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An Evaluation of Employee Performance Based on Imprecise Value Judgments

Two Experiments

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Abstract

In this paper we test the usefulness of imprecise value judgments in evaluating employee performance. The test is based on two experiments which evaluate the performance of college lecturers. The experiments are carried out by applying the PRIME model (Preference Ratios in Multi-attribute Evaluation), a specific multi-attribute value model that supports the use of imprecise value judgments. The test shows that the use of imprecise value judgments, as synthesized by the PRIME model, can remedy a number of defects that are identified in conventional evaluation models in regard to job requirements and employee performance.

KEY WORDS: employee performance; imprecise value judgments; salary compensation

1. Introduction

Job requirements and employee performance are usually evaluated on the basis of a complex aggregate of those criteria and attributes considered relevant to a rational structure of salary compensation. The complexity of this evaluation is often increased by its being based on the assessment of criteria and attributes that lack a precise definition – something that adds a degree of subjectivity to the process. Assessments of an employee's relative degree of responsibility or social competence are typical examples of such vague criteria. In spite of this, many frequently used and conventional models for evaluating employee performance and job requirements not only utilize obviously fuzzy, vague value judgments, but also present these in the guise of precise numerical quantities. This gives the impression that the basic value judgments possess much greater precision than is in fact the case. The resultant job and employee-performance evaluation presents numerical information whose precision is, in fact, artificial and arbitrary. It gives, therefore, a biased presentation of the imprecise value judgments that form its base. This false precision obfuscates the link between the value judgments upon which the evaluation rests and the evaluation results. This is an unsatisfactory situation, especially as increases in non-standardized jobs and individualized systems of salary compensation have led to an increased use of this type of employee evaluation (Lazear, 1998; Kira, 2000). Furthermore, many Equal Pay Acts support the use of job evaluation in order to investigate salary discrimination by gender. A possible way to remedy this problematic situation is to use evaluation models that support the use of imprecise or vague value judgments.

The aim of this paper is to test the usefulness of applying a specific multi-attribute value model, termed PRIME (Preference Ratios in Multi-attribute Evaluation), that supports the use of imprecise value judgments in evaluating employee performance. The test is carried out as two experiments that evaluate the performance of a restricted number of academic lecturers at Södertörn University College. The imprecise and basic value judgments are modeled by numerical intervals, the length of which represents the relative degree of imprecision of value judgments. The software, PRIME Decisions, can be downloaded from: www.hut.fi\Units\SAL\Downloadables\ (Salo and Hämäläinen, 2001; Gustafsson et al, 2000).

As far as we know the PRIME model has not been applied in the context of evaluation of jobs and employee performance. Therefore we decided to delimit the experiments in several respects in order to make a first test more tractable. In the first place, the evaluation of lecturer performance is restricted to a subset of those criteria considered relevant for salary compensation at Södertörn University College. Secondly, the paper does not address many important questions of principles concerning the relation between individualized salary compensation and employee performance – questions such as: What principles should be applied for choosing relevant criteria and for evaluating employee performance? Who should develop such principles? How should the evaluation procedure be organized? and so on. Discussion of such issues should only occur, most appropriately, once the test of the PRIME model supporting imprecise value judgments and its thorough introduction to the decision makers have been completed. These delimitations mean of course that results of the evaluations carried out in the experiments cannot be used without further development in an actual salary setting process. Instead the value of the experiments is to gather experience from using evaluation models such as PRIME that support the use of imprecise value judgments. Such experience is an important basis for the further development of methods, which gives rise to more reliable evaluation of jobs and of employee performance.

The paper is organized as follows. The next section offers a brief description and a critical analysis of a conventional evaluation method, here termed the “point rating” model. This method, which is often used to evaluate job requirements and employee performance, is recommended by the European Project on Equal Pay, which is supported by European Commission (Harriman & Holm 2001). The third section introduces the PRIME model. The fourth section presents the two experiments and ends with a comparison of the PRIME- and the “point rating”- models. The fifth section concludes the paper with a final discussion of the superiority of the PRIME model.

2. A conventional evaluation method

The “point rating” model defines an evaluation process as follows:

1) The decision maker (here abbreviated as DM) defines a set of relevant criteria:

$$C_1, C_2, ...C_k, ..., C_n \quad C_k = \text{criterion } k$$

2) Each criterion is then divided into a number of category-levels:

$$L_k^j \in C_k$$

L_k^j = jth level of criterion k

3) The DM ranks the levels:

$$L_k^{\max} \succ \ldots \succ L_k^j \succ \ldots \succ L_k^{\min}$$

4) The DM rates the levels based on qualitative judgments as described in Table 1:

Table 1: Qualitative judgment and rating of levels

Levels of a criterion	*Qualitative judgment*	*Rating*
L_i^5	*Very high performance*	$v_i(L_i^5) = 5$
L_i^4	*High performance*	$v_i(L_i^4) = 4$
L_i^3	*Normal performance*	$v_i(L_i^3) = 3$
L_i^2	*Low performance*	$v_i(L_i^2) = 2$
L_i^1	*Very low performance*	$v_i(L_i^1) = 1$

5) The DM assesses the relative importance of each criterion, which is represented by numerical weights. The sum of the weights is by convention normalized to 100%, i.e.

$$\sum_{i=1}^{i=n} w_i = 100\%$$

6) The DM collects information of each employee performance, which can be represented as a performance profile:

$$P(E^k) = \langle p_1^k, p_2^k \ldots, .p_j^k \ldots, \ldots, p_n^k \rangle$$

E^k = employee k

p_j^k = employee *k's* observed performance of criterion *j.*

7) The DM collapses the observed employee performance into the category-levels:

$$P(E^k) = \langle L_1^{E^k}, L_2^{E^k} \ldots, .L_j^{E^k} \ldots, \ldots, L_n^{E^k} \rangle$$

E^k = employee k

$L_j^{E^k}$ = level of criterion *j* judged by DM as appropriate for employee *k's* performance.

8) The DM defines the overall value of each profile as:

$$V(E^k) = \sum w_j v_j (L_j^{E^k})$$

where $w_j =$ relative weight of criterion j

$v_j(L_j^{E^k}) =$ rating of level $L_j^{E^k}$

9) The DM ranks employees based on the overall value of each performance profile.

$$E^k \succ E^l \quad \text{if and only if} \quad \sum w_j v_j(L_j^{E^k}) > \sum w_j v_j(L_j^{E^l})$$
$$E^k \sim E^l \quad \text{if and only if} \quad \sum w_j v_j(L_j^{E^k}) = \sum w_j v_j(L_j^{E^l})$$

Thus the ranking of employees is based on an additive value model specified by precise numerical information regarding weights and value functions. The ranking's reliability and stability is questionable, however, because no justification is given for representing the value judgment as precise numerical information. This questionable translation of value judgments into precise numerical information is especially noticeable in steps 4, 5 and 7.

In step 4, the qualitative value judgments expressed by verbal statements, as in Table 1, are represented by an equal interval rating scale, which implies that the DM assesses the value difference between all pairs of adjacent performance levels as equal, i.e.

$$V_i\ (L_i^5) - V_i\ (L_i^4) = V_i\ (L_i^4) - V_i\ (L_i^3) = V_i\ (L_i^3) - V_i\ (L_i^2) = V_i\ (L_i^2) - V_i\ (L_i^1)$$

However, no check is carried out if an equal interval rating scale is consistent with the DM's intuition about value differences between adjacent levels. Thus, the assumed equal interval rating scale might be a biased representation of the DM's possible assessment of value differences between adjacent levels.

In step 5, the assessment of the relative importance of the criteria represented by precise numerical weights is based on an equally arbitrary use of numbers. An elucidation of the weights' function in the additive value model makes this obvious. The weights of two criteria, w_i and w_j, representing the DM's intuition about the relative importance of the two criteria, imply that the value difference between two adjacent levels regarding criterion *i*, i.e. L_i^{k+1} and L_i^k is $\frac{w_i}{w_j}$ times larger than the corresponding value difference regarding criterion *j*, i.e. L_j^{m+1} and L_j^m. In order to defend such precise trade-off statements a tedious process of constructing different levels is required. But no such procedure is described when "point rate" models are used.

