equally preferred	1

alternatives (e.g., A_1 and A_2) with regard to each criterion. If he/she moderately prefers alternative A_1 compared to alternative A_2 with respect to a criterion, a value of 3 is entered into the AHP preference matrix.

2.5.2.1. Pairwise comparison matrix.

The ratio judgments regarding m criteria are entered into an (m x m) pairwise comparison matrix. Similarly, the ratio judgments about the n alternatives with respect to each criterion are also entered in m separate (n x n) pairwise comparison matrices. Let **A** be such an (n x n) pairwise comparison matrix for n objects (criteria or alternatives)

$$\mathbf{A} = [a_{ij}].$$

Reciprocity of the ratio judgments is satisfied by

$$a_{ji} = 1 / a_{ij}.$$

Element a_{ij} denotes how much object i is preferred with respect to object j. For example, if i_{th} object is "extremely preferred" with respect to the j_{th} object, then $a_{ij} = 9$.

The normalized relative priorities R_i (i = 1... n) for the objects are obtained by the eigenvalue method such that

$$\mathbf{A} \cdot \mathbf{R} = \lambda_{max} \mathbf{R},$$

where **R** is the right principal eigenvector and λ_{max} is the corresponding eigenvalue. The priorities satisfy the normalization condition:

$$\sum_{i=1}^{n} R_i = 1.$$

If w^j is the normalized weight of the j_{th} criterion and R_i^j is the normalized relative priority of the i_{th} alternative with respect to the j_{th} criterion, the aggregate relative priority P_i of the i_{th} alternative is defined as:

$$P_i = \sum_{j=1}^{m} R_i^j w^j.$$

2.5.2.2. Consistency index (CI).

The law of transitivity is assumed in a perfect pairwise comparison matrix. However, inconsistency may occur between the pairwise values provided by a DM. Saaty (1980) introduced the consistency index (CI) to measure the degree of consistency:

$$CI = (\lambda_{max} - n) / (n - 1).$$

For each size of matrix, random matrices were generated and their mean CI value, called the random index (RI), was computed and tabulated as shown in Table 2. Accordingly, Saaty (1980) defined the consistency ratio as

$$CR = CI / RI.$$

Table 2. Average Random Index for Various Matrix Sizes

Matrix Size (n)	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Note. From "How to make a decision: The analytic hierarchy process," by T. L. Satty, 1980, *European Journal of Operational Research, 48*(1), p. 9.

The consistency ratio CR is a measure of how a given matrix compares to a purely random matrix in terms of their consistency indices. The consistency ratio should be less than 0.10 to be satisfactory. If the consistency ratio is acceptable, the decision process can continue. If not, the DM should reconsider and revise the pairwise comparison judgments before proceeding with the analysis.

2.5.3. Advantages of AHP to Cell Phone Service Selection Problems

The AHP can break a problem down and then aggregate the solutions of all the sub-problems into a final outcome. It facilitates decision making by organizing perceptions, feelings, and judgments into a framework that exhibits the forces that influence a decision (Saaty, 1990). Because of the efficiency and flexibility of the AHP to handle both quantitative and quality aspects, it has been used in a variety of themes especially in selection and evaluation (Vaidya & Kumar, 2006). In the AHP, pairwise comparisons make it simple to express ratio judgments regarding multiple criteria and alternatives. Compared with other MCDM tools (goal programming, multiple objective programming, multiple-criteria decision analysis, etc.), the AHP is easier to manage (Ossadnik & Lange, 1999). In addition, DMs can use Expert Choice™ to easily conduct the calculation. For above reasons, we chose the AHP approach in this study.

2.5.4. Expert Choice™

In order to facilitate the calculation of eigenvalues, Decision Support Software introduced a software package named Expert Choice™, which provides a user-friendly procedure for implementing AHP on a personal computer.

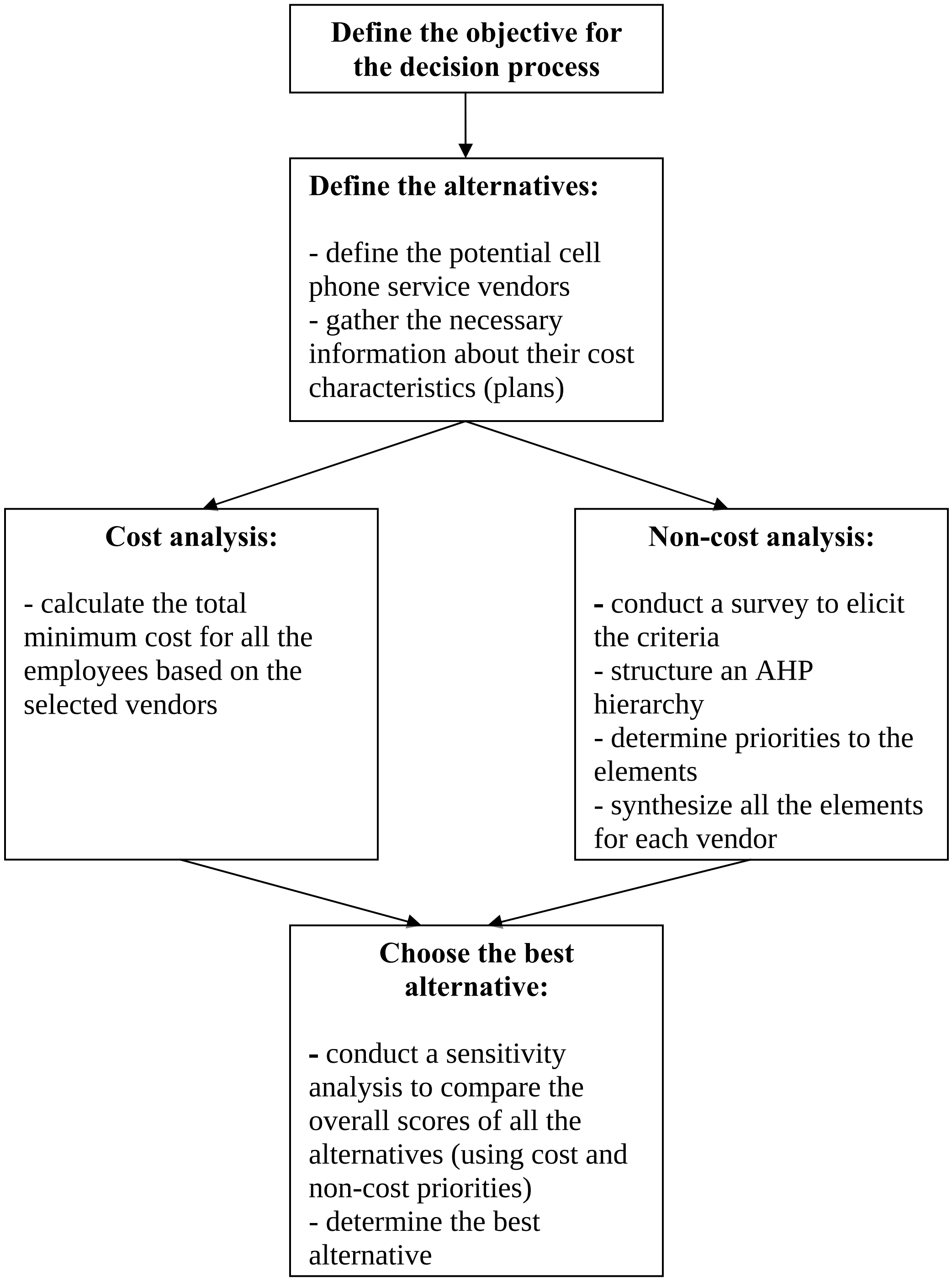
Ossadnik and Lange (1999) evaluated the quality of three software products supporting the AHP. They stated that Expert Choice™ outperforms other software such as AutoMan™ and HIPRE3+™. There are many studies that have used Expert Choice™ as a tool to facilitate the achievement of local priorities in the process of AHP-based decision making (Al-Harbi, 2001; Borenstein & Betencourt, 2005; Curry & Moutinho, 1992; Davies, 1994; Mian & Dai, 1999; Moutinho, 1993; Saad, 2001; Tang & Nam, 1993; Udo, 2000). As a result, Expert Choice™ is adopted in this study.

3. Research Methodology

This study is designed to select the best cell phone vendor and plans for an individual or organization. Given the characteristics of the problem described previously, both cost and non-cost factors need to be considered. The objectives of this study are to 1) develop a model that can be used to accurately and efficiently calculate the costs of a wide variety of usage patterns for a large number of users over a large number of plans, 2) determine which non-cost factors related to this decision process should be considered, 3) determine how important these factors are, and 4) incorporate these factors into cost-based decisions in order to improve decision making.

