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# COWEL: a decision support system to assess welfare of husbandry systems for dairy cattle

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## Abstract

*Animals have various behavioural and physiological needs that are important for welfare. Fulfilment of these needs depends on the quality of housing, management and animal characteristics. The objective of this study was to develop a model to assign welfare scores to husbandry systems for dairy cattle, based on scientific results, and thereby supporting the design of new, welfare-friendly systems. COWEL is a computer-based decision support system that contains attributes regarding housing and management conditions. These attributes are technical specifications that contain various technical units called levels. These levels are ranked from best-to-worst regarding welfare, based on scientific information about animal-based parameters. This information, inserted in the model as statements, was weighted depending on the impact it has on welfare by using weighting categories. Thereafter, a weighting factor was calculated for each attribute which determines how important an attribute is for welfare. The COWEL model contains 2,343 statements on dairy cattle welfare from 476 sources found during a literature survey. The model was applied to four husbandry systems, namely a tie-stall, cubicle housing, a straw yard and a pasture-based system. The welfare scores, calculated by COWEL for these husbandry systems, correspond with the general opinion about these systems. A tie-stall receives a low and a pasture-based system a high welfare score: 211 and 271, respectively. A husbandry system can receive a maximum of 313 on the welfare scale of COWEL. We conclude that COWEL can be used to rank husbandry systems on a welfare scale, and may be a useful tool to develop new, sustainable and welfare-friendly systems for dairy cattle.*

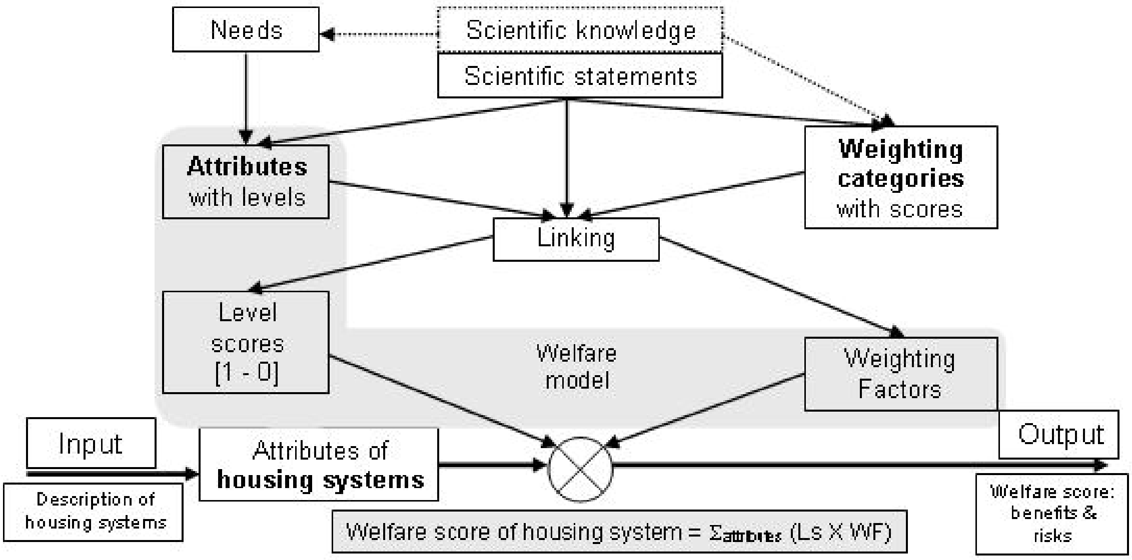
**Keywords**: *animal welfare, dairy cattle, decision support system, husbandry systems, management, semantic modelling*

## Introduction

All over the world, various breeds of dairy cattle are kept in different types of husbandry system with different types of management. These different treatments will consequently have either a positive or negative effect on animal welfare. To meet animal welfare standards, a husbandry system should fulfil the needs of animals (Anonymous 2001). The husbandry system, in terms of housing equipment, management, and animal characteristics, can in fact have a major impact on animal welfare. The floor type (an example of housing equipment), for instance, can be an important cause of lameness for dairy cattle (Somers *et al* 2003) and a non-optimal type of bedding in the cubicles can result in hock lesions (Vokey *et al* 2001). The management of the farmer influences cow welfare as well, eg pushing the animals to walk faster can result in lameness (Berry 2001) and aversive handling by humans can result in acute stress and even lead to chronic stress (Breuer *et al* 2003). Animal characteristics, such as the genotype and phenotype, are also important in relation to the suitability of a husbandry system for a certain type of animal (Haskell *et al* 2007).