Further, there is no explicit reference to the ranges of each criterion, i.e. the value difference between the highest and lowest ranked level of each criterion, something which might give rise to biased and inappropriate assessments of the relative weights of the criteria.

In step 7 a deformation occurs because each employee performance profile is collapsed into the constructed category-levels. A possible deformation can formally be described as follows:

$$P(E^k) = \langle p_1^k, p_2^k, ...,. p_j^k, ..., p_n^k \rangle \text{ and } P(E^l) = \langle p_1^l, p_2^l, ...,. p_j^l, ..., p_n^l \rangle$$

and $p_j^k \succ p_j^l$ for all criteria C_j, which signifies that profile $P(E^k)$ dominates profile $P(E^l)$. However, the two employee performance profiles can be collapsed into an identical performance profile in terms of category-levels if the DM judges the difference between the two employee performances to be too small to be collapsed into different category-levels. Thus the two employees are ranked equal, even though one of the employee performance profiles obviously dominates the other.

Even if the representation of value judgments as precise numerical data is justified by the careful construction of levels, one cannot disregard the possibility of "errors" occurring during the evaluation procedure. In such cases a sensitivity analysis should be carried out in order to test for the stability of rankings for relative small changes in the value functions and weights. However, systematic sensitivity analysis is, it seems, not included in evaluations using a "point rating" model.

We can summarize the defects we have identified in the "point rating" model as follows:

1) An arbitrary use of numbers is employed to translate basic value judgments into misleadingly precise numerical representations.
2) The assessment of weights is carried out with no explicit reference to the range of each criterion.
3) The observed employee performance is collapsed into profiles of category-levels.
4) Those who use the model do not test the stability of rankings through a sensitivity analysis.

Finally, we want to point out that this critique concerns common practice on the evaluation of jobs and are not a general comment on the possibility of applying additive value models in a well founded way. This is done, for instance, in Edwards and von Winterfeld 1986, who demonstrate an evaluation procedure that gives rise to consistent equal interval rating scales and appropriate weights.

In using the PRIME model, which supports imprecise value judgments, we avoid the tedious task of constructing levels consistent with an equal interval rating scale and assessing weights that can justify application of precise numerical information. (For other attempts to model imprecise value judgments, see e.g. Spyridakos et al., 2001 and Dasgupta, 1998.) In the next section we shall describe the PRIME model and its application in the experiments concerning the evaluation of lecturer performance.

3. The PRIME model and evaluation of lecturer performance

3.1. PRIME model

The PRIME model is based on multi-attribute value theory. (For an extensive description of the model and its applications, see Salo and Hämäläinen 2001.) The PRIME model is implemented by a software package called PRIME Decisions, which is a decision-aid that offers interactive decision support. PRIME Decisions can be downloaded from: www.hut.fi\Units\SAL\Downloadables\ (Gustafsson et al, 2000).

In the PRIME model, the overall values of alternatives, which correspond to lecturers in this study, are defined by an additive value model:

$$(1)\ V(E^l) = \sum v_i(p_i^l)$$

The model can be rewritten as:

$$(2)\ V(E^l) = \sum w_i \cdot v_i^N(p_i^l),$$

where $v_i^N(p_i^l) = \dfrac{v_i(p_i^l) - v_i(p_i^{\min})}{v_i(p_i^{\max}) - v_i(p_i^{\min})}$, and by convention: $v_i(p_i^{\min})$ =0,

which implies that: $v_i^N(p_i^l) \in [0,1]$, and

$$w_i = v_i(p_i^{\max}) - v_i(p_i^{\min}),$$

i.e. the attribute weights relate unit increases in normalized value functions to increases in the overall value.

The overall value of an ideal profile, i.e. $P(E^{\max}) = \left\langle p_1^{\max}, p_2^{\max}, ..., p_n^{\max} \right\rangle$, is normalized to one, i.e.

$$(3)\ V(E^{\max}) = V\langle p_1^{\max}, ..., p_n^{\max} \rangle = \sum_{i=1}^{n} w_i \cdot v_i^N(p_i^{\max}) = \sum_{i=1}^{n} w_i = 1$$

The PRIME Decisions has a feature called *elicitation tour*, which guides the DM through a specific sequence of elicitation steps as follows:

Step 1: Ordinal value judgments

The DM is asked to rank performance regarding each criterion. The ranking is represented by an ordinal value function:

$$(4)\ v_i(p_i^{\max}) > v_i(p_i^{l}) > ...... > v_i(p_i^{k}) > v_i(p_i^{\min})$$

Step 2: Cardinal value judgments

The DM is asked to elicit cardinal judgments regarding value differences between pairs of ranked performances. The imprecise cardinal value judgments are represented as interval-valued statements about ratio estimates regarding two value differences. For instance, a comparison of value difference regarding pairs of adjacent performances can be expressed as ratio estimates:

$$(5)\ L \le \frac{v_i(p_i^{l+1}) - v_i(p_i^{l})}{v_i(p_i^{k+1}) - v_i(p_i^{k})} \le U$$

The interval [L, U] represents the degree of imprecision of cardinal value judgments regarding the two value differences. However, the PRIME model supports ratio estimates of value differences regarding arbitrary pairs of performances:

$$(6)\ L \le \frac{v_i(p_i^{k}) - v_i(p_i^{l})}{v_i(p_i^{m}) - v_i(p_i^{\mathrm{n}})} \le U \text{, given that } v_i(p_i^{k}) > v_i(p_i^{l}) \text{ and } v_i(p_i^{m}) > v_i(p_i^{n})$$

Step 3: Weight assessment

The DM is asked to assess the weights by:

1) choosing a reference criterion, which is assigned the weight of 100%.
2) comparing the value difference between the highest and the lowest ranked performance regarding each criterion relative to the corresponding value difference of the reference criterion. The assessments are represented by imprecise ratio estimates as:

(7) $$\frac{L}{100} \leq \frac{w_i}{w_{ref}} \leq \frac{U}{100} \Leftrightarrow \frac{L}{100} \leq \frac{v_i(p_i^{\max}) - v_i(p_i^{\min})}{v_{ref}(p_{ref}^{\max}) - v_{ref}(p_{ref}^{\min})} \leq \frac{U}{100},$$

where [L, U] is the numerical interval mapping the degree of imprecision of weight assessments.

The interval-valued statements expressed by the DM in an elicitation tour are translated into a number of linear constraints, which define a set of feasible weights as: $w = \langle w_1, \ldots\ldots, w_n \rangle \in S_w \subset W = \{w | w_i \geq 0, \sum_{i=1}^{n} w_i = 1\}$, and sets of feasible scores as: $v_i(p_i^l) \in S_i^l \subset [0,1], i = 1, \ldots, n$, where $S_i^l =$ set of feasible scores for alternative E^l, i.e. lecturer E^l, w. r. t. criterion *i*.

Based on the linear constraints the overall value of each performance profile is represented by a value interval computed from the two linear programs:

(8) $$V(E^l) \in \left[\min \sum_{i=1}^{n} w_i v_i(p_i^l), \max \sum_{i=1}^{n} w_i v_i(p_i^l) \right] = \left[\min V(E^l), \max V(E^l) \right],$$

$$\text{s.t. } w = \langle w_1, \ldots\ldots, w_n \rangle \in S_w \text{ and } v_i(p_i^l) \in S_i^l \subset [0,1], i = 1, \ldots, n.$$

3.2. Dominance criteria and decision rules

PRIME Decisions provides two dominance criteria and several decision rules to help the DM rank the alternatives, in this case lecturer. The *absolute dominance criterion* is defined as:

$$(9)\ E^k \succ_D E^l \Leftrightarrow \min V(E^k) > \max V(E^l)$$

According to the *absolute dominance criterion* lecturer E^k is ranked higher than E^l if the smallest possible value of E^k exceeds the largest possible value of E^l. The *absolute dominance criterion* can only be used for pairs of alternatives with nonoverlapping value intervals. In the event of overlapping value intervals, the *pairwise dominance criterion* has to be applied. The *pairwise dominance criterion* is defined as:

$$(10)\ E^k \succ_D E^l \Leftrightarrow \max[V(E^l) - V(E^k)] < 0 \Leftrightarrow \max[\sum_{i=1}^{n} w_i v_i\,(p_i^l) - \sum_{i=1}^{n} w_i v_i\,(p_i^k)] < 0\,,$$

which holds for all combinations of feasible weights and feasible scores as:

1) $w = \langle w_1, ..., w_n \rangle \in S_w \subset W = \{w | w_i \geq 0, \sum_{i=1}^{n} w_i = 1\}$.

