Pilot Study: Development of a Computer Program to Advise/Select a Heating and Ventilation System in Buildings with High Spaces

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Introduction

In general, a climate system in a building has to realise and maintain a certain indoor climate for persons, goods and/or (production)processes. For heating and ventilation of high spaces (> 4 meter) there are many systems available. Every system has characteristic features and is therefore more or less suitable for certain situations and conditions. Currently, the selection of a system is based on perceptions and preferences of the responsible decision-maker. It turned out that perceptions and preferences can differ, so different systems are used in the same situation. In practice not infrequently this leads to a bad operating system, resulting in for instance complaints about the indoor climate and the high energy-use. Often one tries to rectify the complaints by trial and error.

To take all aspects into account is very difficult, even for experts. The selection of a system for heating and ventilation of buildings with high spaces concerns a selection-problem because one has to make the 'best' choice of several alternatives. A survey showed that none of the existing tools met the specific needs for this type of projects. So, TNO and ISSO started a pilot study to develop a computer supported selection-model. In this study the required knowledge for selection-problems in general will be built upon the basis of a specific selection-problem. That is the selection of a system for heating and ventilation of buildings with high spaces.

Approach and Tasks

The selection-problem is generally approached as follows:
1. Define the problem.
2. Determine the alternatives and the criteria of selection.
3. Determine the 'score' of every alternative on all criteria of selection.
4. Determine the 'best' alternative.

Ad 1. Definition of the Problem

The problem is defined by the description of the starting conditions. This is determined by circumstances like the characteristic features of the building, the activities inside, the usage of the space, the desired indoor climate and comfort, particular requirements and/or preferences.

Ad 2. Alternatives and Criteria of Selection
The alternatives will be described univocal and all relevant criteria will be surveyed and set in hierarchic order.

Ad 3. Determination of Scores
All alternatives become an assessment for every criterion of selection. The actual situation to be viewed determines if a criterion is relevant.

Ad 4. Determination of the 'Best' Alternative
The suitability of the alternatives is determined firstly by matching the data of the actual situation to be viewed and the available information about the alternatives and their scores on the criteria of selection and secondly by comparing the relevance of these criteria for that particular case (by using multi-criteria-analysis)

There are so-called hard and soft factors, which determine the influence of a criterion of selection on the final judgement. Hard factors are legislation, standardisation, calculations, modelling, tables, etc.. Soft factors are vision, opinion, intuition, etc. Soft factors often lead to discussion contrary to hard factors. Therefore to solve a selection-problem one has to reach consensus on soft factors.

The tasks with regard to the particular problem consists of two main parts:
1. A survey of available knowledge and the modelling of this knowledge.
2. The development of the computer program, including the implementing of the knowledge.

In figure 1 the approach is represented schematically.

A main task with regard to the computer program is the development of the software framework, including dynamic rules. This task is subdivided into 4 parts:

a. *Transforming the available knowledge into a deductive network.* In the deductive network existing relations between aspects are mapped and where possible made explicit. This network is used by the inference-engine to derive properties from the given data.
b. *Implementation of a inference-engine.* The inference-engine will be responsible for derivation of facts and data, based on the known data. The dependencies represented by the deductive network will be used by this engine in order to achieve this. The inference-engine will help to reduce the burden of providing data by the user. An example of this would be that after providing the length and width of a building, the inference engine will derive the floor-area and thus the user won't be asked to enter this data.
c. *Implementation of an evaluation-module.* Besides 'hard' demands, this module will also support less restrictive 'wishes'. In contradiction to a demand, which must always be met, a wish can be fulfilled to a certain degree by a system. Using a value function, the evaluation module will be able to calculate a score of a specific system on a specific aspect and thus allow for comparison of different systems on different aspects. An example of a demand would be to meet regulations for noise-production. An example of a wish would be a warm-up time of 2 hours. Although there might be no heating system which will be able to fulfill this wish exactly, it is likely that several systems would have a start-up speed close to the wish. Using the value function a

heating system with warm-up time of 1 hour would score higher on this specific aspect than a heating system with 3 hours warm-up time. All scores can be combined to a suitability profile.

d. *Implementation of a ranking-module.* Once all the suitability-profiles (= scores on relevant aspects) of all suitable systems are determined they can be ranked using the ranking module base on multi-criteria-analysis (MCA). The essential part of the ranking module is the input of the priorities the user sets for all relevant aspects. The user could for example indicate that it is much more important that the temperature is to be regulated within 0.5 K then that the start-up time of 2 hours could be achieved. By indicating the priorities, the ranking-module will calculate weighting-factors and use these to rank the suitable systems.