The influence of housing equipment, management and animal characteristics on dairy cattle welfare have been described at length in the literature. However, no formalised procedures or models exist that (can) use this information to assess husbandry systems regarding cow welfare. Semantic modelling is a formalised welfare assessment based on existing scientific findings in literature (Bracke 2008). Up until now, a number of semantic models have been developed to assess the welfare of a wide range of animals, eg pregnant sows (SOWEL, from Bracke *et al* 2002), laying hens (FOWEL, from De Mol *et al* 2006; Shimmura *et al* 2008), and fattening pigs (RICHPIG, from Bracke 2008). The objective of this study was to develop a semantic model to assign welfare scores to existing and new husbandry systems for dairy cattle based on scientific evidence. This model can be a tool in the design process of new, welfare-friendly systems and the path towards sustainable systems will be supported. Attributes were not defined in terms of animal characteristics, this model is concerned with animals with a Holstein background only.

**Figure 1**




Schematic view of the COWEL model. Ls = Level scores, WF = weighting factor.

## Materials and methods

A computer-based decision-support system named COWEL (derived from the words 'cow' and 'welfare') was developed by using Microsoft Office Access 2003®. The model was based on the SOWEL model from Bracke *et al* (2002). A schematic overview of the COWEL model is provided in Figure 1. The input of the model consists of a description of husbandry systems and the output consists of a welfare score for these systems which can be presented in terms of welfare benefits and welfare risks.

The basis of the model is scientific knowledge. Scientific knowledge from literature concerning the needs of dairy cattle and their welfare was collected. Fourteen needs were included in the model: respiration, food intake, water intake, rest, locomotion, body care, thermoregulation, social contact, play, exploration, safety, sexual behaviour, maternal behaviour and health (based on Anonymous 2001 and Bracke *et al* 2002). We chose to exclude the need to urinate and defaecate from the model since cattle do not use a specific elimination area (Anonymous 2001) unlike pigs (Bracke *et al* 2002). Specific statements, 2,343 in total, were derived from 476 original sources written between 1971 and 2008 and they were inserted into the model.

Each husbandry system was described in terms of housing equipment and management characteristics. These characteristics, or technical specifications, were put in the model where they are called 'attributes'. Every attribute is related to one or more needs of the cow. In the literature, a variety of materials (eg concrete and straw bedding), number (eg number of lying places) or sizes (eg cubicle sizes) of the attributes are described along with their impact on cow welfare. These different technical units of the attributes were called 'levels'. All attributes in COWEL have two or more levels, eg the attribute 'number of resting places contains three levels; more than one per cow, one per cow, and less than one per cow. In Table 1, all attributes (42 in total) and the number of levels per attribute are given. COWEL ranks the levels according to their impact on cow welfare.

Every statement, selected from literature, that was inserted in COWEL concerned cow welfare in one or more respects. It can state, for instance, that a concrete floor causes lameness (Berry 2001) which indicates pain, or that exposure to noise (eg human voices and engine noise) in a commercial milking environment increases the heart rate of cows (Arnold *et al* 2007). COWEL links the levels of the attributes with animal welfare effects by using 12 weighting categories; pain, illness, reduced survival, decreased fitness, HPA (hypothalamic-pituitary-adrenocortical) axis, SAM (sympathetic-adrenal-medullary) activation, aggression, abnormal behaviour, frustration and avoidance, natural behaviour, preference and demand (Bracke *et al* 2002). The welfare effects were classified in terms of either a negative (first nine weighting categories) or positive score (last three weighting categories). These scores were –1, –2, or –3 for the negative weighting categories and +1, +2, or +3 for the positive weighting categories for a small, medium or large



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welfare effect, respectively. Whether a small, medium or large welfare effect was scored depended upon the intensity, duration and incidence of the effect (Willeberg 1991). The weighting categories pain, illness, reduced survival, HPA axis, and demand received higher weightings than 1, 2, or 3 points, namely 1, 3, or 5 points, as they were deemed more important to welfare following the procedure described in Bracke *et al* (2002). Furthermore, if a life-threatening situation is present for a large number or even all animals (eg in case of extremely high outdoor temperature that can result in death of animals due to heat stress) this overrules all other scores by a score of –1,000, thereby setting constraints in the model.

