Mathematical support for human resource management at universities

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Abstract. Universities in the Czech Republic are required by law to continuously assess and ensure their quality in a verifiable manner. The quality of university staff, primarily of academic staff, is one of the most important aspects of the quality of a university. This paper describes the current state of development of the information system for academic staff evaluation (IS HAP) and for the evaluation of other university staff (IS HOP) with the focus on evaluation methods.

In the IS HAP the use of objectively verifiable information on the activities of academic staff members and their results in the teaching and research is stressed. Input data is acquired from verifiable sources and evaluated against standards determined for different work positions and evaluated areas. The aggregation of partial evaluations is performed by a fuzzy rule base. The calculated evaluations are represented verbally and using colours. The superiors then use these results to derive the overall narrative evaluations.

The IS HOP is based on the assessment of the main areas of activities of other staff by their superiors, linguistic scales are used in their evaluation and colour representation of outputs is used.

Keywords: Human resource management, university, evaluation models, fuzzy sets, information systems.

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1 Introduction

The quality of human resources is a key factor influencing the quality of a university (see [5]). As far as academic staff is concerned, there is a large amount of information that can and should be used while managing them (data concerning the teaching activities of academic staff, data concerning their creative activity and also data on other activities important for the well-being and development of the university). The Structure of applied data varies from university to university (see e.g. [1, 2, 3, 4, 6, 8]). A great deal of the data is currently readily available in various information systems of universities, there are, however, also additional pieces of data worth gathering (as these can be further used by the university itself). It is reasonable to create a specialized information system for the purpose of managing of academic staff. Considering the amount of data required and used for this purpose, it is necessary to not only gather the data in one information system and make it available in full details for further use, but also to process it within the system and to provide the university management with aggregated information useful for the management of human resource. The mathematical model used for the evaluation should be understandable to the evaluators as well as to the people that are being evaluated and most of all it should provide easily and clearly interpretable outputs. The information system should also be a platform for storing the final evaluation report in which the superior reflects both the information provided by the evaluation model as well as his/her own knowledge of the academic staff member and the relevant context. These are the main principles on which the *Information system for academic staff evaluation* (IS HAP) is based (see [7, 10, 12, 13]). This system was created in 2012 at Palacký University Olomouc and it has been continuously further developed since then. The quality of other (non-academic) university staff is also important to ensure proper functioning of the university. Considering the variety of professions of other academic staff, it is more appropriate to use a simpler model for the evaluation. Thus a unified questionnaire can be used by the superiors for the assessment of all non-academic staff members under their supervision concerning the fulfilment of their duties. Again, the clarity of outputs is important for efficient management – mathematical tools are thus again required for the processing and evaluation of data. The

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information system for the evaluation of other university staff (IS HOP) created at Palacký University in 2015 offers a solution to the problem of evaluation of other university staff.

2 Evaluation of academic staff (IS HAP)

2.1 Input data for the evaluation model

Data considering the annual performance of academic staff is inserted in the IS HAP input form. The form is divided into three main areas: teaching activities, creative activities (incl. R&D) and academic offices and managerial duties. The performance evaluation is based on the first two areas; the third area is used to assess the total time-/work-load of the academic staff member. The area of teaching activities (TA) is further divided into three subareas: a) direct teaching, b) supervision of students, c) activities associated with the development of fields of study. The area of creative activities (CA) is divided into the following subareas: a) outputs resulting in RIV points (according to the Czech methodology for the evaluation of scientific outputs), b) other research outputs, c) administrative activities associated with creative activities, d) outputs resulting in RUV points (according to the methodology for the evaluation of creative work outcomes of art universities and faculties). The objectivity of input data is stressed significantly – mainly basic activities for which information can be obtained from reliable and verifiable sources are reported. Additional information provided by the academic staff members themselves is expected to be checked by their superior.

2.2 The evaluation model and its outputs

The selection of activities to be reflected in the evaluation process is a part of the creation of the evaluation model. The selected activities are subsequently assigned points. In the area of teaching activities, the points reflect time consumption and professional requirements. Time-consumption is, however, not a factor in the area of creative activities; excellence of the output is stressed. The basis (and universal benchmark) for the point-evaluation of activities in CA is the amount of points obtained for a paper published in an impact-factor journal, as computed by the following formula

$$b = 10 + 295 \cdot \frac{1 - N}{1 + \frac{N}{0.057}}, \quad N = 1 - \frac{AP}{100},$$

where b is the amount of points assigned for the paper and AP is the average percentile of the journal with respect to the impact factor across all the clusters in which the journal is indexed in the Web of Science. The scores of other activities in this area were determined by comparison with b, in a similar way as it was done in the methodology for the evaluation of outputs of Research, Development and Innovations activities valid in the Czech Republic in the recent years. The evaluations in RUV are determined on the same scale (point-wise).