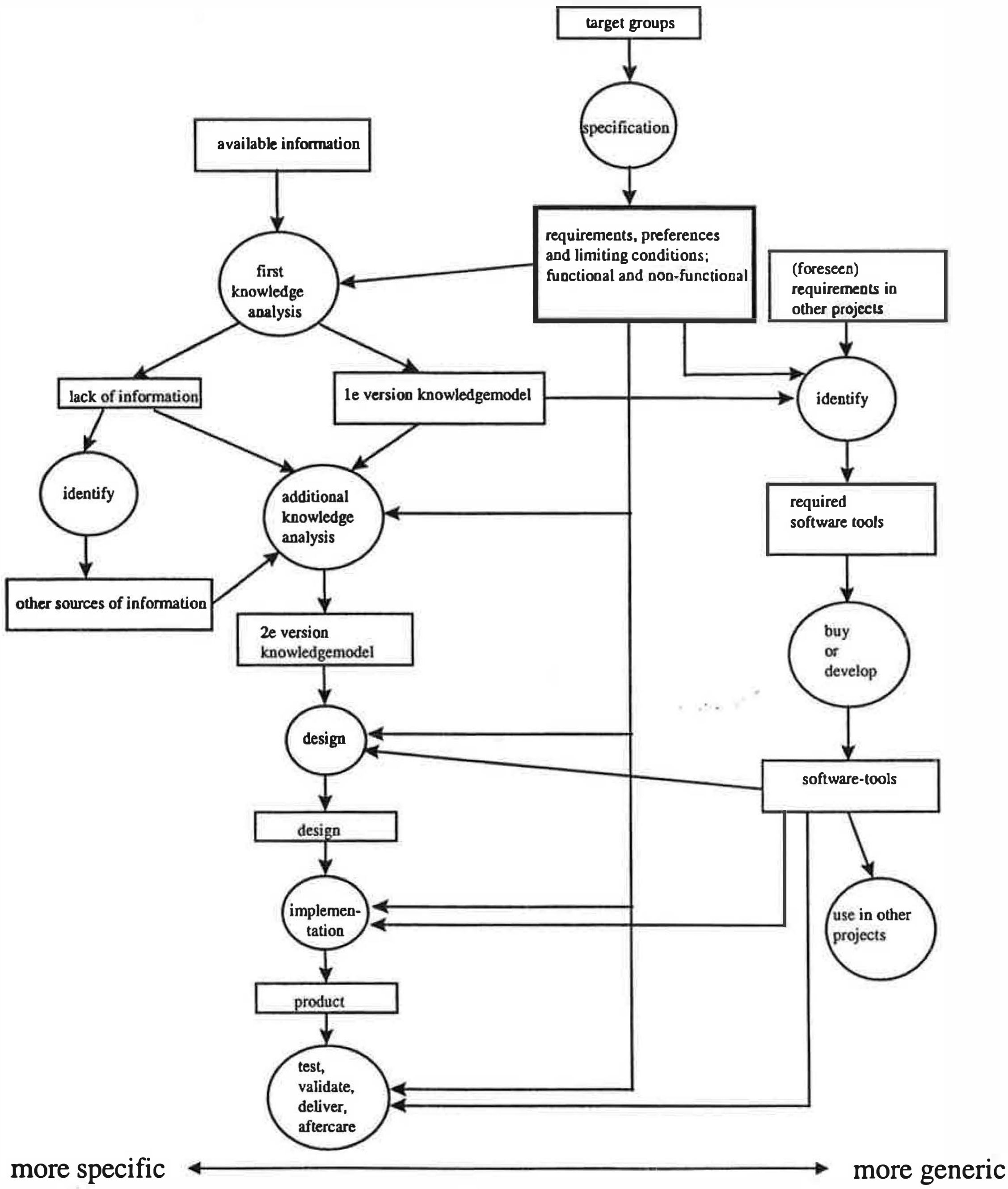

Figure 1. Schematically representation of the approach of the study (generic and specific)

Demarcation of the Pilot Study

The main goal of this pilot study is to examine the chosen approach. Therefore, the number of systems and spaces is limited. Extreme situations are excluded, because such situations require taylor made solutions.

Systems

In this study the following general systems of heating are considered:

- (under)floor heating;
- warm air heating units, low induction;
- air handling unit, low induction;
- warm air heating units, high induction;
- make-up air, directly fired and low induction;
- panel heating, indirectly fired and low temperature;
- panel heating, directly fired and middle temperature;
- panel heating, directly fired and high temperature

Spaces

In this study the following kind of spaces are considered: hangar, shipyard, warehouse and industrial spaces.