2) $v_i(p_i^k) \in S_i^k \subset [0,1], i = 1,...,n$ and $v_i(p_i^l) \in S_i^l \subset [0,1], i = 1,...,n$.

According to this criterion lecturer E^k is ranked higher than lecturer E^l if and only if the overall value of E^k exceeds that of E^l for all feasible solutions of the linear constraints implied by the interval-valued statements in an elicitation tour. A non-dominance relation occurs if the inequality in (10) does not hold, i.e. if there are overall values implying that: $V(E^l) > V(E^k)$. The interpretation of a non-dominance relation between a lecturer E^k and a lecturer E^l is that the DM's value information is not sufficiently precise in order to determine a ranking between the two lecturers. In that case any of the decision rules provided by PRIME Decisions can be applied.

In PRIME four decision rules are stated: 1) minimax 2) maximax 3) minimax regret 4) central values. The definition and the performance of the decision rules are discussed in Salo and Hämläinen, 2001, who recommend on the basis of simulations the minimax regret criterion and the application of central values since they consistently outperform the other rules. In the experiments below we prefer to use the central values owing to ease of computations. The central values are defined as the mid-value of the value intervals defined in (8).

In PRIME Decisions the computation of overall value intervals, weights, and dominance structures is based on linear programs, the solution of which is based on techniques that require plenty of calculation capacity, such as Simplex. PRIME Decisions does not put any a priori restrictions on the number of criteria, the number of alternatives, or the number of levels in a value tree. Computation time is roughly proportional to the third power of the number of linear program problems. The number of these problems, in turn, depends on the number of criteria, and alternatives (Gustafson et al., 2001). With few criteria and alternatives the computation time is very short. In the experiments below the computation time was about 30 seconds on a Pentium III 833 MHz with 128 MB of RAM. After the calculation has finished the results are available in a Windows menu.

3.3. Ranking of lecturers and salary compensation

Applying the dominance criteria allows a dominance structure over lecturers to be established as regards an overall evaluation of their performance. The dominance structure can serve as a guideline for salary setting as follows:

> If a lecturer E^k is ranked higher than lecturer E^l according to the dominance criteria then the DM can justify a higher salary compensation to lecturer E^k than to lecturer E^l.

Thus despite imprecise value information the DM can justify different salary compensation to different lecturers. However, if a non-dominance relation occurs between two lecturers and it is the case that the DM cannot justify more precise value information, then the DM cannot justify different salary compensation for the two lecturers. However, the DM can decide to use the decision rules as recommended by central values in PRIME Decisions in order determine a ranking between the two lecturers.

There is also another reason that might force the DM to apply central values in order to determine a ranking between lecturers related by non-dominance. The reason stems from the fact that non-dominance is an intransitive relation. It might be the case, say, that non-dominance occurs between lecturer E^k and E^l, and between E^l and E^m, respectively, whereas E^k dominates E^m, i.e. denoting the non-dominance relation by "$\sim_{Non-D}$" implies that: $E^k \sim_{Non-D} E^l, E^l \sim_{Non-D} E^m$ and $E^k \succ_D E^m$.

Obviously, an intransitive order gives rise to inconsistent recommendations concerning salary compensations; however, complementing the established partial ranking with calculated central values solves the problem with intransitivity. However, in the experiments presented in the next section, occurrences of non-dominance between pairs of lecturers did not to give rise to intransitivity.

In this study the central values will also be used for another purpose. Since the dominance criteria only determine a ranking, there is no information about relative value differences among ranked lecturers. Central values can be used in order to estimate reasonable value differences among lecturers, which can serve as a guideline for setting appropriate relative salary compensation among lecturers. This is done in the second experiment.

4. The experiments

4.1. Background

We have tested the usefulness of imprecise value judgments in the process of evaluating employee performance by using them in two experiments, both carried out at Sweden's Södertörn College. Ever since its foundation in 1997, the University College has set its lecturers' salary according to a system of compensation based on individual performance, assessed over specific periods of time. The "point rating" model discussed above has frequently been used in evaluating Södertörn employee performance. This enables us to use the defects of the "point rating" model, as identified above, as a point of departure when evaluating the modeling of imprecise value judgments in the PRIME model. The two experiments, which we have termed "Experiment I" and "Experiment II", are restricted, for methodological reasons, to a sample of six and seven lecturers respectively. The lecturers are ranked solely on the basis of an assessment of their relative scientific ability, which is defined by a number of sub-criteria.

4.2. Procedure

The Södertörn experiment was preceded by a meeting at which two decision makers taking part in experiment I and II, respectively, were alerted to the defects of the "point rating" model and then introduced to the PRIME model. This was done by using a simple example, in which four hypothetical employees were ranked according to two well defined criteria. In our experience, an introduction of the PRIME model requires careful elucidation by giving simple examples of the elicitation tasks to decision makers lacking experience of multidimensional models supporting imprecise value judgments, which differ in nature from simple point rating models as discussed in section 2. The decision maker taking part in experiment I is a department chairman for a multidisciplinary department and in experiment II is an associate professor and the Department Chair of History at the University College.

The evaluation procedure carried out in the two experiments presented below was based on personal interviews with the decision makers. Since the PRIME model facilitates interactive work, the decision makers received immediate feedback on their judgments. The evaluation procedure in both experiments took approximately two days, excluding the time needed to sample employee performance data.

4.2.1. Experiment I

The first experiment was based on a sample of six lecturers. Their self-reported performance, regarded as relevant for evaluating scientific ability, is presented in Table 2. The evaluation procedure consisted of personal discussions and correspondence with the lecturer's Department Chairman**.**

Table 2: Performance regarding scientific ability

	Criteria of scientific ability					
Lecturer	*Senior lecturer*[1]	*Examiner*[2]	*Expert adviser*[2]	*Research funds*[3]	*Research team work*	*Number of Publications*
A	No	No	Yes	75%	Normal	3
B	Yes	No	Yes	50%	High	4
C	No	Yes	No	50%	Normal	0
D	No	No	No	50%	Normal	6
E	Yes	No	No	50%	Normal	3
F	No	No	No	50%	Low	3

Notes: 1. "Yes" = have become senior lecturer during the relevant period of time"
2. "Yes" = have been an examiner or expert adviser.
3. "75%" and "50%" means that an application for research funds has been accepted, measured in per cent of full time.

Step 1: Ordinal value judgments

Senior lecturer: V_1(“Yes”) > V_1(“No”)

Examiner: V_2(“Yes”) > V_2(“No”)

Expert adviser: V_3(“Yes”) > V_3(“No”)

Research funds: V_4(“75%”) > V_4(“50%”)

Research team work: V_5(“High”) > V_5(“Normal”) > V_5(“Low”)

Number of publications: V_6(“6”) > V_6(“4”) > V_6(“3”) > V_6(“0”)

In contrast to the “point rating” model, where the employee performance is first collapsed into levels, the ranking occurs in accordance with the employee’s observed performance.

Step 2: Cardinal value judgments

Cardinal value judgments are only meaningful regarding the two last criteria. The DM suggested the following cardinal value judgments, represented as a ratio estimate, as intuitively reasonable:

Research team work: $\frac{V_5(\text{"High"}) - V_5(\text{"Normal"})}{V_5(\text{"Normal"}) - V_5(\text{"Low"})} = 1$

This judgment of equal value differences between the three levels is similar to judgments implied by a rating model that uses fixed and equal interval rating scales. However, the difference is that when using the PRIME model the DM is forced to explicitly formulate this judgment, which is not given beforehand on an equal interval rating scale.

