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Evaluation models for housing loan allocation in the context of floats

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Abstract

In this paper, we analyze the impact of contextual changes to the size, structure and behavior of a qualitative multi-attribute model. The study involves an evaluation model for allocating housing loans in the Housing Fund of the Republic of Slovenia. So far, this model was used in 13 completed floats of loans for citizens. As a result of considerable contextual changes that occurred from float to float, the model had to be adapted accordingly. These changes were reflected in the modifications of model structure, used attributes, and decision rules at various levels of the model. Based on the analysis of time series of different model parameters, we articulate some guidelines for efficient model management, and justify the flexibility of the approach and its robustness to contextual changes. In particular, we show that a model can be designed so that relatively large changes in the decision environment cause minor and isolated changes in the model.

Keywords

Multi-attribute decision making, decision support systems, decision models, evaluation, ranking, context sensitivity, loan allocation, housing

Context Sensitive Decision Support Systems
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1 INTRODUCTION

An evaluation model that supports the allocation of housing loans to citizens by the Housing Fund of the Republic of Slovenia is analyzed regarding 13 floats of loans for a period of six years. These floats represent the changing context of the decision problem. The life cycle of the qualitative multi-attribute model gives an important lesson for the management of contextual change.

The context was changing in terms of available funds and the purpose of loan consumption (e.g., construction, renovation, maintenance). These changes were reflected in the different criteria that determine the priority of applicants, such as the present state of housing, family status, and the age of family members. The model's quality is measured by its flexibility and robustness regarding contextual changes. The challenge is to design models so that they require minor and isolated changes even with relatively large changes in context.

The Fund's model was developed by a knowledge-based approach in which the decision knowledge is represented by two components: (1) a hierarchy of attributes and (2) decision rules that express the aggregation of utilities (Bohanec and Rajkovic, 1993). This approach supports cognitive processes by structuring the knowledge and making it transparent to the users (Fox and Cooper, 1997), which is important for the comprehension and verification of models in changing contexts.

The following section presents the background related to the problems of loan allocation, model development and its computerized support. Section 3 describes context changes that occurred in the Fund's floats. The effects of these changes to various model's parameters are analyzed in section 4. The conclusion summarizes the strengths and weaknesses of the approach regarding context dynamics.

2 BACKGROUND AND PROBLEM DESCRIPTION

Allocation of housing loans to citizens and nonprofit organizations is an important task of the Slovenia's Housing Fund. By the distribution of financial resources in floats of loans, the Fund encourages the construction, renovation and maintenance of housing according to the national housing policy. The resources are earmarked primarily for 'favorable' loans with low interest rates and long repayment time.

The amount requested by applicants usually exceeds the available financial resources. In such cases, the applicants must be ranked into a priority order. A system that supports the loan allocation activities must, among other things, facilitate an efficient determination of priority order, considering both, the housing law and conditions prescribed within each float. The procedure is required to be fast, reliable, transparent, and fair for all applicants. The request for transparency asks for effective explanations of loan priority order, which have to be provided for a large number (typically, several thousands) of applicants.

A management decision support system (DSS) for supporting the activities related to housing loans allocation was developed and first used in 1991 (Bohanec et al, 1996). The system is based on a combination of a knowledge-based system (Klein and Methlie, 1995; Mallach, 1994) and a database of applications, loans and priorities for all floats of loans. The central component of the knowledge base is a qualitative multi-attribute model (Rajkovic and Bohanec, 1991) for the evaluation of loan priority. For a technical support of decision modeling, we used DEX, an expert system shell for multi-attribute decision making (Bohanec and Rajkovic, 1990). The model itself is presented in more detail in section 4.

In the decision model, the Fund's policy is explicitly articulated in terms of attributes' structure and decision rules. Contextual changes, in principle, require different policies and, consequently, different evaluation models. Thus, a permanent participation of knowledge owners in the model's life cycle was vital. Before announcing each float, the model was carefully investigated by the Fund's management and redesigned if necessary. The changes in context that occurred in the floats completed so far are addressed in the following section.