After scoring each statement found in literature, the model contained one or more statements about a level of an attribute in relation to cow welfare in terms of weighting categories. In order to determine the welfare effect of each level of each attribute, the model summed up the lowest scores (–1, –2, –3, or –5) for the negative weighting categories and the highest scores (1, 2, 3, or 5) for the positive categories. Thereafter, the model derived a weighting factor (WF) per attribute, ie the relative importance of the attributes for animal welfare. The weighting factor was calculated as the numerical difference between the highest score (the best level) and the lowest score (the worst level) per attribute. Levels with weighting scores of –1,000 were not included to prevent attributes receiving a very high weighting factor and this would have been irrelevant in terms of the four systems we tested. The maximum possible value for a weighting factor can be determined by calculating the numerical difference between the maximum negative and positive weighting scores that can be given. This occurs when the best level of an attribute scores the maximum number positive welfare points and no negative welfare points, while the worst level scores the maximum number of negative welfare points and no positive welfare points. The maximum negative weighting score that a level can receive is –35, being the sum of all maximum effects of the nine negative weighting categories. The maximum positive weighting score that a level can receive is 11, being the sum of the three positive weighting categories. The numerical difference between these extremes yields a maximum weighting factor of 46.

After determining the weighting scores per level, the levels receive a level score as well. These scores are set between zero (the worst level) and one (the best level). They are calculated by taking the numerical difference of the weighting scores of that level (eg the second) and the worst level and thereafter dividing it by the WF of that specific attribute. Calculating these level scores is an important step for determining the welfare score of an attribute for a specific husbandry system. In COWEL's predecessor, SOWEL, these level scores were distributed evenly over levels, eg an attribute with three levels scored 1, 0.5, and 0 for each level, respectively. However, COWEL can assign any numerical value between 0 and 1 for a level (excluding the best and worst level, which are always 1 and 0), by

**Table 1 Attributes that are included in the COWEL model.**

| Attribute | Total number of levels | Weighting factor |
|---|---|---|
| Number of resting places | 3 | 17 |
| Feed quality | 2 | 16 |
| Negative conditioners and stray electricity | 3 | 15 |
| Freedom of movement and behaviours | 4 | 14 |
| Handling | 2 | 14 |
| Resting area (dimension) | 3 | 14 |
| Temperature Humidity Index | 5 | 14 |
| Walkways floor type | 4 | 14 |
| Feed alley floor type | 4 | 13 |
| Light intensity daylight hours | 4 | 12 |
| Tail docking | 2 | 11 |
| Hygiene | 2 | 10 |
| Bedding material in resting area | 5 | 10 |
| Dehorning | 2 | 10 |
| Feed structure | 2 | 10 |
| Drinking places | 2 | 9 |
| Feed quantity | 2 | 9 |
| Water quality | 2 | 8 |
| Shade availability | 3 | 8 |
| Calf contact | 5 | 8 |
| Eating places | 5 | 8 |
| Lower critical temperature | 4 | 6 |
| Milking system | 3 | 6 |
| Space per cow | 4 | 6 |
| Water quantity | 2 | 6 |
| Predictability of environment | 2 | 5 |
| Hoof trimming | 2 | 4 |
| Milking frequency | 4 | 4 |
| Separation possibility (for calving) | 2 | 3 |
| Diurnal rhythm | 2 | 3 |
| Hoof hygiene | 2 | 3 |
| Air quality | 2 | 3 |
| Shelter availability | 2 | 3 |
| Grooming objects | 2 | 3 |
| Udder hygiene | 2 | 3 |
| Waiting time before milking | 2 | 3 |
| Noise | 2 | 2 |
| Group mixing | 2 | 2 |
| Isolation by farmer | 3 | 1 |
| Herd size | 3 | 1 |
| Walking alleys (dimensions) | 2 | 1 |
| Light intensity night time hours | 2 | 1 |



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calculating these level scores proportionally to the weighting score per level. For example, the attribute 'number of resting places', as mentioned before, consists of three levels: 'more than one resting place per cow', 'one resting place per cow', and 'less than one resting place per cow'. It could be that more than one resting place per cow is only a little bit better for dairy cattle welfare compared to one resting place per cow. Whereas one resting place per cow can be considerably better in terms of welfare compared to less than one resting place per cow. Expressing this in level scores, COWEL calculated the following: 1 point for more than one per cow, 0.765 for one per cow, and 0 points for less than one per cow.