Number of publications:

$$1)\ \ 3 < \frac{V_6(\text{"3"}) - V_6(\text{"0"})}{V_6(\text{"4"}) - V_6(\text{"3"})} < 6 \quad \text{and} \quad 2)\ \ \frac{V_6(\text{"6"}) - V_6(\text{"4"})}{V_6(\text{"4"}) - V_6(\text{"3"})} = 1$$

In the first value judgment the DM suggests that the value difference between “no publications” and “3 publications” is at least three times larger, but less than six times larger then the value difference between “4 publications” and “3 publications”. The imprecise value judgment represents the DM's intuition concerning possible accuracy of cardinal value judgments regarding publications. In other words, the DM thinks that values outside the interval [3, 6] are intuitively unreasonable.

The second value judgment implies that the DM's intuition suggests the value difference between 3 and 4 publications is equal to the value difference between 4 and 6 publications. This corresponds to a decreasing marginal value regarding number of publications. Thus the PRIME model can easily, in addition to imprecise value judgments, consider decreasing (or increasing) marginal values.

Step 3: Assessment of weights

The DM chooses "senior lecturer" as a reference criterion and suggested three weight profiles. In the first profile, all criteria are given equal importance, which seems to have been common practice in previous evaluations of lecturer performance. Confronting the DM with the consequences of suggesting equal weights in this case makes it obvious for the DM that this is an unreasonable weighting. After all, such a weight profile implies that the value difference between "has become a senior lecturer" and "has not become senior lecturer" equals the value difference between "has been an examiner" and "has not been an examiner" – a counter-intuitive value judgment from the perspective of salary compensation. Therefore, it is important that weights are assessed with explicit consideration of the ranges of the criteria, which does not seem to hold for the "point rating" model. In the second profile more reasonable weights are suggested. The DM feels that the second weight profile represents more reasonable weights if we ignore that weights are given by precise numeric information. The third weight profile extends the second profile by adding imprecise judgments on the relative importance of the different criteria. The third weight profile is extended by imprecise but more realistic assessments of the weights.

Table 3: Assessment of weights

Criteria	*Value differences*[1]	*Weights* *Profile I*	*Profile II*	*Profile III*
Senior lecturer	V_1("Yes") - V_1("No")	100%	100%	100%
Publications	V_2("6") - V_2("0")	100%	70%	60-80%
Research team work	V_3("High") - V_3("Low")	100%	40%	30-50%
Research funds	V_4("75%") - V_4("50%")	100%	5%	1-10%
Examiner	V_5("Yes") - V_5("No")	100%	10%	5-15%
Expert adviser	V_6("Yes") – V_6("No")	100%	10%	5-15%

Note: 1. Value differences regarding the highest and lowest ranked performance.

The overall values based on the three weight profiles are presented in Figures 1a-c. The increasing value intervals, when moving from Figure 1a to 1c, represent an increasing imprecision of the value judgments. The ranking of the lecturers based on weight profile I and II are obvious by inspection of figure 1a-b. However, weight profile III gives rise to overlapping value intervals of lecturer A and D and lecturer F and C, respectively. The application of the pairwise dominance criterion implies a non-dominance relation between lecturer A and D and lecturer F and C, respectively.

Figures 1a: Overall values based on weight profile I

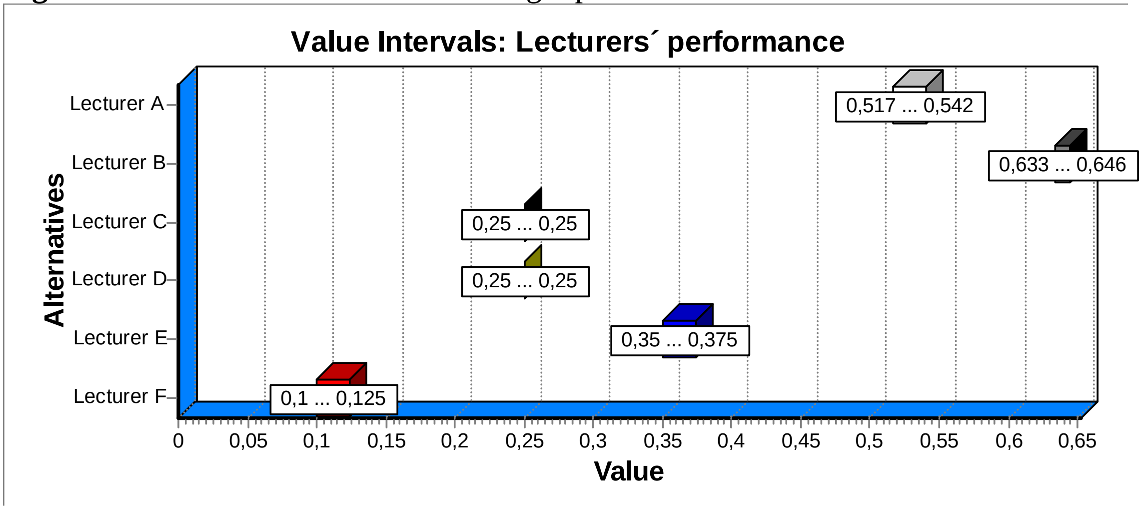


Figure 1b: Overall values based on weight profile II

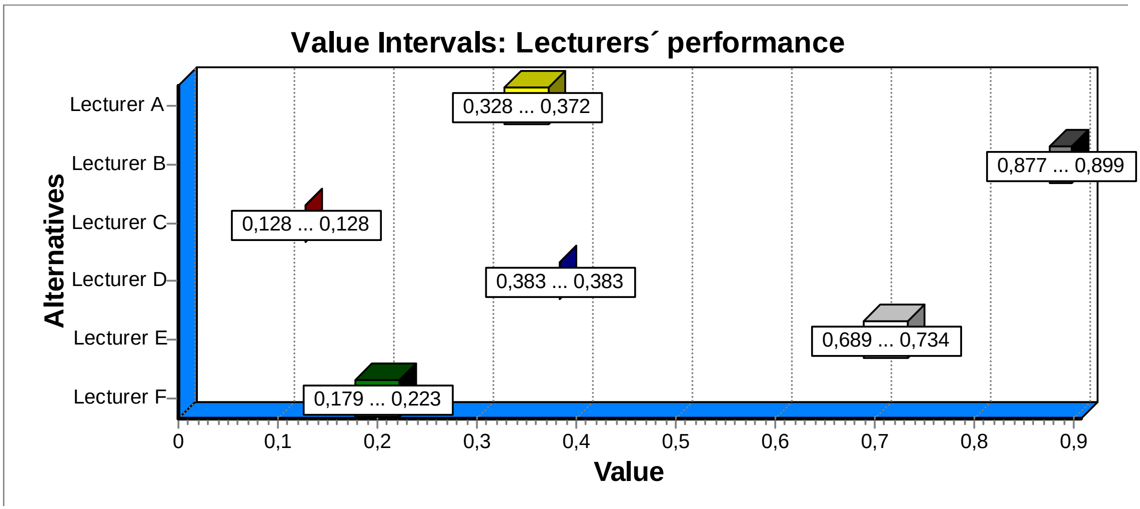


Figure 1c: Overall values based on weight profile III

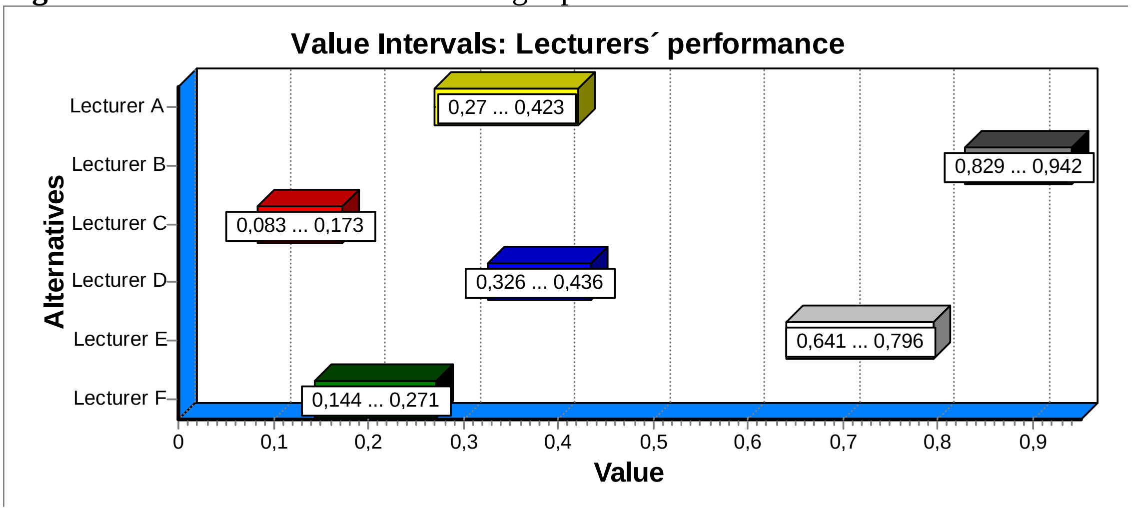


Table 4: Rankings based on the weight profiles I-III.