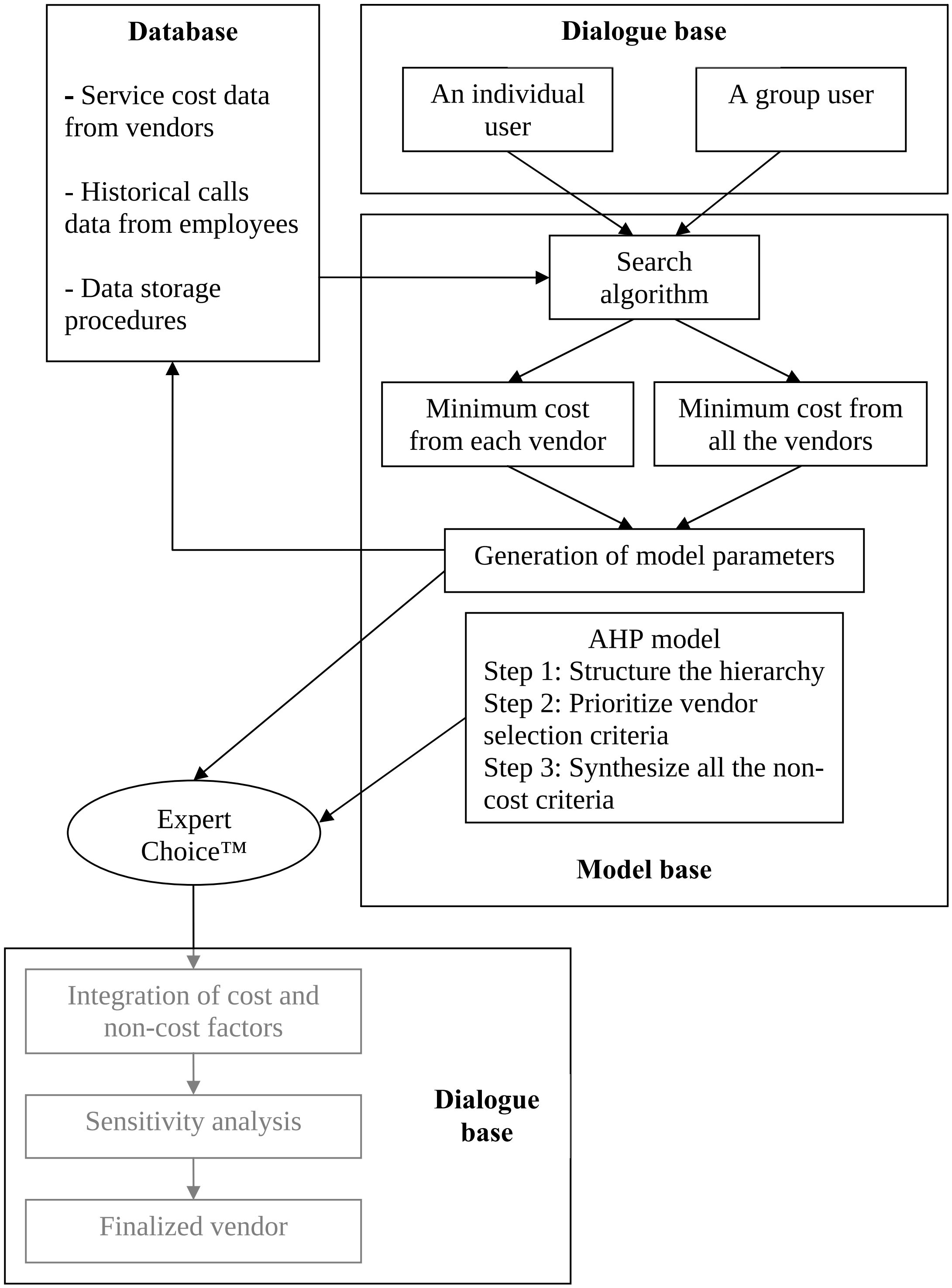
To solve these problems, a MCDSS is designed, developed, and implemented. The MCDSS aims at integrating critical factors involved in vendor selection and supporting the manager with relevant information in the selection process. The selection process is divided into four main phases as shown in Figure 2.

Phase One defines the problem and sets goals for the decision process. In Phase Two, the potential cell phone vendors are selected and the information (service and cost characteristics) needed to evaluate the alternatives is collected. During the Phase Three of the process, the alternative vendors are analyzed and ranked. The analysis involves two parts: 1) in the cost analysis, a computer-based system, developed using Visual Basic.NET 2003™, is employed to help calculate the total minimum cost for simulated data with given users' patterns, and 2) in the AHP-supported non-cost analysis, the alternatives are evaluated and ranked based on non-cost factors. In Phase Four, the outcomes of the cost and non-cost analyses are combined in order to prioritize the alternatives and determine which is optimal. Figure 3 shows the schematic structure of this DSS and its connected database.



(Modified from Korpela and Tuominen, 1996)

Figure 2. AHP-Based Vendor Selection Process



(Modified from Min, 1998)

Figure 3. Architecture of the DSS for Vendor Selection

3.1. DSS to Minimize Cost

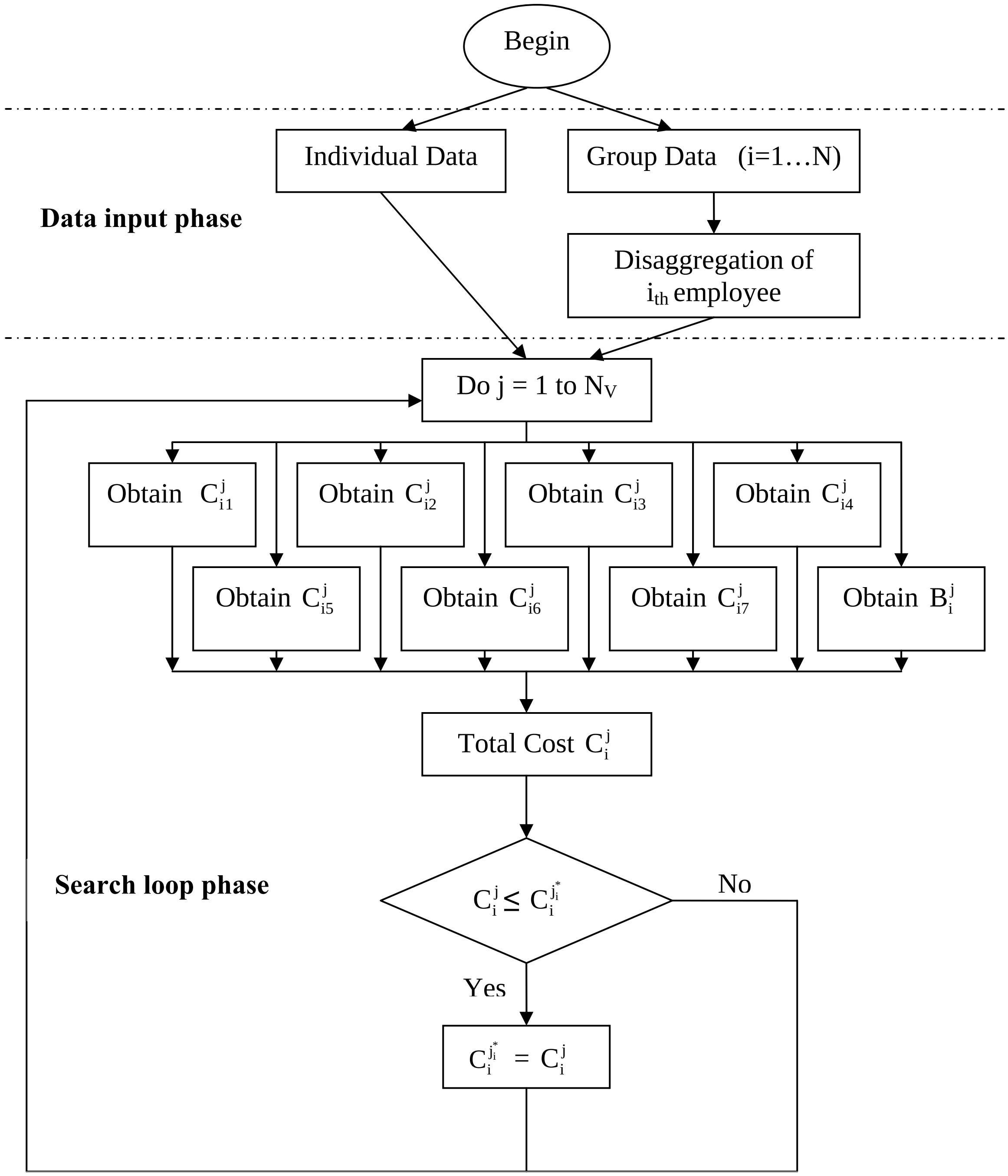
3.1.1. Database

The database requires external and internal data. The external data are service cost data for each plan, which was retrieved on February 2, 2006. In this study, we exclude prepaid and family plans of Bell Mobility and Rogers Wireless because these plans are not designed for business users. Summaries of the plans used in this DSS are presented in Appendices A-F. For internal data, a simulated datasheet containing 500 different calling patterns is generated using Microsoft Excel™ and then exported to Microsoft Access™. These patterns are simulated based on employees' calling patterns in a Canadian corporation. Microsoft Access™ data tables are the repository of data in this proposed DSS. The output data are also stored in Microsoft Access™ data tables. The interface and process model are developed and revised in VB.NET™.

3.1.2. Model base

3.1.2.1. Search algorithm.

A direct search algorithm begins with an initial solution vector. In an inner loop, the solution vector is modified by increasing or decreasing each component of the solution vector by a constant step size. The original value of that component is retained or changed based on whether the objective function value has improved. In an outer loop, the step size is decreased to narrow the search range. The algorithm terminates after a fixed number of iterations or when no improvement of the objective function can be obtained using a constant step size.



$C^{j_i^*}_i$ is defined as an arbitrary large number at the beginning of the algorithm

Figure 4. Logic Flow Diagram of the Search Algorithm

The search algorithm (Figure 4) developed in this study aims to seek the minimum cost with respect to different calling patterns. In the search loop phase, the minimum costs of the seven different usage types for a calling pattern are obtained within the inner search loops, and the total minimum cost will be determined through an outer search loop. In both loops, comparisons are made between the currently achieved cost and its previous optimal cost. If the current cost is less than previous optimal one, we replace the objective function with the current cost. If not, we retain the old value. This algorithm is described in detail in Figure 5.

We tested the system by calculating minimum costs of a small set of calling patterns using the system, and then comparing them with manual calculations. The results were found to be in agreement in each case confirming the validity of the system.

3.1.3. User Interface

The user interface of the DSS is designed in VB.NET™. The main purpose of the user interface is to enhance the user friendliness of the DSS via effective interactive output displays. Figure 6 shows the switchboard of the system. Three buttons direct the user into different functional interfaces. Three main interfaces (see Figures 7-9) are developed to 1) display the minimum cost and plan for each employee, 2) display the organization minimum cost based on vendor-wise or plan-wise scenario, and 3) display the minimum cost plans from the Business Pooling Plans category, respectively.

