Extending the Multi-Criteria Decision Making Method DEX

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Abstract. The purpose of this work is to propose a plan for future research and development of the qualitative decision support method DEX. DEX is a qualitative multi-attribute modelling method used to evaluate and analyse multiple decision alternatives in order to select the best alternative. We propose six extensions to DEX: supporting full hierarchies, using numeric attributes, probabilistic and fuzzy evaluations, general aggregation functions, modularization and using relational models. These will be implemented in a new decision support platform.

Keywords: Decision making, decision support, DEX, probability, fuzzy logic, aggregation functions, modularization, relational models.

1 Introduction

People are able to make simple decisions very quickly, but are prone to making sub-optimal decisions when facing a complex decision. *Decision making* can be supported by appropriate techniques [1, 2]. One of such techniques is DEX [3, 4], a *qualitative decision modelling method*. DEX was successfully used in many applications such as ecology, industry and health care [5, 6, 7].

The motivation for this work follows from the observed needs for new functionalities in practical applications. We propose six possible extensions of DEX that will be further investigated and implemented in the future. In the following, we first describe the DEX methodology (section 2) and then propose the extensions (section 3). Section 4 concludes the work.

2 The DEX methodology

Decision making is a process which involves *evaluating* multiple *alternatives*, in order to select the best alternative. The selected alternative should satisfy the *goals* of the decision maker [1, 2, 4].

DEX is a representative of *qualitative multi-attribute decision support methods* [2, 3, 4]. Its main property is that the observed attributes are represented with *qualitative attributes*. The model developed using DEX methodology is described as a *hierarchy* of attributes. The input attributes are at the lowest level, all other (aggregated) attributes are concepts that logically depend on lower level attributes. Each hierarchy has one or more special nodes, the *root node(s),* that have no parents. The value given to the root nodes represent the final evaluations of the alternative. The main difference between DEX and other multi-attribute methods is in the *aggregation functions*, which are rules evaluating alternatives - each aggregated attribute has one function. Aggregation functions in DEX are represented as tables.

A model developed according to these rules can be used to evaluate alternatives. Alternatives' values are assigned to the lowest attributes of the hierarchy. The evaluation is done in a bottom-up fashion, using aggregation functions. The model is also typically used for the analysis of decision alternatives, such as *what-if analysis*.

DEX is implemented in the software named DEXi [4, 8]. Also, there are some other programs that implement extensions to the basic methodology:

- proDEX [9]: Motivated by demands in ecological modelling [10], proDEX implements *probabilistic* evaluation of alternatives. The final result of evaluation is a probability distribution over the values of the root attribute.
- Model revision [11]: This is a process of creating a new model from an existing model and newly acquired data. The methodology revises the model by modifying probabilities of rules in the model, without affecting the structure of the model.
- HINT [12]: This is a method for constructing DEX models from data. The approach is based on *function decomposition*. HINT is a representative of concept machine learning methods.

3 Proposed extensions to DEX methodology

DEX methodology is evidently very understandable, easy to use and yet strong enough to assess complex decisions. However, further improvements are needed due to practical requirements. In the following, we propose six possible extensions to DEX methodology.

Supporting full hierarchies. In principle, the structure of the DEX model is a hierarchy, i.e., directed acyclic graph. So far, hierarchies were only indirectly supported in DEX [3] and DEXi software [8], using the concepts called "chaining" and "linking" of nodes. In the extension we wish to fully support hierarchies by representing them using the *native graph form*. Hierarchies also natively support multiple root attributes.

Numeric attributes. Currently, DEX models employ only qualitative (symbolic) attributes. The goal is to facilitate models that could simultaneously include both qualitative and *quantitative attributes*. This means that we have to design principles of including numeric attributes into DEX models. This extension is useful in situations where attributes are better described with numeric values, rather than symbolic; for example experts' preference, salary, etc. Numeric values should be used both to describe the properties of decision alternatives and decision makers' preferences according to those properties. Some advances on introducing numeric attributes into DEX are considered in [10, 13]. The main problem here is to introduce mechanisms for conversion and mapping of both types of attributes.