Weights	*Rankings*
Profile I	B $\succ$ A $\succ$ E $\succ$ (C, D) $\succ$ F
Profile II	B $\succ$ E $\succ$ D $\succ$ A $\succ$ F $\succ$ C
Profile III	B $\succ$ E $\succ$ (A, D) $\succ$ (F, C)

Note: 1. The rankings are based on the pairwise dominance criterion, see (9).
2. Non-dominance in parentheses.

As shown in Table 4 and Figures 1a-c, there is an important difference between the first ranking, and the other two rankings. The first ranking should be excluded as a guideline for salary compensation because it is based on an unreasonable assessment of weights. Yet such rankings are possible when using the "point rating" model. The second ranking should be excluded because it is based on unreasonably precise value judgments – as are typical of the "point rating" model. Using the third ranking as a guideline for salary compensation means the DM cannot justify different salary compensation to lecturers A and D, and lecturers F and C, respectively, due to the occurrence of non-dominance. However, if the DM decides to use central values in order to determine ranking there are reasons to differentiate between lecturers A and D and lecturers F and C, respectively, regarding salary compensations. The rankings according to central values are: $V^C(D) = 0.38 > V^C(A) = 0.35$, and $V^C(F) = 0.21 > V^C(C) = 0.13$.

4.2.2. Experiment II

The sample in Experiment II consisted of seven history lecturers. The lecturers were ranked by evaluating their relative scientific ability, as measured by seven sub-criteria: *international publications, national publications, publication in anthologies, published books, function as examiner and/or expert adviser, member of a research project team,* and *leader of a research project*. The evaluation procedure was carried out with the assistance of an associate professor, who is the Department Chair of History at Södertörn University College.

In Experiment II, it was possible to pay more consideration to the relative quality of the lecturers' publications than in Experiment I. This was possible for two reasons. First, the evaluation was carried out by a person (the department chair) who possessed academic competence within the discipline; and, second, because the criterion

”Production of publications” was divided into four sub-criteria: *international publications, national publications, publication in anthologies,* and *published books*.

In the presentation of the evaluation procedure the lecturers are denoted by the letters A to G. The evaluation of performance is expressed as $V_I(B) =$ value of lecturer B’s performance regarding criterion I, etc.

The evaluation procedure as defined by the PRIME model occurs in the three steps. In this case, step 2 (the cardinal value judgments) is divided into two parts: (a) precise cardinal value judgments, and (b) imprecise cardinal value judgments. The evaluation process in steps 2a and 2b is based on intuitive reasoning using hypothetical changes in the observed performance profiles of the seven lecturers. The reason for asking the DM to give precise but tentative cardinal value judgments is based on our assumption that such an approach makes it easier for the DM to understand the meaning of cardinal value judgments, bearing in mind that the DM is unfamiliar with multi-attribute value models such as PRIME. In order to explain the intuitive reasoning which underlies precise and imprecise cardinal value judgments, a more detailed description is provided for the evaluation of the first criterion: *international publications*.

The evaluation procedure is carried out as follows:

Criterion I: “International publications”

Table 5: Performance regarding international publications

Lecturer	*Performance*
B	“2 publications”
G	“2 working papers”
F	“2 conference papers”
A, C, D, E	“No publications”

Step 1: Ordinal value judgments

Table 5 presents the DM’s ordinal value judgments regarding “international publications”, which are represented by a value function:

V_1(“2 publications”) = 1 > V_1(“2 working papers”) > V_1(“2 conference papers”) > V_1(“No publications”) = 0.

Step 2: Cardinal value judgments

a) Precise cardinal value judgments

The DM suggested precise but tentative cardinal value judgments w. r. t. for the three performance levels presented in Table 5 using “No publications” as a reference level, i.e. V_1(“No publications”) = 0:

$$\frac{V_1(\text{"2 publications"})}{V_1(\text{"2 working papers"})} = 2 \text{ and } \frac{V_1(\text{"2 working papers"})}{V_1(\text{"2 conference papers"})} = 1.5,$$

which means that lecturer B’s performance is twice as valuable as lecturer G’s performance and lecturer G’s performance is 1.5 times more valuable than lecturer F’s performance, using “No publications” as a reference level.

b) Imprecise value judgments

In order to avoid ranking the lecturers according to precise but unjustified cardinal value judgments, the DM suggested imprecise value judgment represented by the following ratio estimates:

$$1 < \frac{V_1(\text{"2 publications"})}{V_1(\text{"2 working papers"})} < 3$$

The interpretation of the imprecise ratio estimates is that the DM is intuitively convinced that “2 publications” is more valuable than “2 working papers”, but less valuable than “6 working papers”. Thus the “true” ratio is within the numerical interval [1,3]. The lower and upper limits (1 and 3) can be interpreted as being somewhat too low and too high as ratio estimates of the relative value of the two types of publications. A similar reasoning regarding “conference papers” and “working papers” gives the following ratio estimates:

$$1 < \frac{\mathrm{V_1("2\ \ working\ \ papers")}}{\mathrm{V_1("2\ \ conference\ \ papers")}} < 2$$

Thus according to DM's intuition the value of "2 working papers" compared to the value of "2 conference papers" is within the interval [1,2]. It should be pointed out that the comparison between the different types of publications was not only based on the number of publications. The DM has also intuitively assessed the publications' relative quality, something made possible by her familiarity with the publications and her ability to expertly assess their contents. However, if a DM is faced with a large number of publications, the assessment of their quality must be handled more systematically, by, for instance, the use of relevant subcriteria. A summary of the ordinal and cardinal value judgments gives the following:

Step 1: Ordinal value judgments

$V_1(B)>V_1(G)>V_1(F)>V_1(A)=V_1(C)=V_1(D)=V_1(E)=0$

Step 2: Cardinal value judgment

a) Precise ratio estimates:

$$\frac{V_1(B)}{V_1(G)} = 2 \text{ and } \frac{V_1(G)}{V_1(F)} = 1{,}5$$

b) Imprecise ratio estimates:

$$1 < \frac{V_1(B)}{V_1(G)} < 3 \text{ and } 1 < \frac{V_1(F)}{V_1(G)} < 2$$

The value judgments for the remaining criteria are based on a similar reasoning.

Step 3: Assessment of weights

First, by identifying the highest ranked performance on each criterion and by picking "Research team work" as the reference criterion, the DM suggested precise but tentative weights representing the relative importance of each criterion. The precise weight profile can be described on a scale between 0% and 100% as:

100%------------75%---------------50%----------------25%-------------------0%
V_6(A)-V_7(E)--V_3(B)------------V_1(B)--V_5(E)---V_4(F)-----------------V_2(B)--

Second, the DM suggested imprecise ratio estimates based on a similar intuitive reasoning as above (see the discussion under Criterion I: "International publications"). The precise and imprecise weight assessments are presented in Table 6.

Table 6: Precise and imprecise assessment of weights

Criteria[1]	Value differences[2]	Weights: Precise	Imprecise
International publications	$V_1(B) - V_1(A)$	50%	40 – 60%
National publications	$V_2(B) - V_2(A)$	2%	1 – 4%
National anthologies	$V_3(B) - V_3(C)$	75%	65 – 85%
Books	$V_4(F) - V_4(A)$	30%	20 – 40%
Examiner and/or expert adviser	$V_5(E) - V_5(C)$	40%	30 – 50%
Research team work	$V_6(A) - V_6(G)$	100%	100%
Leader of research project	$V_7(E) - V_7(A)$	90%	85 - 95%

Notes: 1. The criterion "Research team work" is the reference criterion, i.e. $w_{ref} = 100\%$.
2. Value differences regarding the highest and lowest ranked performance of each criterion.