This DSS is tailored for two kinds of users. One is an individual user with a certain calling pattern, and the other is a DM who seeks the most cost-effective plan for a large number of calling patterns. Two types of calculations (local and global) are used for these two interfaces. For the individual user with a certain calling pattern, a local calculation

Let U_{ik} be the projected time usage of type k for the i^{th} employee. In this model seven different usage types are considered:

- Daytime usage (k = 1)
- Weekend usage (k = 2)
- Evening time usage (k = 3)
- Long distance daytime usage within Canada or from Canada to the U.S. (k = 4)
- Long distance weekend and evening usage within Canada or from Canada to the U.S. (k = 5)
- Long distance daytime usage within the U.S. or from the U.S. to Canada (k = 6)
- Long distance weekend and evening usage within the U.S. or from the U.S. to Canada (k = 7)

Every vendor or mobile service provider has different costs for each type of usage for different service plans. A particular vendor V may have N_V plans available. Each plan has a basic service charge and allows a maximum amount of time free of extra cost for each type of usage. When the usage exceeds these amounts, a customer is charged for additional use at various rates. Even for the same vendor, these rates vary from plan to plan and this cost is denoted by $C_{ik}{}^{j}$ and will be calculated whenever applicable by the function $f^{j}(U_{ik})$ for a particular vendor as follows:

$$C_{ik}{}^{j} = f^{j}(U_{ik}) \quad (j = 1, .., N_V)$$

(cost contribution for the k^{th} usage time under j^{th} service plan for the i^{th} employee)

The total cost for the i^{th} employee under a given plan j is given by

$$C_i^j = B_i^j + \sum_{k=1}^{T} C_{ik}^j \cdot Z_k \quad (j = 1, .., N_V)$$

Where:

C_i^j = the total cost for the i^{th} employee under the j^{th} plan

Z_k = {**1** if actual cost is over plan limit; **0** otherwise}

B_i^j = the basic service cost for the i^{th} employee under the j^{th} plan

T = number of types of usage times (T=7)

Then let

$$C_i^{j_i^*} = \min\left\{C_i^j, j \in N_V\right\}$$

(minimum of all costs for the i^{th} employee for the plan j_i^* among all N_V plans)

For a group of N employees, the total minimum cost is:

$$C^* = \sum_{i=1}^{N} C_i^{j_i^*}$$

Figure 5. Description of the Search Algorithm

can determine the minimum cost plan from each vendor. A user can also conduct a global calculation, which determines the minimum cost plan from all vendors.

When used with a group of employees, the system will first input each of their calling patterns into the algorithm. Then, the search algorithm will determine the minimum cost for each pattern. The user can choose a local or global calculation depending upon his or her situation. Finally, the system will aggregate each minimum cost to generate the organization minimum costs of a local or global calculation.

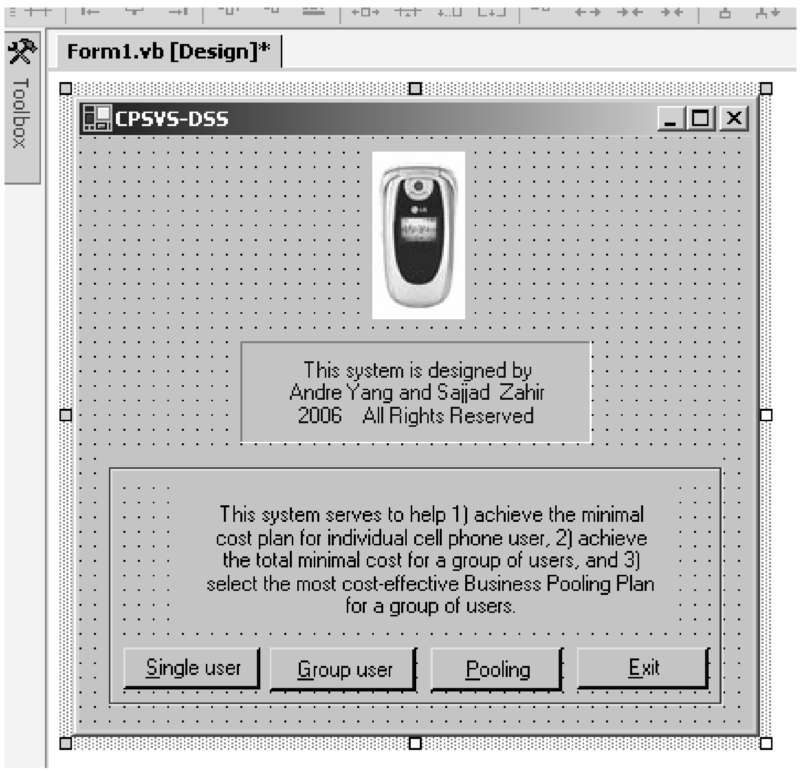


Figure 6. Switchboard of the System

The single user section (see Figure 7) requires the user to input his or her predicted calling minutes. After that, the minimum cost and plan can be determined for each vendor. In this example, the lowest cost plan for TELUS is Plan No. 3, which costs $60.00. The optimal plan from Fido is Plan No. 3 costing $59.80. A set of minimum costs can be aggregated to find the total cost for a group of employees. Finally, the output data can be monitored through a datasheet, which is activated by the "Display" button.

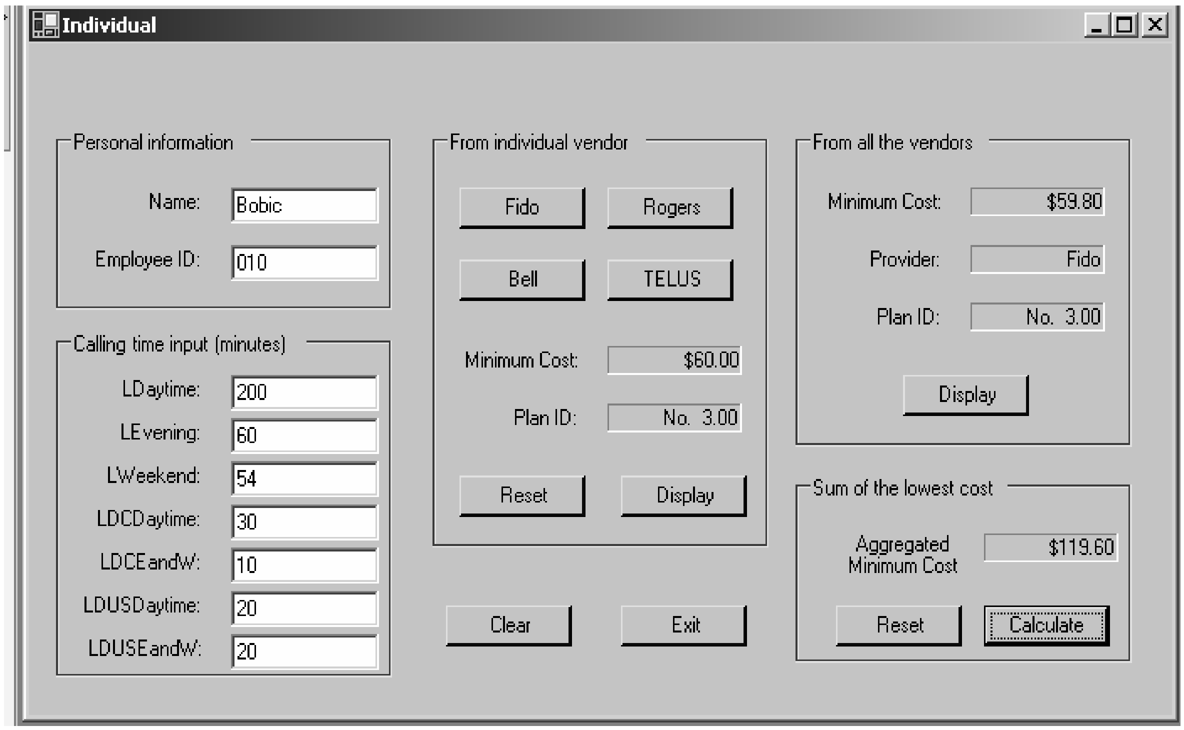


Figure 7. Single User Interface

For a company having a large number of employees, another interface (see Figure 8) is developed where the existing data can be processed at one time no matter the size of the data. The system can calculate the organization minimum cost (total minimum cost for all the employees) for each vendor and the organization minimum cost among all the plans of the four vendors. In this case, the former is $29,025.90 from TELUS and the latter is $28,708.00. The difference between these two numbers is useful, because it can increase the bargaining power of the company when negotiating with cell phone service vendors. The user can also track the output data via a displayed datasheet. Table 3 lists the corresponding organization minimum costs for the simulated data.

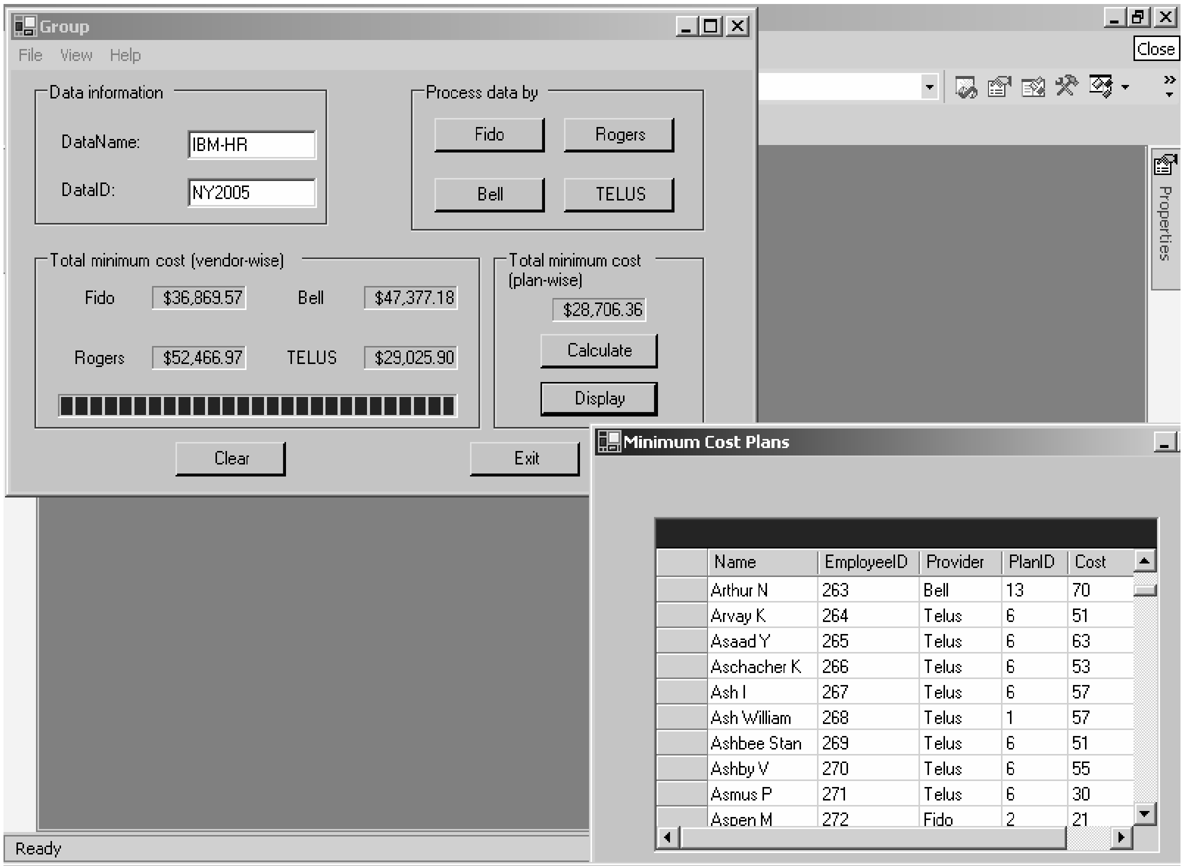


Figure 8. Group User Interface

Table 3. Total Minimum Costs

Vendors	Fido	Rogers	Bell	TELUS	Global
Cost	$36,869.57	$52,466.97	$47,377.18	$29,058.69	$28,708.00