Probabilistic and fuzzy evaluations. The notion of probabilistic computation is needed for *uncertain* problem definitions. Actually, we would like to support both probabilistic and fuzzy computations. Another generalization would be that alternative input attributes would not only support crisp values, but also distributions of values. The problem with supporting both probability and fuzzy logic is combining both in the model, because computations are done differently.

General aggregation functions. With the introduction of numeric attributes, probabilities and fuzziness, we will also have to adapt aggregation functions. Functions will have to be able to compute with combinations of probabilities, fuzzy, symbolic and numeric values. Adding numeric attributes will require adding a whole new set of numeric aggregation functions. One of the main features of the aggregation function is the ability to extract information from the end-user with as low effort as possible. Furthermore, representations of aggregation functions must be comprehensible to the user. Another extension is the capability for functions to receive arbitrary number of inputs – functions such as *sum*, *min*, *max*, etc. The next way to generalize functions is using the current tables, by constructing similar tables with outputs dependant on the non-qualitative attributes. The main problem with this generalization is that the function must be able to adapt when adding or removing direct descendant attributes. The implementation must preserve as much information as possible when doing operations on the model structure.

Modularization. Modularization means to merge a part of the model into one *module*, which looks like an aggregated attribute. The newly created attribute would have the same inputs and outputs as the part of the model before merging. Grouping can be done in more levels, which leads to a tree-like structure of modules and attributes. This means that, in addition to the hierarchical model structure, we need to deal with another structure describing the grouping of attributes and modules. The modularization technique is useful in managing big models, which are hard to deal with. When a user completes a big part of some sub hierarchy, he would create a module from this sub hierarchy and use it in other decision models; this improves the *reusability* of developed components.

Relational models. Currently, DEX is capable of evaluating "flat" alternatives, that is, alternatives described by a vector of values. In reality, however, alternatives may be more complex. For example, we can have a company that is composed of departments; in order to assess the company, we have to evaluate each department separately and the company as a whole. We say that such an alternative is *relational.* We also encounter relational alternatives in group decision making, where all the decision makers have different preferences on the same matter - the matter can be treated as some part of the sub hierarchy. The top aggregation function, where the combination of all sub-model evaluations are combined, is the most important - the aggregation is not constrained just to calculating to simple functions, but it can have more complex structure. Similar technique was already implemented in DEX software as “groups”, but in a limited fashion.

4 Conclusion

The primary contribution of this work was to propose possible extensions and generalization of the DEX methodology. Six extensions were proposed, which will considerably extend the functionality of the approach and facilitate addressing the most complex decision problems encountered to date in practice. These extensions will be further developed and implemented in a new software package with large capabilities.

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For wider interest

The main purpose of this paper is to propose six new extensions to the DEX methodology. The methodology is a member of multi-attribute decision support techniques, which are used for supporting people at making better decisions. Usually such decisions are made in business environments, ecology, industry and also in personal decisions, e. g., choosing a family vehicle.

A DEX decision model is constructed as a hierarchy of attributes, which are connected in a logical sense. For example, when choosing a car, one would logically construct "maintenance price" from "buying price" and "consumption". The attributes used in the hierarchy are presented as qualitative (symbolic) values. The values are not presented as numerical (-1, 0.12, 18, …), but rather as "good", "medium" and "bad". This is particularly useful in decision situations where judgement prevails over exact formal treatment of criteria.

As written in the paper, the methodology was successfully used in many different applications, but still lacks some functionality for the decision maker. Three useful extensions were developed before, but there are still more functionalities needed from the system.

Our goal is to successfully design, investigate and finally implement six additional extensions to the DEX methodology in a new powerful decision support system. The presented extensions are related to the model structure (supporting full hierarchies), attribute representation (facilitating probabilistic and fuzzy computations, and numeric attributes), model representation (introducing modularization), aggregation functions (supporting general aggregation functions) and support for relational models.