The overall values of each lecturer performance profile are based on the following combination of precise and imprecise judgments of cardinal values and weights:

1) *Precise* cardinal values and *precise* weights
2) *Precise* cardinal values and *imprecise* weights
3) *Imprecise* cardinal values and *precise* weights
4) *Imprecise* cardinal values and *imprecise* weights

The fourth combination corresponds to judgments that the DM can confidently justify according to the evaluation procedure as described above.

The first combination (precise values and weights) gives the following overall values of the performance profiles:

$$V(E) = 0.761 > V(B) = 0.587 > V(F) = 0.476 > V(A) = 0.376 >$$
$$V(C) = 0.319 > V(D) = 0.129 > V(G) = 0.099$$

The use of imprecise values and weights gives rise to overall values as presented in Figures 2a-c.

Figure 2a: Overall values based on precise cardinal values and imprecise weights

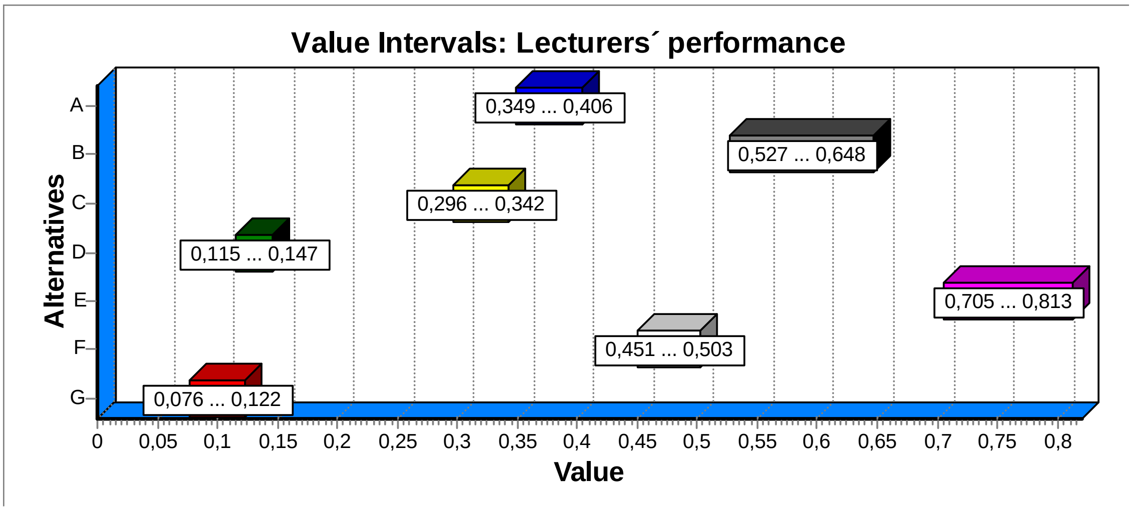


Figure 2b: Overall values based on imprecise cardinal values and precise weights

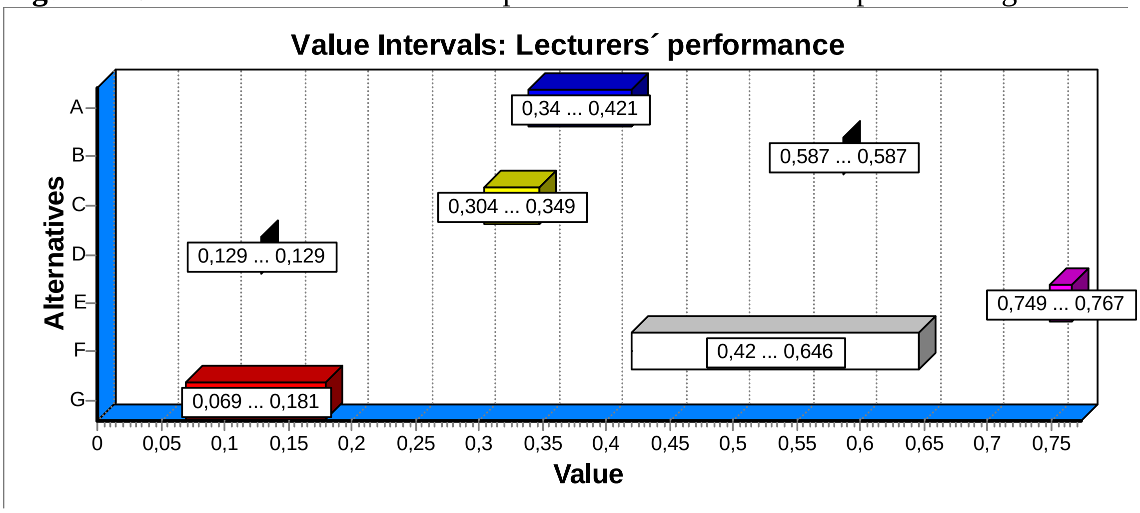
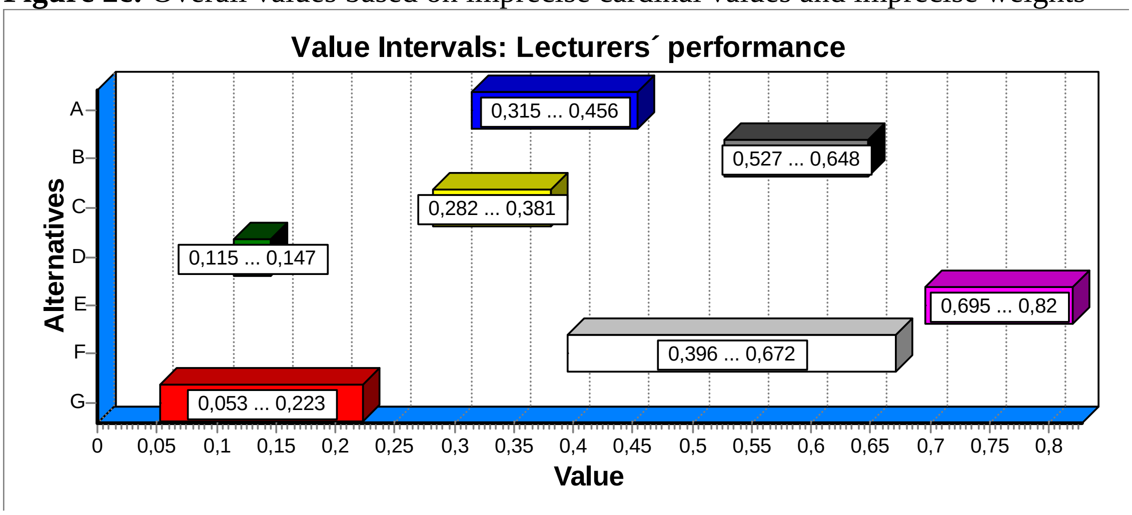


Figure 2c: Overall values based on imprecise cardinal values and imprecise weights



Figures 2a-c reveal several overlapping value intervals. Applying the pairwise dominance criterion defined in (10), we obtain dominance structures as presented in table 7.

Table 7: Rankings based on combinations of types of judgments

Cardinal values/Weights	*Precise weights*	*Imprecise weights*
Precise cardinal values	E $\succ$ B $\succ$ F $\succ$ A $\succ$ C $\succ$ D $\succ$ G	E $\succ$ B $\succ$ F $\succ$ A $\succ$ C $\succ$ D $\succ$ G
Imprecise cardinal values	E $\succ$ (B, F) $\succ$ A $\succ$ C $\succ$ (D, G)	E $\succ$ (B, F) $\succ$ (A, C) $\succ$ (D, G)

Notes: 1. The rankings are based on the criterion of pairwise dominance, see (10).
2. Non-dominances are in parentheses.