The final contribution of this system is its ability to minimize the costs for business pooling plans (i.e., sharing unused times among the pool members). In this proposed system, the business pooling plans of TELUS are selected because they are more flexible for long distance calls. It is assumed that the manager needs to select business pooling plans for five users, and the total predicted calling minutes of the three time slots (local calls, long distance calls from Canada, and long distance calls from U.S.)

are 1565, 495, and 340 minutes, respectively. After running the system, we find that the minimum cost for this group is $412.00 and the selected plans are Plan 1, 1, 2, 2, and 6 as shown in Figure 9. The minimum cost from pooling plans is five per cent less than the total minimum cost of the five users if their costs were calculated separately from individual plans (90 plans). This result demonstrates the effectiveness of business pooling plans in reducing costs.

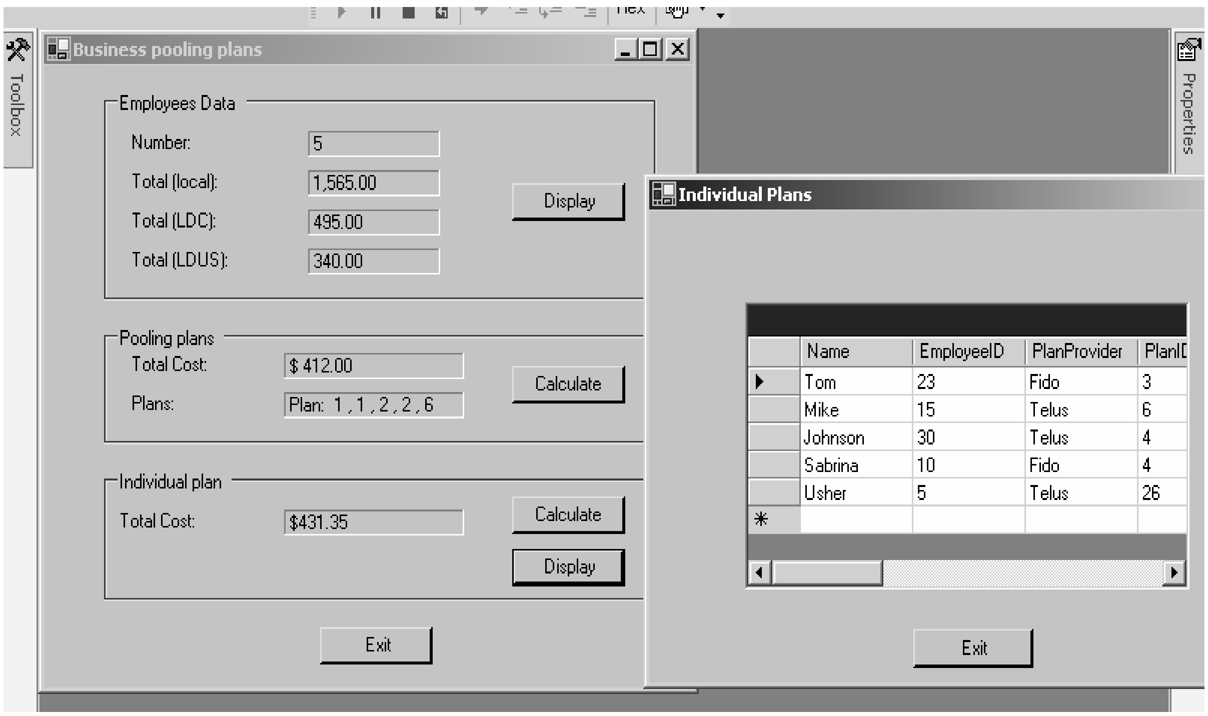


Figure 9. Business Pooling Plans Interface

3.2. Results of Cost Analysis

For each calling pattern, there is a minimum cost plan from each vendor. Based on the simulated data, the percentages of the plans that are selected as minimum cost plans from each alternative vendor are presented in Figures 10-13 (see detailed information in Appendix G). DMs can simplify the selection process by analyzing the difference between the costs resulting from using the plan that has the dominant percentage for all of the calling patterns and the actual minimum cost plans for all of the patterns. For example, a DM can calculate the total cost of 500 calling patterns using Plan 6 of TELUS. If the difference between this number and the organization minimum cost from TELUS is acceptable, the DM can use Plan 6 for all the patterns.