3 CONTEXT CHANGES IN FLOATS

Since its foundation in 1991, the Fund issued 13 floats of loans with favorable terms to citizens. On average, there were about 2 floats per year. So far the Fund has approved more than 17 thousand loans with a total value of around 25 billion Slovenian tolars (SIT), which approximate to 134 million XEU. The total earmarked amount was about 14.7 billion SIT. The global statistics of floats (Table 1) indicates that the Fund had almost to double the earmarked financial resources in order to meet the entitled demand.

In addition to loans for citizens, the Fund also grants loans to nonprofit housing organizations. Since these floats require a considerably different approach to loan allocation and management, we have excluded them from the study presented here; note the missing float numbers in Table 1.

Each issued tender consists of some additional requirements that an applicant needs to fulfill in order to participate in the float. For example, one tender may be designated just for citizens who presently live with their parents and want to buy their first flat; or, applicants that build their own houses are not allowed to participate in this float. These requirements for applicants are changing from tender to tender. The main aim of such requirements is to focus the target group of citizens so that the amount requested by applicants roughly corresponds to the earmarked amount for a given float. In this way, the task of loan allocation becomes more feasible. Nevertheless, since the demand of the targeted group of citizens is estimated according to the experience from previous floats, the amount requested by applicants usually exceeds the available financial resources.

These prescribed requirements can be viewed as the **context** for a particular float. In Table 1, they are partially responsible for the reduction of applications from 'All' to 'Verified'. The second part of the task, which determines 'Approved' applications from 'Verified' ones, is accomplished by the multi-attribute DSS (Bohanec et. al. 1996). In the following, we describe how the context of prescribed requirements has been changing from tender to tender.

Table 1 Number of applications to the Fund's tenders, together with the earmarked and approved financial amounts

Float	*Applications*			*Amount (million SIT)*	
	All	*Verified*	*Approved*	*Earmarked*	*Approved*
1	4774	3538	3495	2000	1908
3	5962	4598	2452	1000	1672
4	1445	813	646	1000	1075
5	1507	382	337	500	686
7	1841	680	678	1000	1243
8	2948	2246	2189	800	2689
9	488	434	434	600	212
11	1966	1318	1169	814	2531
14	2836	1284	1264	1500	2694
16	1858	882	882	1000	2240
18	3350	1951	1951	2000	3659
19	685	480	480	1000	1387
20	2119	1152	1152	1500	2991
Total	31779	19758	17129	14714	24987

The first tender was unique; it was designated for the citizens who already had loans with unfavorable terms from commercial banks. They got the possibility to repay the unfavorable loans with new ones, which were more favorable in terms of interest rates and repayment time.

In the third tender, there were no special prescribed requirements. Therefore, not only was the number of all applicants (see Table 1) the highest in all floats, but also the number of verified applicants had to be cut-off drastically by the DSS priority evaluation procedure in order to select approved applications. The lesson that we learned at that point was that we had to restrict the context by means of some additional requirements in order to maintain the task of loan approval feasible. Also, since we took the stand that the ranks from the DSS had meaningful explanations, we had to approve the loans accordingly. This is the main reason why from the earmarked amount of one billion SIT, the approved sum increased to 1.672 billion SIT.

Having learned the lesson, we limited the purpose of loan consumption in the fourth tender. Namely, apart from the construction of individual houses, buying of only newly built flats was allowed. In Table 1 it can be observed that the main cut-off now falls between the 'All' and 'Verified' applications. The limitation of the purpose of loan consumption has remained in all the following tenders. Besides, in order to achieve a better flexibility, some additional requirements were introduced.

In the fifth tender, buying old flats, which had already been owned by other citizens, was again allowed. However, a new limitation was introduced. The sellers of such flat had to prove that they were investing the money further into buying a new flat or building an individual house. Unfortunately, this limitation turned out to be misunderstood or disregarded by most of the applicants, so there were only about 25% of 'Verified' applications – the lowest of all floats.