The ranking based on the first combination (precise cardinal values and weights) differs in one important respect from the ranking based the fourth combination. The complete ranking of lecturers based on the first combination is changed, when using the fourth combination, to non-dominance relations between the pair of lecturers: (B, F), (A, C) and (D, G), respectively. This means that the DM cannot justify different salary compensation to these three pair of lecturers. The DM can, however, decide to use the calculated central values in order to determine a ranking between these pair of lecturers. The rankings according to central values are:

$V^C(B) = 0.59 > V^C(F) = 0.53$, $V^C(A) = 0.39 > V^C(C) = 0.33$, and

$V^C(G) = 0.14 > V^C(D) = 0.13$.

In this case the central values of lecturer G and D are almost identical, which might be a strong reason for an equally salary compensation to both lecturers.

It is of interest to speculate about what results would have been produced, had the “point rating” model been applied to the same data. Since the “point rating” model uses precise numerical information, the result might coincide with the first ranking received by the PRIME model. But rankings based on the “point rating” model might also coincide with the fourth ranking based on imprecise cardinal values and weights. This could be the case since the “point rating” model defines each criterion in terms of ordered category-levels into which each employee performance is collapsed. This deformation of basic value information can give rise to rankings that coincide with rankings received by the PRIME model based on imprecise judgments. But even when the two models produce similar results, there remains a substantial difference in each model’s ability to justify the resultant rankings. In the PRIME model, every step in the evaluation procedure is both explicit and based on considered value judgments. The

PRIME model is thus more conducive to rational communication and negotiation between the parties involved – employers, employees, and their representatives.

4.4. Central values and recommended relative salary compensation

The justified ranking of lecturers established above gives no guidelines for suggesting differences in relative salary compensations based on evaluations of the observed lecturers' performances – something that is, obviously, of vital importance in the construction of a rational system of salary compensation. One way to estimate value differences between the ranked lecturers is to calculate central values for each overall value interval and to use the differences between the central values as a crude (at the least) basis for recommended relative salary increases between the lecturers. Table 8 contains central values for each lecturer and corresponding recommended relative salary increases. In Table 8 we have calculated the same central values for the three pairs of lecturers related by non-dominance.

Table 8: Central values and recommended relative salary increases

Lecturer	V^{min}	V^{max}	V^{C}	Recommended relative salary increases [2]
E	0.695	0.820	0.76	6
B and F[1]	0.370	0.668	0.49	4
A and C[1]	0.282	0.455	0.37	3
D and G[1]	0.053	0.221	0.13	1
"No activity"	0	0	0	0

Notes: 1. For overlapping value intervals consistent with non-dominance, the min and max values are based on the intervals with the lowest and the highest values, respectively.
2. The value ratios use "No activity" (i.e. the profile containing only the lowest ranked performance) as a reference level and the central value for lecturer D and G as a unit level.

Thus, according to the central values, the salary increase recommended for lecturer E should be about six times higher than the salary increase recommended for lecturers D and G when using the performance profile "No activity" as the reference level. In the same manner, lecturer E's salary increase should be twice the salary increase of lecturers A and C. The suggested relative salary increases can work, indeed, as an intuitive test of how reasonable the value judgments are that underlie the evaluation procedure. If several of the proposed relative salary increases appear obviously counter-intuitive, then an adjustment of some of the basic value judgments is called for. An iterative process switching between basic value judgments and intuitive judgments about resulting salary compensation might end with a reflective equilibrium concerning a rational basis for salary compensation. Due to the restricted number of criteria used in the evaluation of employee performance in the experiment such a test would seem unfruitful and is beyond the scope of the present study.

4.5. The decision maker's *perception of the PRIME-model*

We end the section by reporting about the DMs' perception of the PRIME-model as compared to models as the "point rating" model presented in the second section. After the evaluation processes were finished we encouraged the DMs to attend a meeting to discuss their perception of the two approaches. The DM who took part in the second experiment was the only one to attend the meeting. As department chair of history at Södertörn University College she is directly responsible for the evaluation of lecturer performance and for recommending salaries. The evaluation of lecturer performance takes place every year. The DM has an extensive experience of evaluating the performance of history lecturers.

When evaluating lecturer performance, the DM has used simplistic models, such as point rating models, and intuitive considerations. As we will stress the DM is completely unfamiliar with structured multi-attribute value models, such as PRIME. For this reason we believe that the qualitative information based on the interviews despite its anecdotal quality gives important insight about a DM's perception of strengths and weaknesses of theoretically well-founded multi-attribute value models such as PRIME. Such information is of course important for the implementation of more full-scale experiments in this type of evaluation context.

The interview with the DM was structured as follows. Firstly, we asked specific questions about her perception of the elicitation tasks such as ordinal and imprecise cardinal value judgements. Secondly, we asked questions about her perception of the assessment of weights as defined in PRIME. Thirdly, we asked her to comment on the weaknesses and strengths of the PRIME-model as regards its usefulness and ease of understanding. (For extensive studies of comparisons of multi-attribute value models from a DM's point view, see Wallenius 1975, Belton 1986, Buchanan 1994).

Comments on evaluation tasks as ordinal and imprecise cardinal value judgments

The first step in an elicitation tour to rank-order lecturers w. r. t. using each criterion was, according to the DM, a rather easy task. Further, the DM regarded this very basic step in multi-attribute evaluations as very instructive since it became obvious to the DM that value differences between various observed performance levels are not at all consistent with an equally spaced interval scale based on semantic categories as presented in Table 1. It seems that the DM was aware of the fact that such a scale imposes unjustified restrictions on her value judgements. The DM gave two obvious reasons for continuing to use fixed scales such as 1 to 5 in order to represent evaluation of lecturer performance. Firstly, the DM was not familiar with approaches based on multi-attribute models, such as PRIME, while "point rating" models are promoted by executives at the university college and are widely used when jobs and employee performance are evaluated. Belton and Stewart (2002 pp. 320-237) report on the use of similar simplistic and theoretically unfounded models in other application areas. Secondly, the DM deemed it as necessary to use simplistic models such as point rating models when the number of lecturers or criteria became too large. In such cases the DM judged that it is not recommended to rely solely on a purely intuitive evaluation of lecturer performance.

The second step in an elicitation tour to elicit imprecise cardinal value judgements represented by numerical intervals was regarded by the DM as more demanding than rank-ordering observed performance. However, after a detailed instruction on how to interpret the numerical intervals the DM perceived that expressing cardinal value judgements in an imprecise manner represented by numerical intervals to be a more reliable representation of her intuitive value judgements compared to the restrictive representations in point rating models. Further, according to the DM being able to express imprecise cardinal value judgements increased her awareness of the defects of using a fixed scale in this type of evaluation context, where, as the DM pointed out, most of the criteria are qualitative in nature. However, the DM pointed to the obvious problem of how to justify precise upper and lower limits of the numerical interval representing the imprecise value judgements. Salo and Hämäläinen (2003) discuss the interpretation of precise upper and lower limits.

Comments on the assessment of weights

The DM perceived the assessment of weights to be the most demanding process in an elicitation tour. She gave two reasons for this judgment. Firstly, the assessment of weights as defined in PRIME was unfamiliar to the DM, as is expected. The DM was not able state a definition of the weights other than to say in loose terms that a weight assigned to a criterion is a function of its importance for the achievement of main objectives for the university college, which seems to imply that the DM assumed that the weights are independent of how the measurement scales for value judgments are constructed in the specific evaluation model. The DM found it very difficult to understand the definition of weights in the PRIME-model. Detailed instructions, based on simple examples, were required in order to make the DM realize the function of weights in a multi-attribute value model. The unambiguous interpretation of weights among DMs in situations that are multi-attribute fashioned is well-documented (see Belton and Stewart 2002, pp. 288-291, Weber 1993, Weber and Borcherding 1993).

Secondly, the DM stressed that, even if weights as defined in PRIME are used the task is difficult, since the assessment of weights means that an evaluative comparison takes place between different types of performance as compared to intra-criterion evaluations. The DM perceived that her intuition about reasonable cardinal value judgements across various criteria was less stable compared to intra-criterion evaluations.

However, one important advantage of the PRIME approach to encouraging tradeoffs between explicitly stated differences between performances and across various criteria is, according to the DM, that it increased her awareness that intuition about reasonable tradeoffs has to be guided by the purpose of evaluation. And in this case the purpose of the evaluation concerns giving reasons for relative salary compensation based on various observed performance.