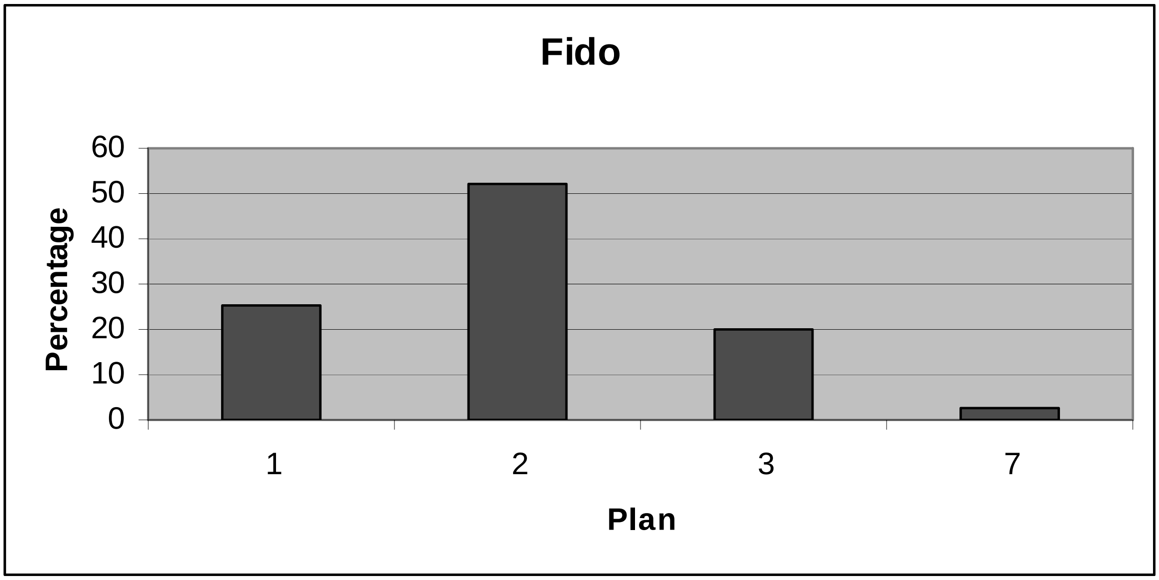


Figure 10. Percentage of Selected Plans from Fido

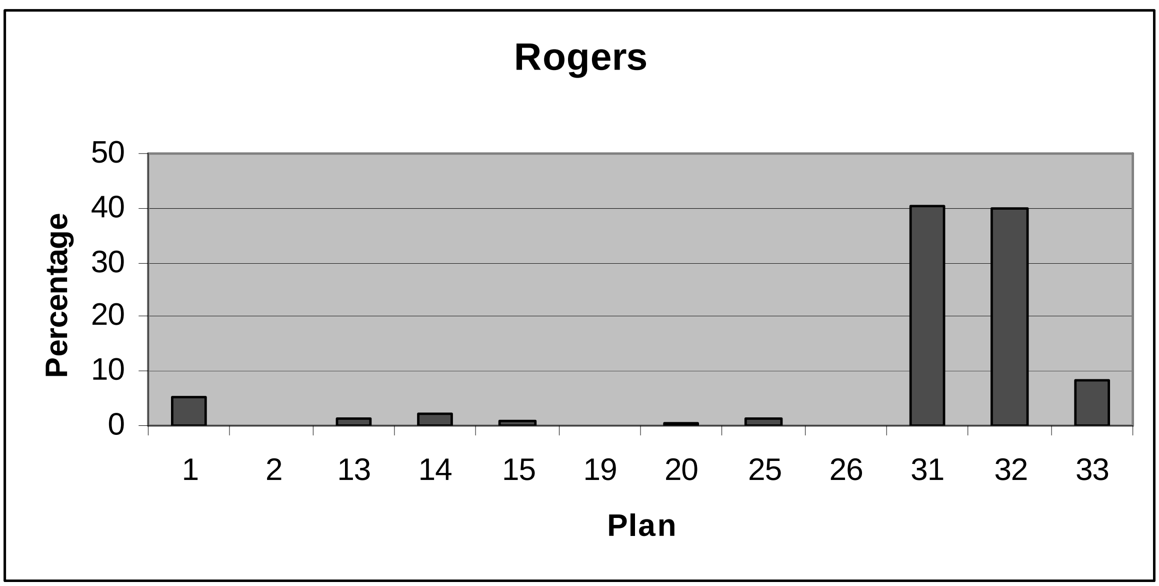


Figure 11. Percentage of Selected Plans from Rogers

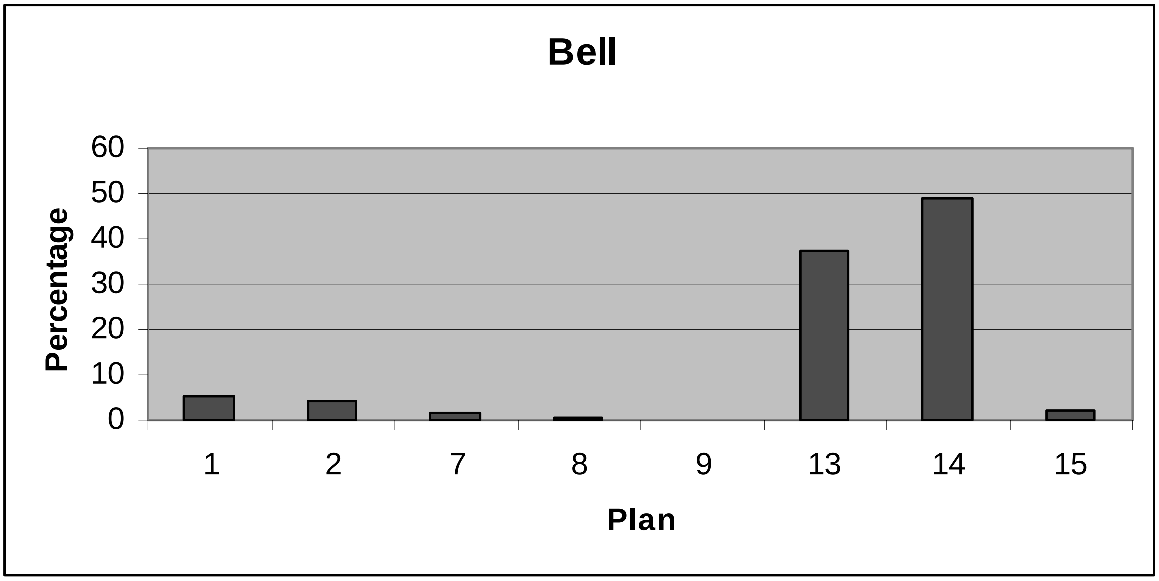


Figure 12. Percentage of Selected Plans from Bell

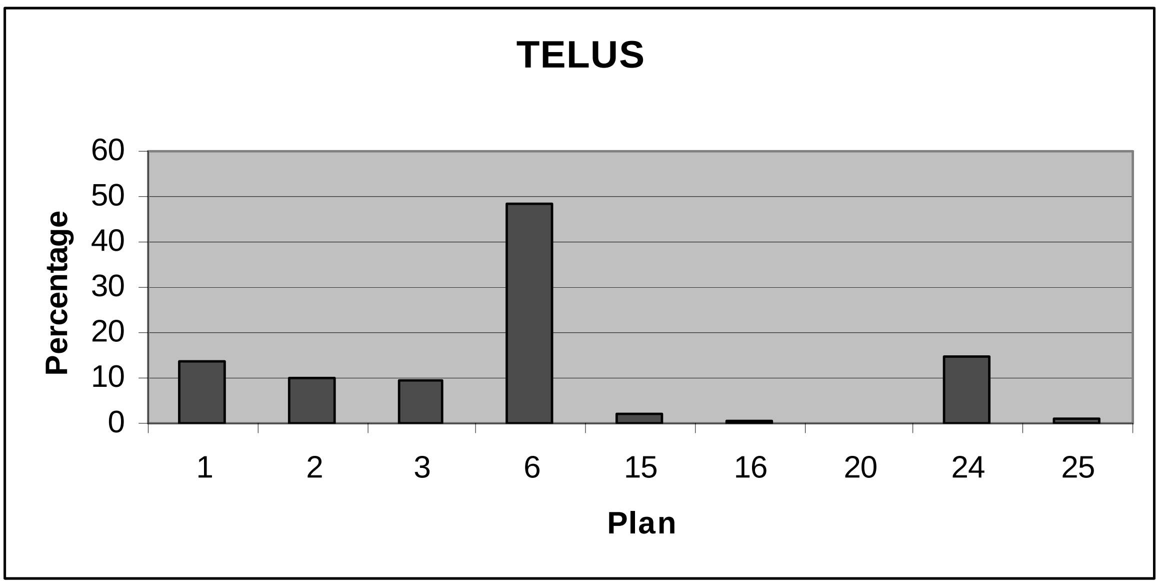


Figure 13. Percentage of Selected Plans from TELUS

3.3. Non-Cost Analysis

3.3.1. Vendor Selection Criteria

Vendor selection decisions are often driven by multiple criteria (Dickson, 1966; Weber, 1996; Weber & Current, 1993; Weber, Current, & Benton, 1991; Weber, Current, & Desai, 1998, 2000; Weber & Ellram, 1993). Vendor selection decisions are complicated because: 1) there are generally a large number of options, 2) there is generally no vendor that has the best performance on all the criteria, and 3) vendors may alter their performance on the relevant criteria (Weber et al., 2000). Dickson (1966) surveyed 273 purchasing managers and identified 23 key criteria. Weber et al. (1991) reviewed 74 articles in academic journals that addressed vendor selection and proposed six most significant criteria. For vendor selection decisions in different industries, some industry specific criteria may need to be added. In this study, we need to determine the critical criteria for selecting a service vendor.

3.3.2. Questionnaire Development

A survey was conducted in the local community to determine the significant criteria that DMs consider when selecting a cell phone service vendor. According to the cell phone service industry literature (Cummings & Smith, 2005; Goode, Davies, Moutinho, & Jamal, 2005; Mao et al., 2005; Navarro, 2005; Totten et al., 2005; Woo & Fock, 1999), 13 criteria (see Table 4) were selected for measurement. A five-point Likert scale was adopted to measure each criterion in this questionnaire. In addition, some demographic data were collected to help understand the characteristics of local business cell phone users. Two response methods (regular mail or Web-based system) were provided for each participant.

We asked 10 academic researchers with extensive research background in Canadian and US cell phone industries to examine the clarity of the questions, the accuracy of the language, and the structure of the questionnaire. The questionnaire was refined and finalized after incorporating feedbacks from the pre-test (see Appendix H).

Table 4. Importance of Criteria

	Criteria	Average Value
1	Signal coverage	4.53
	Customer support service	4.53
3	Accurate billing	4.47
4	Frequency of dropped calls	4.45
5	Provider's attitude and willingness to maintain the business relationship	4.37
	Fixed cost of the plan(s)	4.37
7	Vendor's reputation	4.26
8	Additional minute rate	4.21
9	Flexibility in changing or upgrading plans	4.03
10	Hardware component(s) (e.g. handset, battery, charger, etc.)	3.66
11	Cost of purchasing the cell phones	3.61
12	Wireless network technology (e.g. adoption of GSM and/or CDMA)	2.76
13	Additional features (e.g. wireless web browser, music player, camera, etc.)	1.82

3.3.3. Data Collection

A total of 130 questionnaires were mailed to random companies in Lethbridge, Southern Alberta, Canada. The source of the samples was 'The Lethbridge Yellow Pages' and most of the selected companies were in construction, transportation, and automobile.

A 29.2 per cent response rate was obtained within four weeks. The results (Table 4) show that among these criteria, the most important non-cost factors were: 1) signal coverage, 2) customer support service, 3) accurate billing, 4) frequency of dropped calls, 5) vendor's attitude to maintain the business relationship, and 6) vendor's reputation. Because the weights of these non-cost criteria are close to the weights of cost criteria (fixed cost of the plan and additional minute rate), non-cost criteria are no less important when choosing cell phone plans.

Table 5. Demographic Data

		Frequency
Vendor	Fido	0
	Rogers	10
	Bell	5
	TELUS	28
Expense range (monthly)	< $500	9
	$500-$1,000	13
	$1,000-$2,000	6
	>$2,000	6
Employee size	<10	17
	10-25	12
	25-50	5
	>50	0

Demographic data (see Table 5) show that TELUS dominates the cell phone service market in Lethbridge. Five companies selected two vendors as their service providers and seven companies did not answer the optional questions. Most of the cell phone bills from the local companies are less than $2,000, and very few companies are responsible for cell phone bills for over 50 employees. The average monthly cost for each local user is about $64.71, which is close to the average monthly cost ($73.26) of the simulated usage patterns (see Appendix I).

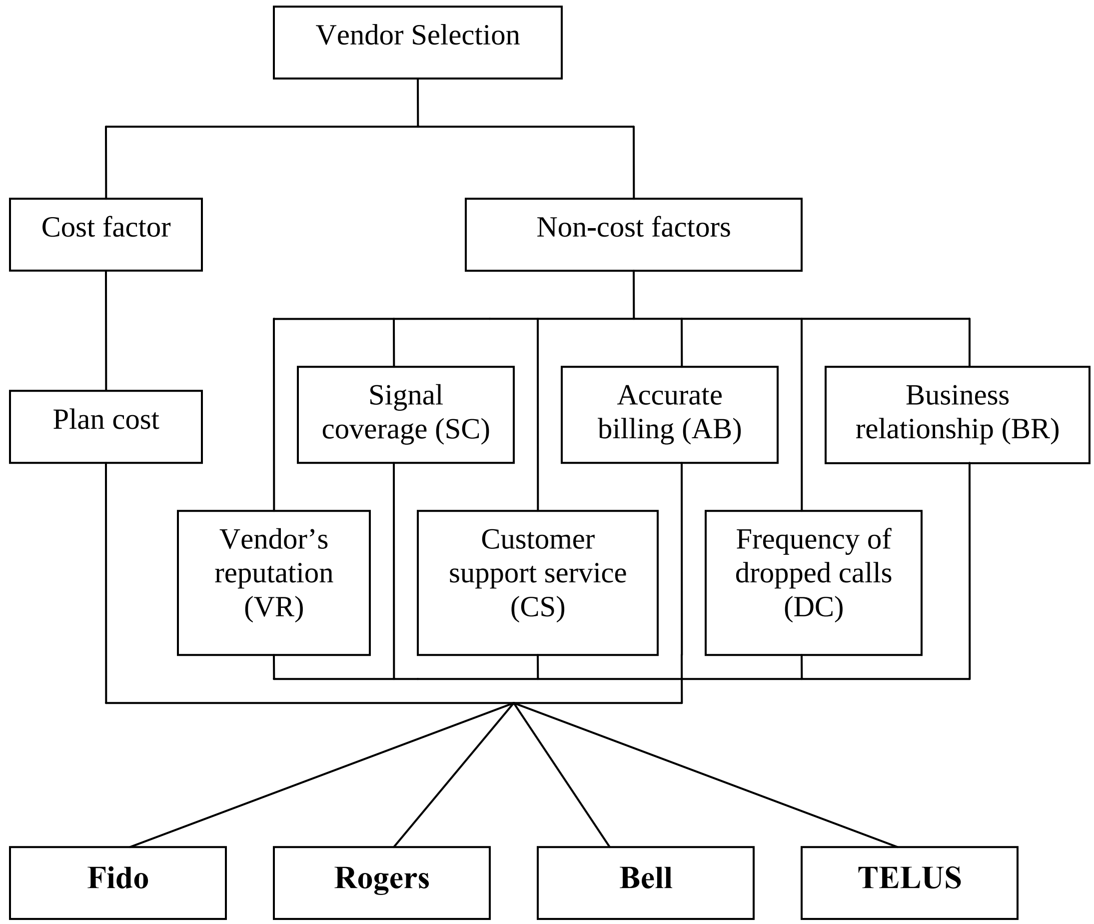


Figure 14. A Four-Level AHP Hierarchy for Selecting Cell Phone Service Vendors

3.4. AHP-based Model

The first step of AHP begins by decomposing a complex MCDM problem into a hierarchical form to represent goal, criteria, sub-criteria, and alternatives. A four-level AHP structure (see Figure 14) is developed based on the results of the survey. The six most important non-cost factors are adopted as the criteria to measure the performance of each vendor. We chose these six criteria because of their averages are above 4.20 (see Table 4). Therefore, we considered them to be the most important criteria in this case. A structured method can elicit information from DMs or experts helping them to make more accurate decisions by identifying the key elements of criteria and alternatives (Cheng & Li, 2001).