Evaluation scores of an academic staff member in TA and CA areas are computed as sums of points assigned to the activities the staff member has reported in the given area. It is also possible to set the maximum frequency with which certain activities will be reflected in the overall evaluation score in the given area. This is intended to prevent situations, where a large number of low-point activities would overweight crucial activities and outputs. Its purpose is also to weaken the possible influence of difficult-to-verify data provided by the academic staff members on the overall score in the given area.

The overall scores for TA and CA are standardized with respect to the academic position of the staff member by the following formulas:

$$ta = \frac{b_{TA}}{s_{TA}}, \quad ca = \frac{b_{CA}}{s_{CA}},$$

where ta is the standardized evaluation in TA area and ca is the standardized evaluation in the CA area for each academic staff member on the given position, b_{TA} and b_{CA} are the overall evaluations of the given staff member (point gains) in TA and CA area respectively, and s_{TA} and s_{CA} are the standard scores for the given area and position.

The standard scores are set up during the implementation of IS HAP for a given university/faculty based in the analysis of the data stored in IS HAP and also reflecting the goals of the management of the university/faculty. Statistical tools intended to facilitate the set-up process of standard scores are available directly in IS HAP.

It is necessary to reflect the different character of the scales used for the assessment of performance in TA and in CA (stemming from the different grounds for the determination of scores of individual activities and from different possibilities of getting higher multiples of standard scores in each area of activities) when calculating the overall aggregated evaluation of a given academic staff member. Instead of using some of the usual aggregation methods which assume the same character of the evaluation scales (i.e. weighted average), IS HAP uses the tools of linguistic fuzzy modelling (see [9]) for the aggregation of partial evaluations – linguistic fuzzy scales, fuzzy rule bases and fuzzy inference. Linguistic fuzzy scales currently used in the IS HAP for the interpretation of evaluations
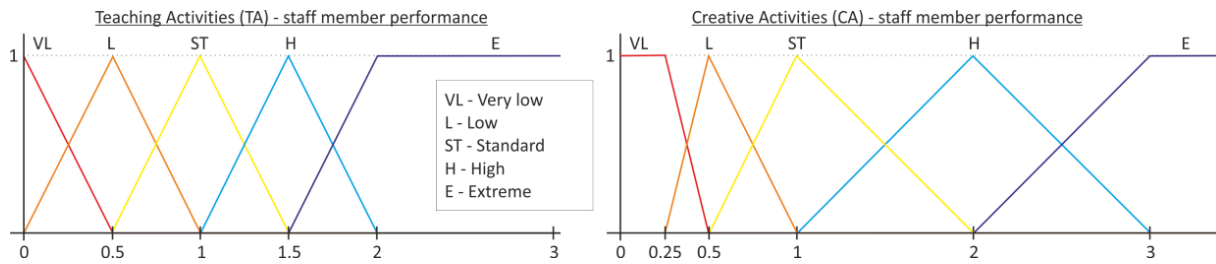
Figure 1: Linguistic fuzzy scale for the assessment of performance of a given academic staff member in TA (left) and CA (right) in IS HAP. Units of the x-axis are multiples of standard scores.
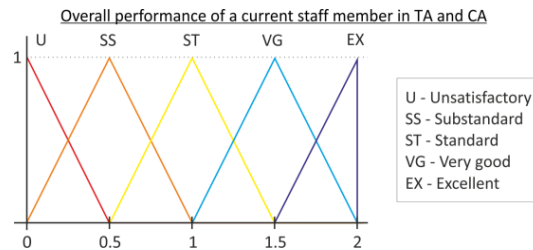

Figure 2: Linguistic fuzzy scale for the interpretation of the overall aggregated evaluation of a given staff member in TA and CA in IS HAP.

in TA and CA areas are depicted in Figure 1, the linguistic scale used for the interpretation of overall performance evaluation of a given academic staff member is depicted in Figure 2. The form of the fuzzy rule base used for the aggregation of partial evaluations in TA and CA areas into an overall performance evaluation depends on the type of faculty; Figure 3 presents a fuzzy rule base used for faculties with a balanced performance in teaching and creative activities, where a lower performance in one of the evaluated areas can, to some extent, be compensated by a higher performance in the other area of activities. When the Sugeno-Yasukawa fuzzy inference [11] is used, the aggregation function derived from the rule base assumes the following form:

$$eval(ta, ca) = \frac{\sum_{j=1}^{25} A_j(ta) \cdot B_j(ca) \cdot ev_j}{\sum_{j=1}^{25} A_j(ta) \cdot B_j(ca)} = \sum_{j=1}^{25} A_j(ta) \cdot B_j(ca) \cdot ev_j,$$

where $eval(ta, ca)$ represents the overall performance evaluation of a given academic staff member computed from his/her standardized partial evaluations ta and ca in TA and CA areas respectively, $A_j(.), B_j(.), j = 1, 2, \ldots, 25$, are all the combinations of pairs of membership functions of the elements of the two fuzzy scales depicted in Figure 1, and ev_j is the value from the kernel of a fuzzy set representing the overall evaluation (see Figure 2 for the 5-element linguistic scale used) corresponding with the j-th combination of fuzzy evaluations in TA and CA areas as specified by the fuzzy rule base depicted in Figure 3.