Considering the DM’s perception of the assessment of weights, we conclude that this elicitation task plays a key role in successfully implementing multi-attribute value models, such as PRIME. This means that when introducing the PRIME-model to DMs unfamiliar with multi-attribute value models, specific care should be taken when the definition of weights is explained. It is also important to stress that in order to make meaningful trade-off statements the DM has to be aware of the meaning of the overall value. In this evaluation situation the overall values are used to give reasons for relative salary compensation. Mustajoki et al (2005) discuss practical and procedural matters concerning weighting methods.

Comments on weaknesses and strengths of the PRIME-model

Besides the DM's perception of details in an elicitation tour we also asked questions about her perception of other weaknesses with the PRIME-model. Firstly, as to be expected the DM finds the PRIME-model more involved than a "point rating" model, which means that a DM is dependent on an analysis and that an evaluation process becomes time consuming. The DM perceived that the PRIME-model, at least as in its current design, will not be a realistic approach for evaluation of lecturer performance in larger departments at the university college. The department involved in *Experiment II* contained eleven lecturers, which the DM perceived as an obvious realistic number for an implementation of multi-attribute value models such as PRIME, even when the number of criteria considered in *Experiment II* increased. Secondly, the synthesis of value judgements and decision criteria used to determine final ranking of lecturers with respect to an overall evaluation have a design that is too technical to be understood by DMs unfamiliar with multi-attribute value models. This means that an application of PRIME gives rise to a "black box" effect on its users. Thirdly, this "black box" effect, as the DM stressed, may be the most important weakness with more sophisticated multi-attribute models such as PRIME, since it will give rise to difficulties in communicating the results to lecturers. Thus, due to this "black-box" effect, results of the evaluation and suggested salary compensation might receive a low confidence among lecturers.

In contrast to this serious weakness the DM finds that a structured multi-attribute value approach as defined in PRIME increased her discipline and awareness in the evaluation process, which means, among other things, that it increased her awareness of problems concerning the proper definitions of criteria, the elicitation of reasonable value judgments and how to evaluate the final results.

We summarize the DM's perception of the PRIME-model in terms of weaknesses and strengths. Its weaknesses are: 1) The evaluation process is time-consuming, which means that the application of PRIME seems to be restricted to evaluations of a relative small number of lecturers. 2) The DM has to be supported by a decision analyst. 3) Due to a "black-box" effect the results might be difficult to communicate to lecturers.

Its strengths are: 1) The possibility of expressing intuitive but imprecise cardinal value judgement means that clustering of different performances into the same categories is avoided. 2) The explicit way of defining weights related to relative differences between highest and lowest performance. 3) The structured way of carrying out the evaluation process increases the discipline and the awareness of problems concerning the proper definitions of criteria, the elicitation of value judgments and how to evaluate the final results.

5. Conclusions

This paper began by pointing out a number of defects inherent to using "point rating" models for evaluating employee performance. The two experiments show how the PRIME model's ability to synthesize imprecise value judgments corrects many of these defects:

1) Ordinal and cardinal value judgments are applied to observed employee performance, thus avoiding the deformation occurring when employee performance is collapsed into category-levels.
2) The assessment of weights is explicitly based on relative value differences regarding the highest and lowest ranked performance of each criterion, thus avoiding severe biased assessment of weights.
3) Imprecise judgments of cardinal values and weights are represented by numerical intervals, thus avoiding deformation of imprecise value judgment into unrealistic precise numerical statements.
4) The evaluation process occurs along well-defined steps forcing the decision maker to explicitly express his or her value judgments and increasing the discipline of the decision maker in the evaluation process.

By interviewing the DM we also identified two important issues that should be investigated in a follow-up study. Firstly, due the technical design of the PRIME-model the DM finds it difficult to understand the logic of the model, and believed that it will be difficult to communicate the results of an evaluation. Therefore, a comparison of the PRIME-model and simplistic models such as point rate models as regards effectiveness in terms of communication of results should carried out. Secondly, the assessment of weights is, according to the DM, the most demanding elicitation task for both formal and substantial reasons. This means that in order to improve the applicability and the reliability of the PRIME-model in this type of evaluation context, the functioning of various procedures used for assessing weights should be investigated.

The study concludes by indicating two paths for further investigation as suggested by the two experiments and the interview. The first would be a follow-up study that included a greater number of employees and a greater range of criteria (such as pedagogical skills). Second, a follow-up study examining the possibility of defining the performance profiles by a value tree structure. The evaluation of a value tree, which is supported by the PRIME model, makes it possible to carry out more detailed evaluations of complex criteria, which should be partitioned into a number of sub-criteria. One such complex and important criterion is “Quality of publications”, of which a more detailed assessment would be possible using this method.

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Appendix: Value judgments regarding the criteria used in experiment II.

Criterion I: International publication

Step 1: Ordinal value judgments

$V_1(B)>V_1(G)>V_1(F)>V_1(A)=V_1(C)=V_1(D)=V_1(E)=0$

Step 2: Cardinal value judgment

b) Precise ratio estimates

$$\frac{V_1(B)}{V_1(G)}=2 \text{ and } \frac{V_1(G)}{V_1(F)}=1{,}5$$

b) Imprecise ratio estimates:

$$1<\frac{V_1(B)}{V_1(G)}<3 \text{ and } 1<\frac{V_1(F)}{V_1(G)}<2$$

CriterionII: National publication

Step 1: Ordinal value judgments

$V(B) > V(F) > V(A) = V(C) = V(D) = V(E) = V(G) = 0$

Step 2: Cardinal value judgments

a) Precise cardinal value judgments:

$V(F) – V(A) = 3[V(B) – V(F)]$

b) Imprecise value judgments

$$2[V(B)-V(F)]<V(F)-V(A)<4[V(B)-V(F)]$$

Criterion III: National anthologies

Step 1: Ordinal value judgments

$V(B) > V(E) > V(F) > V(A) > V(C) = V(D) = V(G) = 0$

Step 2: Cardinal value judgments

a) Precise cardinal value judgments:

$V(B) – V(E) = V(F) – V(A)$

$V(E) – V(F) =2[V(B) – V(E)]$,

$V(A) – V(C) = 3[V(F) – V(A)]$.

b) Imprecise value judgments

$$0{,}5[V(F)-V(A)]<V(B)-V(E)<1{,}5[V(F)-V(A)]$$

$$V(B)-V(E)<V(E)-V(F)<3[V(B)-V(E)]$$

$$2[V(F)-V(A)]<V(A)-V(C)<4[V(F)-V(A)]$$

Criterion IV: Books

Step 1: Ordinal value judgments

V(F) > V(C) > V(A) = V(B) = V(D) = V(E) = V(G) = 0

Step 2: Cardinal value judgments

a) Precise cardinal value judgments:

V(F) – V(C) = 2[V(C) – V(A)]

b) Imprecise value judgments

$V(C) - V(A) < V(F) - V(C) < 3[V(C) - V(A)]$

Criterion V: Examiner and/or expert adviser

Step 1: Ordinal value judgments

V(E) > V(A) = V(C) = V(F) = V(G) > V(B) = V(D) = 0

Step 2: Cardinal value judgments

a) Precise cardinal value judgments:

V(E) – V(A) =2[V(A) – V(B)]

b) Imprecise value judgments

$V(A) - V(B) < V(E) - V(A) < 3[V(A) - V(B)]$

Criterion VI: Research team work

Step 1: Ordinal value judgments

V(A) = V(B) = V(C) = V(E) > V(D) = V(F) > V(G) = 0

Step 2: Cardinal value judgments

a) Precise cardinal value judgments:

V(A) – V(D) = V(D) – V(G) > 0

b) Imprecise value judgments

$0{,}5[V(D) - V(G)] < V(A) - V(D) < 1{,}5[V(D) - V(G)]$

Criterion VII: Leader of research project

Step 1: Ordinal value judgments

V(E) > V(F) > V(A) = V(B) = V(C) = V(D) = V(G) = 0

Step 2: Cardinal value judgments

a) Precise cardinal value judgments:

V(E) -V(F) = 2[V(F) -V(A)]

b) Imprecise value judgments

$V(F) - V(A) < V(E) - V(F) < 3[V(F) - V(A)]$