In the seventh tender, a new group of context changes was introduced. Besides the purpose of loan consumption, which was limited to the building of individual house, the age of applicants, their current estate ownership status, and stage of their housing problem solving were also subjects to limitation. For instance, only young applicants currently living in their parents' house and building their first house could apply.

By varying these criteria, contexts for more or less all other tenders were formed. Additionally, in the fourteenth tender, a new limitation excluding all applicants that had already acquired a favorable loan was introduced. In the last two tenders, the number of children in applicant's family was also added as a limiting factor. Namely, in the nineteenth tender, only applicants with more than two children could participate. By contrast, the twentieth tender was designated only for young families with up to two children.

A special context occurred in the ninth tender. Here, the Fund offered short-term loans for the renovation of old flats or houses. The earmarked amount was 600 million SIT. However, due to the heavily limited context and, more importantly, less favorable short-term loans, only 35% of the earmarked funds were approved. In this case, it turned out that limiting the context too much might cause undesirable effects, such as decreased interest of citizens for loans.

The relation between the prescribed float conditions and the corresponding evaluation model can be viewed as two concentric circles. The outer circle represents the prescribed conditions, while the inner one represents the decision model. The path of an applicant leads through both circles to their center. First, applicants have to fulfill the conditions of the outer circle in order to become 'Verified'. Then, they have to pass through the evaluation circle to become 'Approved'. The two circles have to be in accordance with each other; the outer one has to restrict the number of applicants so that the task of the inner one becomes more feasible. The context of the outer circle is much broader in the sense that it represents common grounds for a specific float. The context of the inner circle, which is much narrower but of even greater importance, is described in the following section.

2 CONTEXT CHANGES IN EVALUATION MODELS

In the Fund's DSS, the ranking of applications into a priority order is accomplished by qualitative multi-attribute evaluation models developed according to the DEX methodology (Bohanec and Rajkovic 1990). In this section, we analyze the impact of contextual changes to the structure, size, and outcomes of evaluation models. First, using the model that was designed for the eighth float as an example, we introduce basic concepts and terminology of the approach. This is followed by an overview of model structure changes that were needed to adapt the model to the requirements of subsequent floats. Finally, the time series of all models developed so far is studied with respect to model size, number of structural changes that occurred from float to float, and class distributions generated by the models.

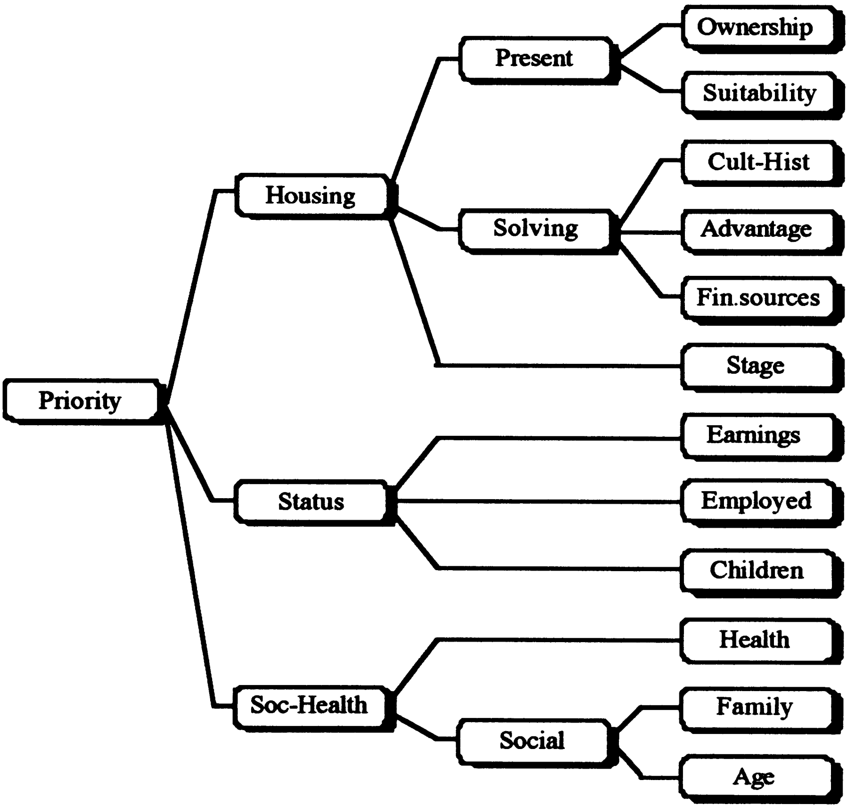

Figure 1 Structure of the evaluation model in Float 8.