3.5. AHP-Based Integrated Analysis

The minimum costs for each vendor (as shown in Table 3) are obtained using the system. To determine the relative priorities of the vendors with respect to cost, we generate the pairwise comparison matrix. The lower the cost, the more preferred it is. For example, the cost of selecting Fido is 1.423 (52,466.97/36,869.57) times preferred compared to that of selecting Rogers. Following this approach, the reciprocal pairwise comparison matrix (see Table 6) is generated.

Table 6. Ratio Preferences of Vendors' Costs

Vendors	Fido	Rogers	Bell	TELUS
Fido		1.423	1.285	
Rogers				
Bell		1.107		
TELUS	1.269	1.806	1.630	

In general, in the AHP, an *n* x *n* pairwise comparison matrix requires *n* (*n*-1)/2 entries (Saaty, 1980) . In this study, six entries are sufficient since the others can be readily obtained by using the reciprocity relation $a_{ji} = 1/ a_{ij}$. The relative priorities of each vendor with respect to cost are generated using the Expert Choice™ (see Table 7). TELUS is the optimal choice if only cost is considered.

Table 7. Relative Priorities of Vendors in Cost-Based Scenario

Vendors	Fido	Rogers	Bell	TELUS
p_i^C	0.267	0.187	0.208	0.338

Inconsistency = 0.00

However, non-cost criteria are also important in decision making. As noted earlier, the six most important criteria (see Table 4) resulting from the survey are considered in this case. Expert Choice™ is used to generate the relative priorities of the criteria and the relative priorities of the alternative vendors with respect to each criterion.

In order to determine the weight of each criterion in this decision making, 15 entries are required for the pairwise comparison matrix of the criteria. For the sake of illustration, we presented in Table 8 a set of example ratio judgments, which may vary from one DM to another. After that, the ratio preferences of alternatives with respect to each criterion were entered in pairwise comparison matrices. Since there are four vendors (i.e., alternatives), six entries are required for each matrix (Tables 9-14). Finally, the aggregate relative priorities (combining the criteria weights with the relative priorities of the vendors) were generated using the Expert Choice™ in Table 15 which shows that for the DMs who only consider non-cost criteria, Bell is the best choice.

Table 8. Pairwise Comparisons of Criteria

Criteria	SC	CS	DC	AB	BR	VR	Priorities
SC			3.0			2.0	0.136
CS	2.0		4.0	1.0	2.0	2.0	0.258
DC							0.065
AB	3.0		3.0		2.0	2.0	0.270
BR	2.0		2.0			2.0	0.168
VR			2.0				0.105

Inconsistency = 0.03

Note. SC: Signal coverage;
CS: Customer support service;
DC: Frequency of dropped calls
AB: Accurate billing;
BR: Provider's attitude and willingness to maintain the business relationship
VR: Vendor's reputation

Table 9. Pairwise Comparisons of Vendors with Respect to Signal Coverage

(SC)	Fido	Rogers	Bell	TELUS	Priorities
Fido					0.140
Rogers	2.0		1.0		0.232
Bell	2.0				0.232
TELUS	2.0	2.0	2.0	2.0	0.395

Inconsistency = 0.02

Table 10. Pairwise Comparisons of Vendors with Respect to Customer Support

(CS)	Fido	Rogers	Bell	TELUS	Priorities
Fido		1.0		1.0	0.200
Rogers				1.0	0.400
Bell	2.0	2.0		2.0	0.200
TELUS					0.200

Inconsistency = 0.00

Table 11. Pairwise Comparisons of Vendors with Respect to Frequency of Dropped Calls

(DC)	Fido	Rogers	Bell	TELUS	Priorities
Fido		1.0			0.169
Rogers					0.288
Bell	2.0	1.0		1.0	0.205
TELUS	2.0	2.0			0.338

Inconsistency = 0.02

Table 12. Pairwise Comparisons of Vendors with Respect to Accurate Billing

(AB)	Fido	Rogers	Bell	TELUS	Priorities
Fido		2.0	1.0	2.0	0.333
Rogers				1.0	0.333
Bell		2.0		2.0	0.167
TELUS					0.167

Inconsistency = 0.00

Table 13. Pairwise Comparisons of Vendors with Respect to Vendor’s Attitude and Willingness to Maintain the Business Relationship

(BR)	Fido	Rogers	Bell	TELUS	Priorities
Fido		2.0	1.0	2.0	0.333
Rogers				1.0	0.333
Bell		2.0		2.0	0.167
TELUS					0.167

Inconsistency = 0.00

Table 14. Pairwise Comparisons of Vendors with Respect to Vendor's Reputation

(VR)	Fido	Rogers	Bell	TELUS	Priorities
Fido		2.0	2.0	2.0	0.395
Rogers				2.0	0.232
Bell		1.0		2.0	0.232
TELUS					0.140

Inconsistency = 0.02

Table 15. Aggregate Relative Priorities of Vendors in a Non-Cost Scenario

Vendors	Fido	Rogers	Bell	TELUS
p_i^{NC}	0.269	0.193	0.323	0.215

Inconsistency = 0.02

However, relative priorities of the vendors obtained with respect to both cost and non-cost factors need to be integrated to produce the overall final ranking of the vendors which can be produced by combining two sets of relative priorities in terms of the chosen weights for cost and non-cost factors (Sarker & Zahir, 2006). Let p_i^C and p_i^{NC} be the relative priorities of i_{th} vendor for cost and non-cost factors, and w_1 and w_2 be weights of the factors, respectively (subject to $w_1 + w_2 = 1$). The overall aggregate relative priority A_i for the i_{th} vendor is:

$$A_i = w_1 \times p_i^C + w_2 \times p_i^{NC}.$$

The DM can choose different weights in accordance with the goal of the organization, and finally determine which vendor is the optimal one. After that, the minimum cost plans from that vendor can be obtained and regarded as optimal.

As shown in Table 16, for this specific case, 1) Rogers does not show any competitive advantage compared with the other three vendors; 2) Bell outperforms the rest of the vendors when the cost weight is less than 46 percent; and 3) TELUS is the best choice when the cost weight is over 46 percent. Figure 15 shows that only Bell or TELUS can be the optimal solution. This finding is consistent with Table 16.

Table 16. Aggregate Relative Priorities of Vendors for Different Cost and Non-Cost Weights

Cost Weight (w_1)	Fido	Rogers	Bell	TELUS
0%	0.269	0.193	**0.323**	0.215
10%	0.269	0.192	**0.312**	0.227
20%	0.269	0.192	**0.300**	0.240
30%	0.268	0.191	**0.289**	0.252
40%	0.268	0.191	**0.277**	0.264
46%	0.268	0.190	**0.270**	**0.272**
50%	0.268	0.190	0.266	**0.277**
60%	0.268	0.189	0.254	**0.289**
70%	0.268	0.189	0.243	**0.301**
80%	0.267	0.188	0.231	**0.313**
90%	0.267	0.188	0.220	**0.326**
100%	0.267	0.187	0.208	**0.338**

Note. $w_1 + w_2 = 1$ (w_2 is non-cost weight)

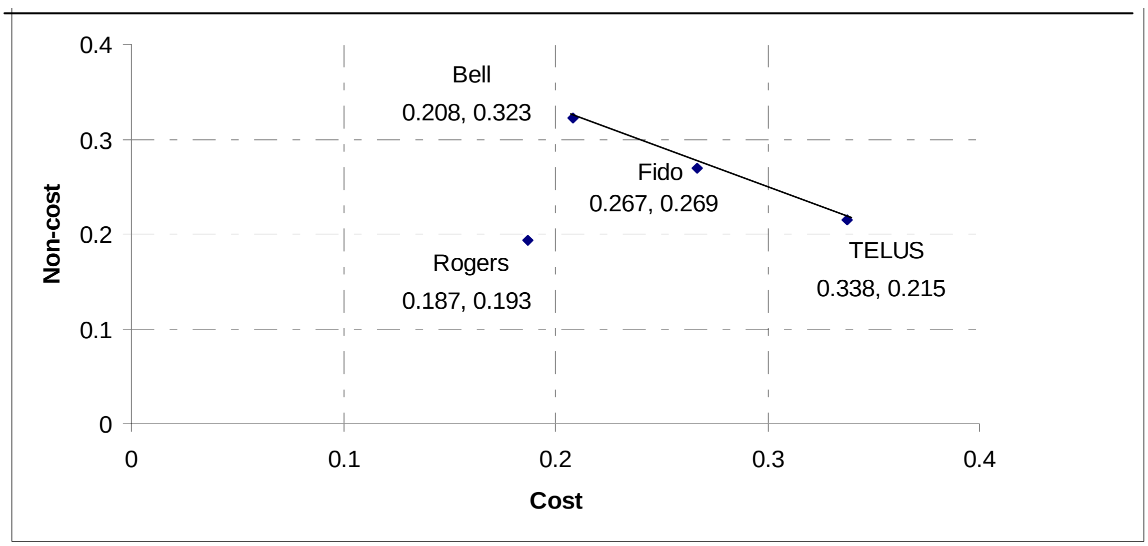


Figure 15. Vendors' Relative Priorities with Respect to Cost and Non-Cost Factors

In this section, an integrated methodology has been applied to solve a cell phone service selection problem. The proposed approach not only allows DMs to make a correct choice based on cost, but also helps to improve the quality of the vendor selection by analyzing and evaluating the key non-cost criteria.