Criteria of Selection

In the survey below criteria are included, which are relevant for the selection of a system for heating and ventilation of buildings with high spaces. It should be mentioned that this survey concerns the criteria which might be important for the selection. The actual situation to be viewed determines which criteria are relevant.

Criteria which are relevant for a case can differ in impact on the final judgement. If a certain criterion is very important it will become of great weight in the judgement.
Some criteria are not suitable for a score, but only for advises. If these advises lead to a change of the current situation, it creates a new situation, which has to be evaluated as a new case. See figure 2.

An important part of this approach is that the user of the program will get several advises en recommendations. So the user will be encountered with all the aspect which are relevant for selecting a system.

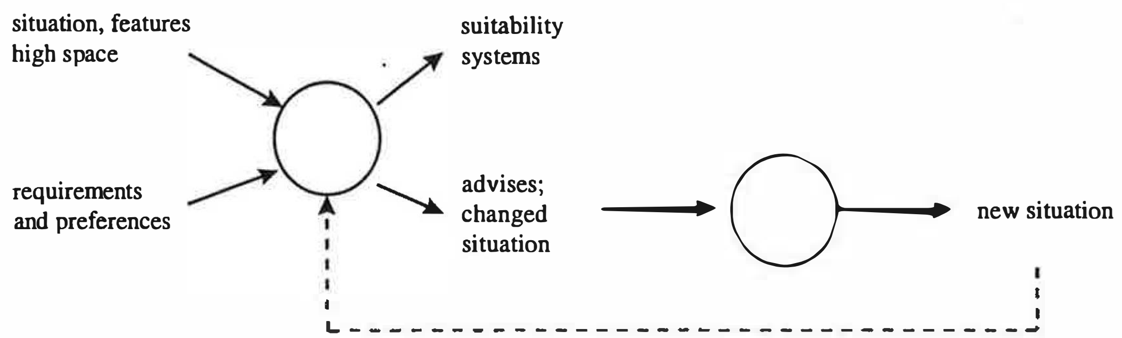

Figure 2. Judgement in relation to advises

Criteria hierarchy:

I. Functional suitability with regard to heating
- A. Suitability with respect to the heat-demand
  1. **Heating (steady heat demand)**
  2. **Pre-heating**
- B. Suitability with respect to permitted distribution of temperature
- C. Suitability with respect to obstacles and disturbances
  1. **Obstacles**
  2. **Disturbances continuously**
  3. **Disturbances momentary**

II. Functional suitability with regard to ventilation

III. Functional suitability with regard to (regulation of) humidity

IV. Functional suitability with regard to cooling

V. Realised comfort
- A. Thermal comfort
- B. Noise from equipment
- C. Smell from equipment
- D. Aesthetic fit in of the system in the room and environment

VI. Practical/technical implementability
- A. Implementability of the system with regard to the installation of the system
  1. **Pre-conditions with regard to the installation**
  2. **Ease of installation**
- B. Implementability of the system in relation to products, processes and/or machinery
- C. Implementability of the system with regard to changes of the situation

VII. Ease of operation en possibilities of control

VIII. Operational safety

IX. Safety/risks for health

X. Environmental impact
- A. Environmental impact based on Life Cycle Analysis (LCA)
- B. Suitability with regard to air-filtering

XI. Costs
- A. Equipment
- B. Installation
- C. Exploitation
- D. Dismantle and removal

Deliverables

The project has a specific and a generic part, so, this also applies the deliverables.

Specific Deliverables

1. A running computer program, which will be the base for developing a distribution version. This program will be implemented in IBM VisualAge™ and will support full functionality. With this base version the program and the ideas behind it can be tested. As one of the first 'real' world uses of this program, an attempt will be made to derive 'new' knowledge and rules, not previously recognised.
2. Several commonKADS models (knowledge-model, communication-model) Parts of these model will use the UML notation of UML (Unified Modelling Language). These models are both used for designing and implementing the computer program and as a base for future development.
3. A comprehensive report on the collected and categorised domain-knowledge. This document will be available both in printed as in (browsable) html format and can be directly used to gain insight in the domain.

The result of a run with the program will be an installation advise, based on both the description of the building and its projected usage and the preferences given by the user.

Generic Deliverables

1. A reusable design, partly made in IBM UML-Designer™ and implementation. The design consists of both the commonKADS models and the software design. The generic framework + the implemented domain-knowledge together form the program as mentioned under specific 1.
2. A method for developing knowledge-intensive computer systems, specifically for selection problems. This method will be based on the lessons learned during the project and will be reported in a manual. This manual can be used for all kinds of selection problems. The emphasis of this manual will be on knowledge-acquisition, -analysis and formalization and how to properly use this in the existing framework. More specific software-design related tasks are not covered in this manual, since many methods are readily available.