4.1 Models for the evaluation of application priority

The aim of **evaluation models** is to establish a partial priority order of applications for loans. Each application is ranked into one of five priority classes, where the class 1 denotes the lowest, and the class 5 the highest priority. The priority is determined according to a hierarchically organized structure of **qualitative attributes** and **decision rules**. For the model that was used in the eighth float, the hierarchy of attributes is shown in Figure 1. It consists of three main subtrees:

1. Applicant's Housing conditions, expressed in terms of the ownership and suitability of present housing, the way of solving the applicant's housing problem, and the stage of solving.
2. Applicant's Status in terms of earnings, the number of employed members of the family, and the number of their children.
3. Social and health conditions of the applicant.

The model is qualitative, so all the involved attributes are discrete: their values are words (labels) that typically express a level of priority. For example, there are three priority levels for the Social attribute: (1) normal, (2) priority, and (3) high_priority. The remaining internal attributes have from two to four similar values, and the root attribute Priority has five values that correspond to the five priority classes. Depending on the position of attributes in the hierarchy, we distinguish between:

- basic attributes: terminal nodes, such as Ownership and Suitability;
- aggregate attributes: all internal nodes (e.g., Status and Social), including the root attribute (Priority).

In the priority evaluation procedure, these two types of attributes are treated differently. The values of basic attributes are obtained from the application form. Aggregate attributes, on the other hand, are evaluated by decision rules, i.e., a set of if-then rules defined according to the Fund's loan allocation policy and propositions of each tender. There is a set of decision rules defined for each aggregate attribute in the model. Table 2, for instance, shows decision rules for the Soc-Health attribute as defined in Float 8.

Table 2 Decision rules for Soc-Health in Float 8 (the asterisk denotes any value)

Health	*Social*	*Soc-Health*
(1) normal	(1) normal	(1) normal
(1) normal	(2) priority	(2) high_priority
*	(3) high_priority	(3) high_priority
(2) priority	*	(3) high-priority

According to the model structure (Figure 1), this attribute depends on two lower-level attributes: Health and Social. Therefore, the table contains a set of rules that uniquely determine the value of Soc-Health for all the possible combinations of Health's and Social's values.

4.2 Changes in model structure

To illustrate typical changes that occur in evaluation models when they are adapted for specific requirements of a new tender, let us start with the model of Float 8 and compare its structure to the models that were developed for later floats.

Float 9 differed from Float 8 in that it offered only less favorable short-term loans for the renovation of old flats or houses. By this, the attributes related to new flats and long-term loans became irrelevant. This affected the Housing subtree of attributes: two attributes, Cult-Hist and Advantage, were removed, and the whole subtree restructured as shown in Figure 2(a). This modification also required a considerable redesign of decision rules for Housing. The remaining two subtrees, Status and Soc-Health, remained the same as in Float 8. Overall, the size of the model decreased from 19 to 17 attributes.