4. Conclusion, Limitation, and Future Research

4.1. Conclusion

This study uses an integrated framework for the cell phone vendor selection process. The method is a significant improvement compared with existing cost-oriented methods used for cell phone vendor selection. The AHP-based analysis of potential vendors makes it possible to include multiple non-cost criteria. The factors relevant to the cell phone vendor selection can be manipulated in accordance with the user's preferences. DMs can also modify and upgrade the system to meet different situations. Finally, non-cost analysis, which is becoming increasingly important in the cell phone service industry, can be documented in detail and communicated to interested groups.

The results of the survey indicate that several non-cost criteria play important roles in determining the optimal cell phone service provider. Non-cost criteria are at least as important as cost factors in the selection process. Cell phone services selection can be solved as a MCDM problem involving both quantitative and qualitative factors.

4.2. Limitation and Future Research

The result of the survey shows that most of the sample companies in Lethbridge provide less than 50 employees with cell phone service. This fact might hinder the appearance of some significant issues or concerns for cell phone customers overall. Further research based on a larger sample size and a more diversified business environment could improve the quality of this study, as well as contribute to the marketing research in the cell phone service industry. Some non-cost factors such as contract handling and warranty might be considered important criteria in a bigger sample. These observations can be investigated in a future study.

The selection result is subject to individual judgment on qualitative criteria analysis. This inevitably leads to different individual ratings, which are attributed to either the lack of available knowledge or personal subjective opinions about certain items. To reconcile the conflict of the results from different DMs, the Delphi method (Dalkey & Helmer, 1963) is recommended. This technique, developed by the Rand Corporation, is to obtain the most reliable consensus of opinions from a group of experts or professionals without direct confrontation. A group of experts in the cell phone service industry will significantly improve the consistency and accuracy of the result of the AHP application, thus, improve the decision making.

One important feature of cell phone plans, free calls among same vendor subscribers, is not included in our model. This feature might affect decisions in specific cases. With the limitation of anticipating this kind of calling minutes, extra methods or tools may be needed in order to solve this issue. However, if historical data were available from the vendors, one possible way could be to sample the prior recorded minutes of this type of calling minutes, and then to estimate the reasonable calling minutes based on statistical analysis.

Other operational problems such as resource allocation, production capacity planning, and demand forecasting can also be solved using this methodology. DMs can use different techniques to address quantitative and qualitative aspects and integrate both aspects by the AHP.

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Appendices

Appendix A. Cell Phone Vendors' Official Websites

Fido Wireless	http://www.fido.ca/portal/en/packages/monthly.shtml
Rogers Wireless	http://www.shoprogers.com/store/wireless/services
Bell Mobility	http://www.bell.ca/shop/en_CA_AB/PrsShpWlsRtp_Landing.page
TELUS Mobility	http://www.telusmobility.com/ab/plans/index.shtml
Business pooling plans (TELUS)	http://www.telusmobility.com/ab/plans/pcs/business_pooling.shtml

Note. Plans for cell phone users in Alberta, Canada

Appendix B. Summary of Cell Phone Plans (Fido)

Plan Name	Plan ID	Plan Price	Minutes included			Cost per min. over (local)	Cost per min. (long distance in Canada)	Cost per min. (long distance in U.S.)
			Weekdays	Evenings &Weekends	Anytime Local			
	1	$15	50	0	50	$0.30	$0.20	$0.67
	2	$20	100	1,000	0	$0.25	$0.20	$0.67
	3	$25	200	1,000	0	$0.25	$0.20	$0.67
	4	$30	300	ULTD	0	$0.25	$0.20	$0.67
	5	$45	600	ULTD	0	$0.25	$0.20	$0.67
Unlimited incoming calls	6	$25	100	1,000	0	$0.25	$0.20	$0.67
Anytime	7	$20	0	0	200	$0.25	$0.20	$0.67
Evenings and weekends packages	8	$45	250	ULTD	0	$0.25	$0.20	$0.67
	9	$65	500	ULTD	0	$0.25	$0.20	$0.67
	10	$100	1,000	ULTD	0	$0.25	$0.20	$0.67
City Fido	11	$45	0	0	750	$0.25	$0.20	$0.67
	12	$65	0	0	1,500	$0.25	$0.20	$0.67

Note. ULTD: Unlimited
Weekdays: Monday to Friday from 8 a.m. to 7 p.m.
Evenings and weekends: Monday to Friday from 7 p.m. to 8 a.m. & Friday 7 p.m. to Monday 8 a.m.
Taxes, 911 service ($0.50), and system access fee ($6.95) apply to all the plans.

Plan Name	Plan ID	Plan Price	Minutes included					Cost per min. over (local)	Cost per min. over (LDC)	Cost per min. over (LDUS)	Cost per min over
			Evenings &Week-ends	Any-time (local)	LDC	LLDC	LLDUS				
Extreme 35	1	$35	1,000	100	100	0	0	$0.30	$0.30	$0.30	N/A
Just Talk 30	2	$30	ULTD	60	0	0	0	$0.30	$0.30	$0.30	N/A
Talk & More 35	3	$35	ULTD	100	0	0	0	$0.30	$0.30	$0.30	N/A
Jawbreaker 50	4	$50	ULTD	350	0	0	0	$0.25	$0.30	$0.30	N/A
Jawbreaker 75	5	$75	ULTD	700	0	0	0	$0.25	$0.30	$0.30	N/A
Jawbreaker 100	6	$100	ULTD	1000	0	0	0	$0.25	$0.30	$0.30	N/A
Canada 150	7	$30	0	0	0	150	0	N/A	N/A	N/A	$0.30
Canada 250	8	$40	0	0	0	250	0	N/A	N/A	N/A	$0.30
Canada 500	9	$60	0	0	0	500	0	N/A	N/A	N/A	$0.30
Canada 750	10	$90	0	0	0	750	0	N/A	N/A	N/A	$0.20
Canada 1250	11	$150	0	0	0	1250	0	N/A	N/A	N/A	$0.20
Canada 2000	12	$220	0	0	0	2000	0	N/A	N/A	N/A	$0.20
North America 200	13	$70	0	0	0	0	200	N/A	N/A	N/A	$0.30
North America 400	14	$100	0	0	0	0	400	N/A	N/A	N/A	$0.25
North America 800	15	$170	0	0	0	0	800	N/A	N/A	N/A	$0.25
North America 1600	16	$300	0	0	0	0	1600	N/A	N/A	N/A	$0.20

Note. ULTD: Unlimited
LDC: long distance in Canada
LDUS: long distance in U.S.
LLDC: local and long distance in Canada
LLDUS: local and long distance in U.S.
Evenings and weekends: Monday to Friday from 7 p.m. to 8 a.m. & Friday 7 p.m. to Monday 8 a.m.
Taxes, 911 service ($0.75), and system access fee ($6.95) apply to all the plans.

Appendix D. Summary of Cell Phone Plans (Rogers)

Plan Name	Plan ID	Plan Price	Minutes included					Cost per min. over (local)	Cost per min. over (LLDC)	Cost per min. over (LLDUS)
			Weekends	Evenings & Weekends	Anytime (local)	LLDC	LLDUS			
Business Plans - Alberta	1	$30	0	0	250			$0.25		
	2	$45	0	ULTD	250			$0.25		
	3	$40	0	0	350			$0.20		
	4	$55	0	ULTD	350			$0.20		
	5	$50	0	0	500			$0.20		
	6	$65	0	ULTD	500			$0.20		
	7	$75	0	0	750	N/A	N/A	$0.20	N/A	N/A
	8	$90	0	ULTD	750			$0.20		
	9	$100	0	0	1000			$0.15		
	10	$115	0	ULTD	1000			$0.15		
	11	$150	0	0	1500			$0.15		
	12	$165	0	ULTD	1500			$0.15		
Canadian One Rate Plans	13	$30	0	0	0	150			$0.35	
	14	$40	0	0	0	250			$0.30	
	15	$60	0	0	0	500			$0.30	
	16	$100	0	0	0	800			$0.20	
	17	$150	0	0	0	1250	N/A	N/A	$0.20	N/A
	18	$200	0	0	0	1800			$0.15	
	19	$45	250	0	0	150			$0.35	
	20	$55	250	0	0	250			$0.30	
	21	$75	250	0	0	500			$0.30	
	22	$115	250	0	0	800			$0.20	

Plan Name	Plan ID	Plan Price	Minutes included					Cost per min. over (local)	Cost per min. over (LLDC)	Cost per min. over (LLDUS)
			Weekends	Evenings & Weekends	Anytime (local)	LLDC	LLDUS			
Canadian One Rate Plans	23	$165	250	0	0	1250	N/A	N/A	$0.20	N/A
	24	$215	250	0	0	1800			$0.15	
	25	$55	0	0	0	150			$0.35	
	26	$65	0	0	0	250			$0.30	
	27	$85	0	0	0	500			$0.30	
	28	$125	0	0	0	800			$0.20	
	29	$175	0	0	0	1250			$0.20	
	30	$225	0	0	0	1800			$0.15	
Digital One Rate Plans	31	$85	0	0	0	0	250	N/A	N/A	$0.40
	32	$110	0	0	0	0	400			$0.35
	33	$170	0	0	0	0	700			$0.33
	34	$220	0	0	0	0	950			$0.30
	35	$330	0	0	0	0	1600			$0.25

Note. ULTD: Unlimited
LLDC: local and long distance in Canada
LLDUS: local and long distance in U.S.
Evenings and weekends: Monday to Friday from 7 p.m. to 8 a.m. & Friday 7 p.m. to Monday 8 a.m.
Taxes, 911 service ($0.50), and system access fee ($6.95) apply to all the plans.

