A goal-based and multi-criteria decision analysis approach to the certification of professional engineers in Colombia

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ABSTRACT: Described in this article is a methodological approach for the systematic analysis of criteria and alternatives for professional engineering certification in Colombia. The methodology is goal-based and uses multi-criteria decision analysis. Based on previous studies related to professional engineering certification in Colombia, criteria and alternatives were established to determine the most appropriate model for the certification of engineering professionals. Based on a review of articles related to goal-based and multi-criteria analysis, a combined methodology was developed that systematises the information related to the criteria, sub-criteria and alternatives.

INTRODUCTION

Colombian professional engineering is affected by the need to comply with the requirements for overseas degrees, which affects engineers' job mobility if moving to other countries. In addition, the criteria for professional certification differ between certification bodies. The key to improving occupational mobility is to adapt to each country's conditions [1].

In this article is presented a description of the methodologies used for the organisation, analysis of criteria and alternatives for professional engineering certification. The goal-based approach is used as a framework for decision making and for the application of the PrOACT (problem, objectives, alternatives, consequences, trade-offs) method [2] and AHP (analytical hierarchy process) [3]. Each of the phases of the methodology is goal-based using the PrOACT method and AHP [3].

GOAL-BASED APPROACH

In multi-criteria analysis there are various methods to facilitate systematic decision analysis. The goal-based approach is one of the most used techniques, which analyses alternatives and criteria for decision making using the PrOACT method [4][5]. The goal-based approach is a methodology to structure information systematically, which includes problem identification, determination of objectives and alternatives, and evaluation of the alternatives *vis a vis* the objectives. This leads to establishing a preference among the alternatives [6].

Eight key elements are identified for the analysis of decision making. The first five elements are named with the acronym PrOACT. The three remaining elements are uncertainty, risk tolerance and related decisions; these elements are considered additional where there is significant uncertainty [5].

The general theory of the goal-based approach has emerged based on recent studies [6]; on consumer decision-making [7]; the constructive processes of consumer choice [8]; goals and plans for making decisions [9] and the focus of consumer choice goals [10]. The decision-making process in conflict situations [11], requires knowing the alternatives on which the consumer (decision maker) can focus, based on needs to be met (criteria), towards the determined goal (meta-objective).

The advantage of the goal-based approach to decision making is the systematic organisation of information for effective decision making. The elements of the approach include: problem recognition; setting objectives or goals; establishing alternatives; determining consequences and using trade-offs to establish the preferred alternative. These elements help to divide the problem into parts to be analysed in an orderly manner, hence converting a complex problem into more manageable elements. The elements for decision making are defined below [5].

Problem (Pr)

Define the decision problem. It is one of the most important elements, since the definition of the problem channels the other elements of analysis, to solve the problem correctly [5].

Objectives (O)

Clearly identify the objectives of the decision. The objectives specify what the decision is expected to achieve. Knowing the objectives is fundamental for decision making, as is widely accepted by researchers and decision science professionals. [12-15]. In the goal-based approach, objectives identify goals during the selection process and influence the selection of one goal over another [4].

Alternatives (A)

They are the different choices that the decision maker has to satisfy the decision [11]. The possible alternative solutions to the problem are described, taking into account the objectives [5].

Consequences (C)

Describes how each alternative relates to the objectives in terms of possible restrictions resulting from the alternative proposed. The comparison of how the objectives are met by different alternatives can have an important effect on the decision.

Trade-offs (T)

Establish trade-offs where there is ambiguity in achieving the objectives. It involves the analysis of the alternatives and the consequences in achieving the objectives of the problem posed, and how the alternatives maximise or minimise the impact of the decision.

Three additional elements are defined that are applicable when the decision problem presents significant uncertainty [5]:

1. Uncertainty - focuses on identifying and quantifying the greatest uncertainties that may affect the decision.
2. Risk tolerance - the *room to manoeuvre* over the risk in the decision.
3. Related decisions - how some decisions may affect others, in the development of activities related to the fulfilment of the goals set and objectives proposed in these other decisions.

The goal-based approach and the application of the PrOACT method organises the decision-making by structuring the information to perform the analysis for each of the aspects to be considered.

MULTI-CRITERIA DECISION ANALYSIS

Multi-criteria decision analysis is a broad term that includes a collection of concepts, methods and techniques that seek to help individuals or groups to make decisions that involve conflicting points of view and multiple stakeholders [16]. In spite of the existence of a multi-criteria scientific literature, the tools and methods remain largely unknown to technicians and managers at all levels [11].

There are various and varied applications of multi-criteria decision analysis. Its application focuses on complex decision-making situations, where operations research tools are inadequate to determine the *best decision* [5][17]. Multi-criteria decision analysis can support the decision maker in real decision situations [11]. Among the most used tool in multi-criteria decision analysis is the analytical hierarchy process (AHP), a technique widely used in various fields of science, engineering and the social sciences.

Reviews and investigations ratify the technique as able to handle uncertainty in the data and in the process of analysis [18], with the confirmation, analysis and evaluation of the decision making by a group or panel of experts [19]. The application of the technique in different disciplinary fields has taken into account the different bibliographic reviews [20-22].

DEVELOPMENT OF THE DECISION ANALYSIS METHODOLOGY

In order to outline the phases that constitute the decision analysis methodology for the certification of engineering professionals, elements defined in the goal-based approach and the multi-criteria analysis were considered, with research related to the structuring and organisation of the phases appropriate to an engineering department [23]. The methodology for the certification of engineering professionals is divided into phases and each phase has activities to be carried out in a systematic way. The methodology follows the fundamental precepts of the goal-based approach and multi-criteria decision analysis.