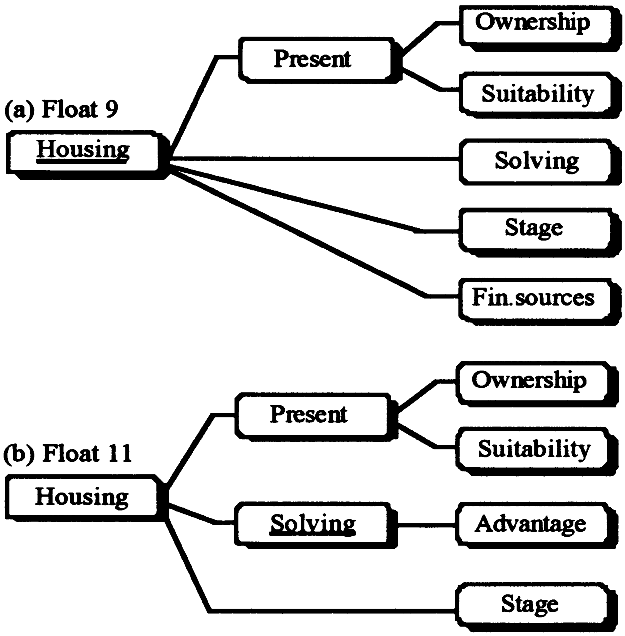

Figure 2 Structure of the Housing subtree in Floats 9 and 11. (The attributes that changed with respect to Float 8, Figure 1, are underlined.)

The next float, numbered 11, was limited to applicants solving their housing problem for the first time by buying a new flat. Different tender propositions again affected the structure of the Housing subtree (Figure 2), which became quite similar to the one of Float 8. Actually, this subtree was copied from Float 8 and adapted by deleting the attributes Cult-Hist and Fin.sources, and redesigning the decision rules for Solving. In addition, based on the experience with previous models, the new model was improved within the Status subtree (see Figure 1). Namely, the attributes Earnings and Employed had been found highly correlated, making the latter practically redundant. Therefore, Employed was removed from the Status subtree, requiring a slight modification of the corresponding decision rules. The overall size of the model decreased again, this time to 16 attributes.

The changes such as the above were typical for most of the floats until Float 14. Usually, a few attributes were added and/or deleted, affecting one or at most two subtrees. Although the majority of changes can be attributed to the changes of float context, there were also changes aimed at the improvement of the model based on the experience with previous floats.

The adaptation itself was, in most cases, relatively easy: it usually required a meeting of the development team with the Fund's management that took about one or two hours, and a few additional hours to test the model and adapt the supporting software. On one hand, this indicates that the approach is flexible and that the evaluation models can be easily adapted to context changes. On the other hand, the fact that such an adaptation had to be performed for each new float, even when it was similar to one of the previous floats, caused a lot of dissatisfaction. More importantly, as the number of different floats increased, so did the number of different models. It became very difficult to compare various models and, consequently, the evaluation results of various floats with each other.

For these reasons, we decided to redesign the model in order to make it more general and stable. All the previous models were reviewed; the most relevant and general common attributes were identified and included in the new model (Figure 3). It was also noted that the majority of previous structural changes occurred in the Housing subtree and were caused by different:

- primary loan purposes, such as buying a new or old flat, or building a house;
- various criteria that were awarded as an advantage to the applicant, for example additional financial sources provided by the applicant to solve his or her housing problem (Fin.sources).

The new Housing subtree was therefore designed to account for these differences. It consists of three subtrees: Present, Stage, and Advantages. While the first two are considered stable, the third one depends on the primary loan purpose. There are four different Advantages subtrees depending on whether the applicant intends to buy a new flat, an old flat, to build a new individual house, or to renew his or her current flat. These subtrees are small and, respectively, consist of 1, 1, 2, and 4 basic attributes. They are the only parts of the model that are expected to change with float context. So far, these expectations have been confirmed. In four subsequent floats, numbered 14, 16, 18, and 19, the structure of models remained exactly the same, including the Advantages subtrees. Only a minor improvement of decision rules was required for Float 18. In the most recent Float 20, a single attribute was added to the four Advantages subtrees. The new attribute, which occurred for the first time in float context, was related to demographic problems of the housing area.