Appendix E. Summary of Cell Phone Plans (TELUS)

Plan Name	Plan ID	Plan Price	Minutes included				Cost per min. over (local)	Cost per min. over (LLDC)	Cost per min. over (LLDUS)
			Evenings & Weekends	Anytime (local)	LLDC	LLDUS			
Super Talk 20	1	$20	1000	50	0	0	$0.30	$0.25	$0.50
Super Talk 25	2	$25	1000	150	0	0	$0.30	$0.25	$0.50
Super Talk 30	3	$30	ULTD	200	0	0	$0.30	$0.25	$0.50
Super Talk 40	4	$40	ULTD	350	0	0	$0.30	$0.25	$0.50
Talk 25	5	$25	0	175	0	0	$0.25	$0.25	$0.50
Talk To Me 30	6	$30	1000	100	100	0	$0.30	$0.25	$0.50
Talk 75	7	$75	ULTD	750	0	0	$0.25	$0.25	$0.50
Talk 100	8	$100	ULTD	1000	0	0	$0.25	$0.25	$0.50
Talk 150	9	$150	ULTD	1500	0	0	$0.10	$0.25	$0.50
Talk CAN 30	10	$30	0	0	100	0	$0.30	$0.30	$0.50
Talk CAN 50	11	$50	0	0	250	0	$0.25	$0.25	$0.50
Talk CAN 100	12	$100	0	0	800	0	$0.25	$0.25	$0.50
Talk CAN 150	13	$150	0	0	1250	0	$0.25	$0.25	$0.50
Talk CAN 250	14	$250	0	0	2500	0	$0.15	$0.15	$0.50
Talk CAN 30+	15	$45	ULTD	0	100	0	$0.30	$0.30	$0.50
Talk CAN 50+	16	$65	ULTD	0	250	0	$0.25	$0.25	$0.50
Talk CAN 100+	17	$115	ULTD	0	800	0	$0.25	$0.25	$0.50
Talk CAN 150+	18	$165	ULTD	0	1250	0	$0.25	$0.25	$0.50
Talk CAN 250+	19	$260	ULTD	0	2500	0	$0.15	$0.15	$0.50

Summary of Cell Phone Plans (TELUS) Cont

Plan Name	Plan ID	Plan Price	Minutes included				Cost per min. over (local)	Cost per min. over (LLDC)	Cost per min. over (LLDUS)
			Evenings & Weekends	Anytime (local)	LLDC	LLDUS			
Talk North America 75	20	$75	0	0	0	250	$0.30	$0.30	$0.30
Talk North America 100	21	$100	0	0	0	400	$0.25	$0.25	$0.25
Talk North America 150	22	$150	0	0	0	700	$0.25	$0.25	$0.25
Talk North America 300	23	$300	0	0	0	1600	$0.20	$0.20	$0.20
Talk North America 75+	24	$90	ULTD	0	0	250	$0.30	$0.30	$0.30
Talk North America 100+	25	$115	ULTD	0	0	400	$0.25	$0.25	$0.25
Talk North America 150+	26	$165	ULTD	0	0	700	$0.25	$0.25	$0.25
Talk North America 300+	27	$310	ULTD	0	0	1600	$0.20	$0.20	$0.20

Note. ULTD: Unlimited
LLDC: local and long distance in Canada
LLDUS: local and long distance in U.S.
Evenings and weekends: Monday to Friday from 9 p.m. to 7 a.m. & Friday 9 p.m. to Monday 7 a.m.
Taxes, 911 service ($0.50), and system access fee ($6.95) apply to all the plans.

Appendix F. Business Pooling Plans (TELUS)

Plan Name	Plan ID	Plan Price	Minutes included	Cost per min. over (local)	Cost per min. over (LLDC)	Cost per min. over (LLDUS)
Pool 25	1	$25	200	$0.20	$0.20	$0.50
Pool 40	2	$40	400	$0.20	$0.20	$0.50
Pool 100	3	$100	1000	$0.20	$0.20	$0.50
Pool Canada 30	4	$30	100	$0.30	$0.30	$0.50
Pool Canada 50	5	$50	250	$0.25	$0.25	$0.50
Pool Canada 100	6	$100	800	$0.25	$0.25	$0.50

Note. LLDC: local and long distance from Canada to Canada or U.S.
LLDUS: local and long distance from U.S. to U.S. or Canada
Evenings and weekends: Monday to Friday from 9 p.m. to 7 a.m. & Friday 9 p.m. to Monday 7 a.m.
Taxes, 911 service ($0.50), system access fee ($6.95), and monthly pooling charge ($5) apply to all the plans.
Other additional services such as monthly unlimited local mobile-to-mobile calling ($5), unlimited local nights & weekends ($15 & $25), and extend clock ($5) are not included in the system.

Appendix G. Minimum Cost Plans Selected by the System

Vendor	Plan	Frequency	Percentage
Fido	1	126	25.2
	2	261	52.2
	3	99	19.8
	7	14	2.8
	Total	500	100
Rogers	1	26	5.2
	2	1	0.2
	13	7	1.4
	14	10	2.0
	15	4	0.8
	19	1	0.2
	20	2	0.4
	25	6	1.2
	26	1	0.2
	31	202	40.4
	32	199	39.8
	33	41	8.2
	Total	500	100
Bell	1	27	5.4
	2	20	4.0
	7	8	1.6
	8	2	0.4
	9	1	0.2
	13	186	37.2
	14	245	49.0
	15	11	2.2
	Total	500	100
TELUS	1	69	13.8
	2	50	10.0
	3	48	9.6
	6	243	48.6
	15	10	2.0
	16	2	0.4
	20	1	0.2
	24	73	14.6
	25	4	0.8
	Total	500	100

Note. The results are based on the simulated data.

Appendix H. Cover Letter and Survey Questionnaire

Cover Letter

Dear Sir/Madam:

As a graduate student in the M.Sc. in Management program at the University of Lethbridge, I am conducting a study to develop a Decision Support System to help organizations select a suitable cell phone service vendor. The study seeks to analyze the main factors which affect decision making, such as cost-effectiveness and quality of service. We would greatly appreciate your participation so we could learn more about the factors organizations consider when choosing cell phone services.

All of the information we receive from you will be kept confidential. We will not ask for any information of a personal nature. The questionnaires will be used only for our study and will be destroyed at the end of the research project. Questions of a general nature about research may be addressed to the Office of Research Services, University of Lethbridge (Phone: 403-329-2747).

Your response is extremely important to us and will help us improve the quality of our results. Your participation is entirely voluntary and you have the right to refuse to reply with no consequences. If you would like to receive the results of this research, please send a separate email/letter to preserve your anonymity.

You can choose two response methods to help our study. One is by regular mail, and the other is by an online survey (http://www.surveymonkey.com/s.asp?u=506352095233). Please feel free to choose one of them.

Your input and opinions are greatly appreciated. If you have any other questions, or wish to receive more information about this project, please call me at (403) 382-7158 or email the address below. Thanks!

Sincerely,

Andre Yang
andre.yang@uleth.ca
M.Sc. Candidate (Management)
University of Lethbridge

Professor Sajjad Zahir (Supervisor)
zahir@uleth.ca
Faculty of Management
University of Lethbridge

Survey Questionnaire

Instructions:
Thank you for agreeing to participate in this study. As a participant, you will be asked to complete a number of questions concerning selection of a cell phone service. It should take you no more than 15 minutes. Please answer the questions as best as you can. (If N/A, please leave it blank)

1. Which cell phone service provider(s) are you currently using for your employees?

☐ Fido ☐ Telus ☐ Bell ☐ Rogers

If others, please list: ____________________

2. The following are some factors that affect the selection of a cell phone service provider. Please tell us how important each factor would be if you were going to choose a cell phone service provider today.

a) Cost of purchasing the cell phones

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

b) Fixed cost of the plan(s)

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

c) Additional minute rate

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

d) Signal coverage

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

e) Accurate billing

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

f) Hardware component(s) (e.g. handset, battery, charger, etc.)

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

g) Frequency of dropped calls

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

h) Wireless network technology (e.g. adoption of GSM and/or CDMA)

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

i) Flexibility in changing or upgrading plans

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

j) Provider's attitude and willingness to maintain the business relationship

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

k) Provider's reputation

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

l) Customer support service (e.g. problem solving aids, the performance of customer support center)

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

m) Additional features (e.g. wireless web browser, music player, camera, etc.)

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

3. If you feel that some other factors would also influence your selection, please list and evaluate them.

Other factor: ______________________________

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

Other factor: ______________________________

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

Other factor: ______________________________

1	2	3	4	5
☐	☐	☐	☐	☐
Unimportant	Somewhat important	Moderately important	Important	Very important

4. The following questions are optional but will help us understand your situation better. This information will be kept confidential and destroyed after this study.

a) What is the current total monthly cost to your organization of cell phone services provided for your employees?

- ☐ Less than $500
- ☐ $500 to $1,000
- ☐ $1,000 to $2,000
- ☐ More than $2,000

b) How many cell phones (users) are included in the above cost?

- ☐ Less than 10
- ☐ 10 to 25
- ☐ 25 to 50
- ☐ More than 50

If you would like to receive the results of this survey, please send a separate email to me at andre.yang@uleth.ca. Or, if you wish, enter your mailing address below:

Thank you for participating in this study

Appendix I. Average Monthly Cost

Average Monthly Cost for Local Cell Phone Users

Monthly expense = (250×9+750×13+1,500×6+2,000×6) / (9+13+6+6) = $970.59
(250, 750, 1500, and 2000 are values of expenses estimated from corresponding ranges; 9, 13, 6, and 6 are numbers of sample companies in expense ranges).

Employee size = (5×17+18×12+38×5) / 34 = 15
(5, 18, and 38 are employee sizes estimated from corresponding ranges; 17, 12, and 5 are numbers of sample companies in employee size ranges).

Average monthly cost = $970.59 / 15 =$64.71 (A)

Average Monthly Cost for Simulated Usage Patterns

Monthly expense = $52,466.97×10/43 + $47,377.18×5/43 + $29,058.69×28/43
= $36,632.53
(52466.97, 47377.18, and 29058.69 are total minimum costs of Rogers, Bell, and TELUS respectively; 10, 5, and 28 are numbers of sample companies that select Rogers, Bell, and TELUS, respectively; 43 is the sum of these numbers).

Employee size = 500
(500 is the number of simulated usage patterns).

Average monthly cost = $36,632.53 / 500 = $73.26 (B)

Numbers in (A) and (B) are close enough to convince ourselves that the simulated data are not far from the reality.