The output of the above described evaluation model is a real number. However, considering the imprecisions of the overall evaluations (stemming from the fact that all the possibly relevant activities can never be captured by the input form) and also for better interpretability of the outputs, we prefer linguistic and colour representation of the outputs of the evaluation model. A 5-element linguistic scale defined on the $[0, 2]$ universe of discourse of

Overall performance of an academic staff member in TA and CA		Creative Activities performance				
		Very low	Low	Standard	High	Extreme
	Very low	Unsatisfactory	Unsatisfactory	Substandard	Standard	Very good
	Low	Unsatisfactory	Unsatisfactory	Substandard	Very good	Excellent
Teaching Activities performance	Standard	Substandard	Substandard	Standard	Very good	Excellent
	High	Standard	Very good	Very good	Excellent	Excellent
	Extreme	Very good	Excellent	Excellent	Excellent	Excellent

Figure 3: Linguistic description of the fuzzy rule base for the aggregation of evaluations in TA and CA used in IS HAP.

Name	Teaching activities		Creative activities		Overall evaluation	
Academic Staff Member 1 Associate professor (1.00)	Extreme (100%)		High (35%), Extreme (65%)		Excellent (100%)	
	Teaching activities	1615.00	Creative activities	119.15	Overall evaluation	2
	a) lecturing	37.0 %	a) R&D results (RIV)	17.0 %		
	b) supervising students	15.9 %	b) other R&D results	38.6 %		
	c) development of fields of study	47.1 %	c) CA-related activities	44.5 %		
			d) artistic results (RUV)	0 %		
Academic Staff Member 2 Assistant professor (1.00)	Standard (93%), High (7%)		High (11%), Extreme (89%)		Very good (10%), Excellent (90%)	
	Teaching activities	828.00	Creative activities	57.75	Overall evaluation	1.95
	a) lecturing	78.3 %	a) R&D results (RIV)	36.4 %		
	b) supervising students	0 %	b) other R&D results	63.6 %		
	c) development of fields of study	21.7 %	c) CA-related activities	0 %		
			d) artistic results (RUV)	0 %		
Academic Staff Member 3 Assistant professor (0.70)	Low (43%), Standard (57%)		Low (61%), Standard (39%)		Unsatisfactory (4%), Substandard (96%)	
	Teaching activities	440.00	Creative activities	9.75	Overall evaluation	0.48
	a) lecturing	88.6 %	a) R&D results (RIV)	46.2 %		
	b) supervising students	11.4 %	b) other R&D results	53.8 %		
	c) development of fields of study	0 %	c) CA-related activities	0 %		
			d) artistic results (RUV)	0 %		

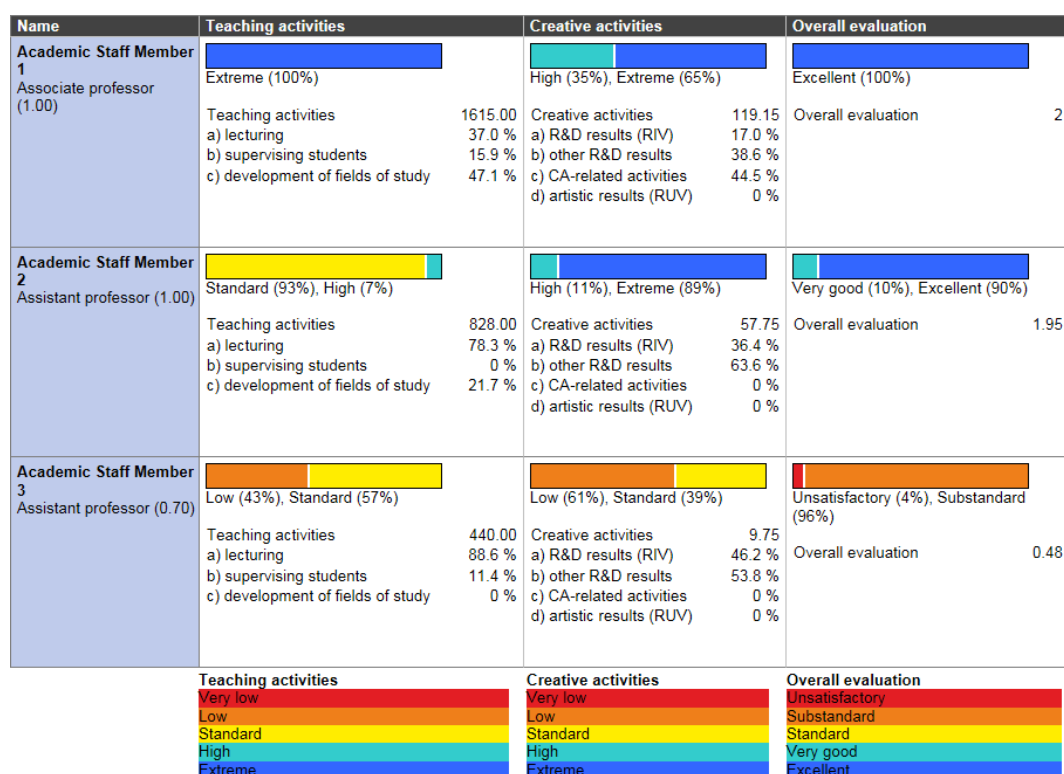| Teaching activities	Creative activities	Overall evaluation
Very low	Very low	Unsatisfactory
Low	Low	Substandard
Standard	Standard	Standard
High	High	Very good
Extreme	Extreme	Excellent