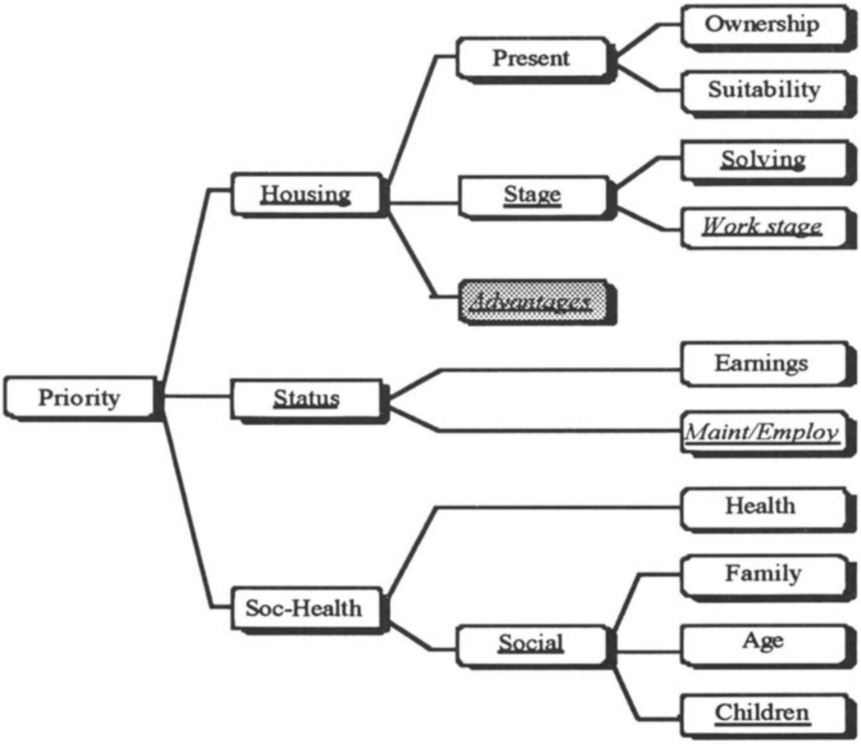

Figure 3 Redesigned model structure for Floats 14, 16, 18, and 19. (Underlined are the attributes that were *added* or modified with respect to Float 8, Figure 1).

4.3 Changes in model size

To assess the extent of changes that occurred in the evolution of the Fund's models, we look at the time series of all models developed so far and analyze them according to various parameters.

We start with model size, i.e., the number of attributes included in the model. Note that the structure, and thus the size, of the models developed since Float 14 depends on the purpose of loan consumption (see section 4.2). To facilitate the comparison with previous models, the most common loan purpose is assumed for these models: buying a new flat. The size of models is represented by a line in Figure 4. In this series, the average size is 18.5.

In addition, each model is compared with a corresponding previous model in terms of the number of attributes that have been added, deleted, and retained from the previous model. These are represented by bars in Figure 4. On average, 2.6

attributes were added, 1.0 deleted, and 15.8 retained from each previous float. Among these, 9 appeared in all the models: 5 basic attributes (Family, Earnings, Children, Age, Health), and 4 aggregate ones (Priority, Status, Soc-Health, Social).

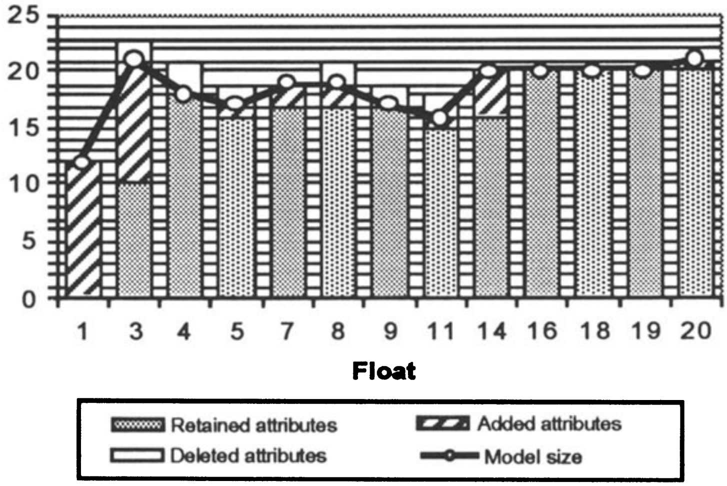

Figure 4 Size of evaluation models together with the number of retained, added and deleted attributes with respect to each previous model.