The methodology consists of four phases:

Phase 1: Input analysis

In this phase, activities related to the recognition of the problem, establishment of goals, definition of objectives, determining alternatives and establishing the criteria, are considered [6].

Phase 2: Review of alternatives and criteria

Analysis and review of the alternatives and their relationship with the criteria; analysis and review of the criteria and their relationship with sub-criteria, based on the multi-criteria analysis methodology and the hierarchical analysis process technique; generate preliminary analysis results [1].

Phase 3: External review process

Design and validation of information-gathering instruments; the development and validation of the panel of experts; application of the panel of experts are reviewed [24]; making decisions taking into account the experts, their characteristics and limitations [18][25][26].

Phase 4: Presentation of results

Output elements of the application of the methodology considered as a result of the prioritisation of certification models [23], in the organisation and presentation of results. The methodology constructed for the decision making is shown in Figure 1.

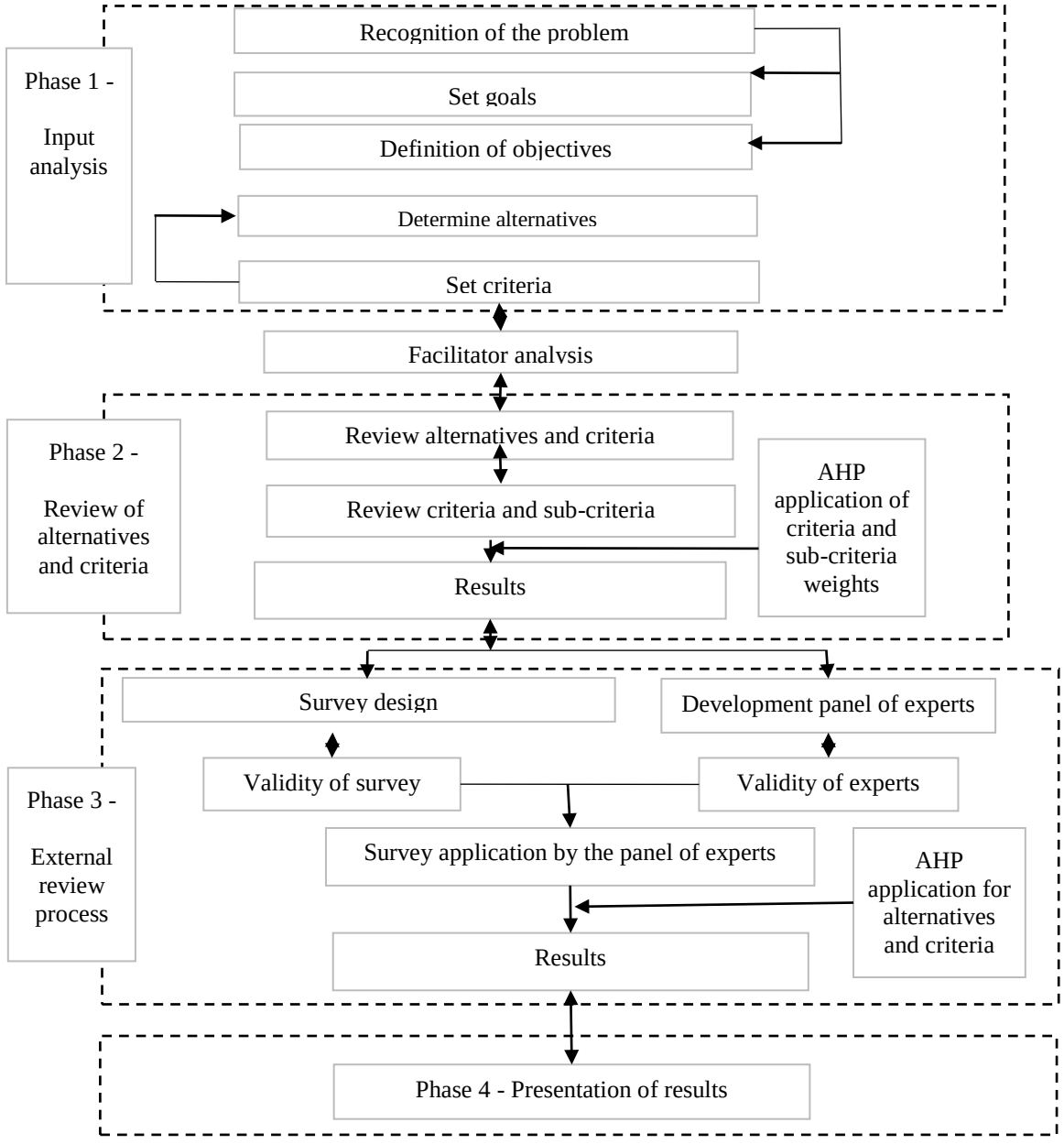

Figure 1: Decision-making methodology.

CONCLUSIONS

The PrOACT method and the goal-based approach systematically organise the input elements for the analysis of the decision-making. The multi-criteria analysis uses the criteria related to the alternatives to help the decision maker to establish the most appropriate solution that satisfies the objectives and goals. Figure 1 is an overview of the decision-making methodology.

The AHP technique has been little used in education and in universities. Where it has been used is in budgetary decision making, planning and utilisation of physical resources, the alignment of strategic objectives with technology and the programming of academic loadings on teachers.

There is little scientific literature regarding professional competences; however, there are four articles related to the quality of education in institutions [23][27-29] and an article related to professional competencies in information technologies [30].

The proposed methodology relates to phases of decision making. The fulfilment of each phase supports the prioritisation of the certification models. The proposed methodology was applied in this preliminary study to professional engineering certification [1].

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