Figure 4: Overview of the evaluations of academic staff members.

the output variable (depicted in Figure 2) is therefore used. Using this linguistic scale, a real-number final output of the evaluation of e.g. 1.6 is thus interpreted as *80% very good* and *20% excellent*, or alternatively using a graphical representation by a rectangle which is 80% light-blue and 20% dark-blue. Partial evaluations in TA and CA areas are represented analogously. The graphical representation also allows for a comprehensive summary of the performance of staff of the whole unit (e.g. department) – see Figure 4.

2.3 Final evaluation of an academic staff member

The IS HAP is a tool for decision support; using this tool, the superiors of the evaluated academic staff members are provided with "hard" data concerning the activities of the academic staff member as well as with an aggregated information characterising his/her performance. The superiors are expected to add "soft" data concerning the given academic staff member relevant for the evaluation and reflect it in the final step of the evaluation process – the evaluation interview. The final narrative evaluation resulting from the evaluation interview is put by the superior into the respective field in IS HAP for storage.

3 Evaluation of other university staff (IS HOP)

3.1 Evaluation questionnaire and its outputs

Unlike academic staff, where the evaluation is based on a large amount of "hard" data and its sophisticated aggregation, other university staff is evaluated by a much simpler model (it is desirable to make the process simpler and the data requirements lower). Nevertheless, also the evaluation of other staff carried out regularly across a long period of time and stored in a specialized information system is an important tool for the management of university human resource. The IS HOP designed for this purpose therefore shares some features with IS HAP – its webpages look similarly and it uses the same organisational structure of the university and the same mechanisms for the identification of staff members. The main difference between the systems lies in the fact that in IS HOP the evaluation is carried out by the superiors of other university staff directly – by a selection of one of the pre-defined answers to the questions (items) of the evaluation questionnaire. The items included in the questionnaire are dependent on the specific requirements of the university/faculty/unit. The questionnaire can include e.g. just basic items concerning the quality of work, attitude to professional development, teamwork and approach to clients (a suggested solution of this type is presented in Figure 5). IS HOP, however, also supports the use of more complex evaluation questionnaires with different numbers of elements of the evaluation scales for each item. The same established way of presenting results as in IS HAP – i.e. graphical representation using colours – is adopted also in IS HOP. The

Figure 5: A screenshot from IS HOP – an example of evaluation questionnaire.

Figure 6: A screenshot from IS HOP – overview of non-academic staff members performance evaluations.

calculation of colours of elements of evaluation scales with different numbers of values represents the mathematical aspect of this model. The standard presentation of outputs in IS HOP is in the form of a linguistically labelled colour profile of each non-academic staff member (see Figure 6). The aggregation of the partial evaluations into an overall evaluation (by a suitable aggregation function) is, however, also possible if required.

4 Conclusion

The system for the evaluation of academic staff performance IS HAP has undergone a rapid development since its initial creation. This included, among other things, the connection to external sources of information and a development of the underlying mathematical evaluation model. Based on the experience with the implementation of IS HAP on different types of faculties of five Czech universities, modifications were made to the evaluation linguistic fuzzy scales for the performance in the evaluated areas and in the linguistic scale used for the interpretation of the overall evaluation. Several alternative rule bases were also developed to be used with different types of faculties and university units. The evaluation methodology of IS HAP has also been significantly improved, namely in terms of the integration of IS HAP into the internal system for quality assessment at universities. The system for the evaluation of other (non-academic) university staff IS HOP is in an earlier stage of development, its place in the internal system for quality assessment at universities is, however, also undeniable.

Acknowledgements

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