Three distinctive stages of model evolution can be identified in Figure 4. First, there was a stage of initial model development, which is characterized by a fast growth of the model. Interestingly, this process involved not only one, but two floats in which more than 10 attributes were added per float. This is partially because the first float was somewhat special (see section 3), but mainly because of knowledge and experience gained in the first float.

The second stage comprises Floats 4 to 11 in which the models were gradually adapted to the specifics of each float as sketched in section 4.2. The average model size in this stage was 17.7. To adapt for context changes, 1.0 attributes were added and 1.8 deleted on average for each new float. This is about 6% and 10% of the model size, respectively. The general trend in this stage was towards smaller and more specific models.

The last stage occurred after the model had been redesigned for context change. After adding 4 attributes and considerably restructuring the model for Float 14, it became very stable with respect to size. Even then, however, an unforeseen change of context caused a small increase of model size in Float 20.

4.4 Changes in priority distributions

An important common characteristic of the models is that they classify applications into five priority classes. Both the models and floats can be thus characterized and compared by means of **distributions** of priority classes over a given population of applications. Let A denote a set of applications, and $c \in \{1,2,3,4,5\}$ a priority class. Then, $P_M(c,A)$ is defined as the proportion of applications from A that are ranked by the model M into the class c. We study distributions D_M of P_M over the five classes, so that $D_M = \langle P_M(c,A); c \in \{1,2,3,4,5\} \rangle$.

Depending on the selection of A, we distinguish between **model** and **float** distributions. For model distributions we assume the applications in A to be uniformly distributed with respect to (qualitative) basic attributes of M. Therefore, model distribution can be interpreted as a property of the model itself that indicates its a priori bias regarding the priority classes; it is thus useful for comparing models with each other. In contrast, float distributions are obtained from real applications. In this case, the set A consists of all 'Verified' applications (Table 1) of the corresponding float. Therefore, float distribution is a combined property that depends on both the model and the population that has actually applied in the float.

Two distributions D_1 and D_2 are compared by means of **similarity**, a measure that sums up the relative proportions of applications that are classified equally in both distributions:

$$\mathrm{Sim}(D_1, D_2) = \sum_c \min(P_1(c), P_2(c)), P_1 \in D_1, P_2 \in D_2.$$

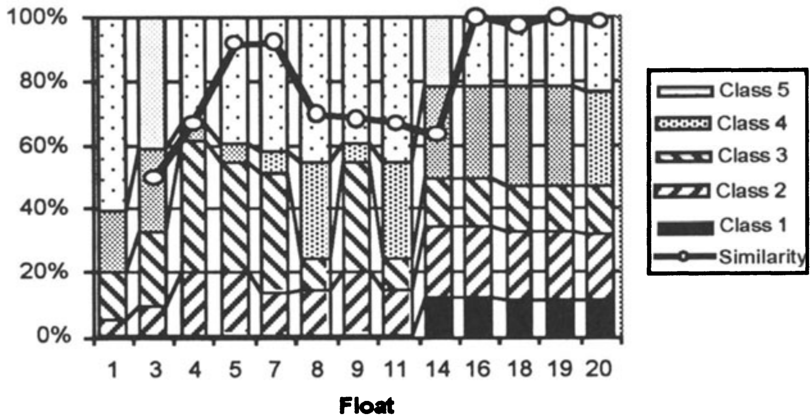

Figure 5 Model priority distributions (bars) and similarity of distributions with respect to each previous model (line)

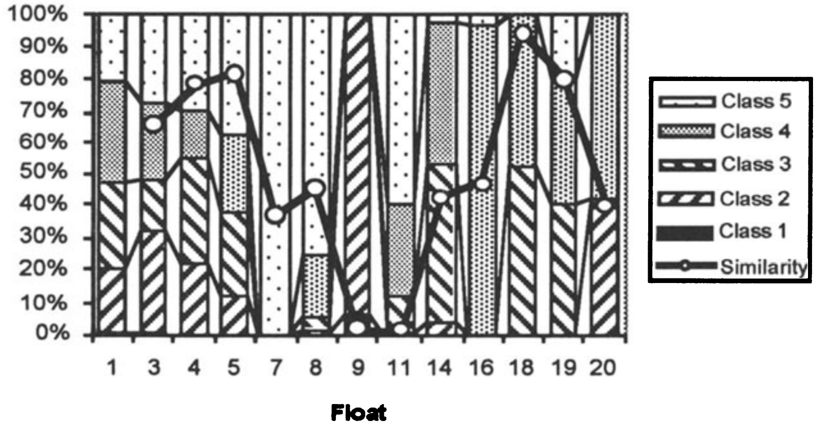

Figure 6 Float priority distributions (bars) and corresponding similarities (line)

Model distributions for the Fund's floats are shown in Figure 5 together with the similarities of sequential pairs of distributions. The similarity curve follows a similar pattern as the size in section 4.3. Up to and including Float 14, the similarity varies between 50% and 92% with the average of 71%, indicating that the adaptations of the model considerably affected its overall behavior. After the redesign of the model, the distributions remained almost constant: two distributions in this period exactly match their predecessors, and the similarities corresponding to Floats 18 and 20 are as high as 97.5% and 98.4%, respectively. The former difference was caused by a minor modification of decision rules, and the latter by the addition of new attribute.

In comparison with model distributions, float distributions (Figure 6) show a much greater variety. In some parts of the series, for instance around Float 9, the similarity is as low as 1%. The average similarity is only 51%, indicating that context changes indeed largely affected the population of citizens applying for loans. In the last five floats, in which practically the same model was used, the similarity of distributions is relatively low as well, ranging from 40% to 91% with the average of 65%. Therefore, as the context was changing considerably, the model remained relatively stable, indicating its robustness to contextual changes.

5 CONCLUSION

We studied qualitative evaluation models that support the principal activity of the Slovenia's Housing Fund: allocation of housing loans to citizens. During 13 completed floats of loans in six years time, the models evolved due to:

- experience gained in previous floats and improved knowledge about loan allocation; and,

- considerable contextual changes that occurred from float to float in terms of available funds, purpose of loan consumption, and requirements prescribed with each tender.

Apart from the initial model development stage, which lasted for two floats, the models evolved in two different stages. First, there were six floats in which the models were gradually adapted to the context of each new float. A typical adaptation affected about 10% to 20% of the model in terms of attributes and decision rules. For the second stage, the model was redesigned to deal with contextual changes. During the last five floats, even though the context was changing, the models remained stable, except for two minor modifications.

The knowledge-based approach to modeling was found highly flexible. In the first stage, it facilitated relatively easy adaptations of models, which took, at most, a few hours. For the second stage, it offered sufficiently rich mechanisms to design the more general and robust model. Also, it facilitated an explicit articulation of a relatively small and isolated part of the model that is expected to change with context.

The approach employed in the first stage had several drawbacks. For each new float, the model had to be adapted to contextual changes. Furthermore, some additional improvements were introduced, causing the series of models to 'drift'. In other words, even when the context of a new float was similar to one of the previous floats, it was impossible just to take the previous model, since the changes that had occurred in the meantime had made it obsolete. This resulted in an increasing number of different models whose maintenance and understanding became more and more difficult. It was also difficult to compare the outcomes of different models and, consequently, different floats.

None of these drawbacks, except the possibility of drift, apply to a model that is truly stable with respect to contextual changes. So far, this has been confirmed with the current Fund's model, which is 'almost' stable. However, an open question for the future is for how long, and to which extent of contextual changes, can its stability really last.

In the Fund's case, it took eight floats and about four years time to attempt the development of a model that accounts for contextual changes. In our opinion, this was motivated and enabled by two prevalent factors:

- sufficient knowledge gained about the context of floats; and,
- sufficient dissatisfaction with difficulties caused by contextual change.

In other words, both 'skill' and 'will' are required to fight with contextual changes.

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8 BIOGRAPHIES

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