Finally, the overall welfare score of a husbandry system can be calculated by the model as the weighted average score. To this end, the weighting factor for each attribute is multiplied by the corresponding level score and all scores of all attributes are totalled to give the total welfare score of a husbandry system. The outcome not only shows the welfare benefits for each attribute, it also shows the welfare risks of a husbandry system. The shortcomings of a system, ie the welfare risks per attribute and thus for the husbandry system can be calculated by subtracting the maximum possible welfare score (the WF of that specific attribute or 313 if considering the overall husbandry system) from the received welfare score. The maximum possible welfare score is, by definition, the sum of all weighting factors.

The model was tested with four existing husbandry systems. A pasture-based system, a straw yard, a cubicle house and a tie-stall were described and results were evaluated against each other and with practical knowledge and expectations. These systems are representatives of the typical husbandry systems found in The Netherlands and in Europe, but differences exist in practice. In order to compare them, most management attributes (eg 'milking system' and 'cow-calf contact') were set the same for each system.

A sensitivity analysis was conducted using six different calculation options, to determine the impact of weighting factor and level score on the numerical results for the husbandry systems given above and to determine which calculation option could be used best. These six options were: (i) weighting factors based on weighting scores (ie based on the calculated numerical difference between the weighting scores of the best and worst level of the attributes, these WFs range from 1 to 17 as shown in Table 1), equal distribution of level scores over levels (ie 0, 0.5, 1 in case of three levels); (ii) weighting factors based on attribute order (ie 42 for the most important attribute, 1 for the least important one; the model consists of 42 attributes in total), equal distribution of level scores over levels; (iii) all weighting factors equal (set at 1), equal distribution of level scores over levels; (iv) weighting factors based on weighting scores, proportional distribution of level scores over levels (eg 0, 0.765, 1 in case of three levels for the attribute 'number of resting places'); (v) weighting factors based on order, proportional distribution of level scores over levels and (vi) all weighting factors equal, proportional distribution of level scores over levels.

The model gives the following results: level scores, weighting factors and total welfare scores (both in terms of welfare benefits and welfare risks). Along with the results per husbandry system also the maximum score for welfare is presented, representing the best possible system.

## Results

Figure 2 presents the results for the six different calculation options by ranking the tested husbandry systems on a relative scale (the best system received a maximum score set at 10 and the worst system received a minimal score set at 0). Most options put the systems in the same order except for options 3 and 6, which deemed the straw-yard system better than the pasture-based system, and the cubicle housing much better than the tie-stall system (and also much better as compared to the other calculation methods). Both options calculated with the underlying assumption that the weighting factors for all attributes were equal, ie all attributes were equally important for cow welfare. Options 1 and 2 gave similar results as well as options 4 and 5. This pointed out that calculating the welfare scores based on the actual weighting factor or based on the order of the weighting factors did not give a large difference. The difference between option 1 and 4 (especially within the straw-yard system) was due to the level scores, which were either distributed equally over the levels or proportional to the weighting scores of the levels. The difference was small, but remarkable. All further results presented in this paper are from calculation option 4 (weighting factors based on weighting scores, proportional distribution of level scores over levels). This calculation option takes small and large differences in welfare effects between levels and attributes into account. The analysis behind this decision is discussed in the first paragraph of the *Discussion* in this paper.

The level scores COWEL calculates provided an insight into the ranking of the levels of the attributes, thereby also presenting the proportional distribution between the levels, which was not included in the SOWEL model. For instance, the attribute 'number of resting places' has three attribute levels: 'more than one resting place per cow', 'one resting place per cow', and 'less than one resting place per cow'. The best level received +5 welfare points based on the weighting category scores, the second best level received +1 point, and the worst level received –12 points. For this attribute, the weighting factor is 17 (numerical difference between 5 and –12). The level scores are proportional to the weighting scores of the levels, resulting in: 1, 0.765 (numerical difference between 1 and –12 divided by 17) and 0. If level scores were attributed equally the results would be 1, 0.5 and 0. It should be noted, however, that it is possible to receive positive as well as negative points per level and not only positive or negative ones as shown in this case. If we consider a tethered cow (during the whole winter period) for instance, this is negative for welfare when considering freedom of movement and behaviours (it results in stereotypies). However, it has also been suggested that tethering a cow is positive for preventing lameness (Faye & Lescourret 1989, cited in Phillips 2002).



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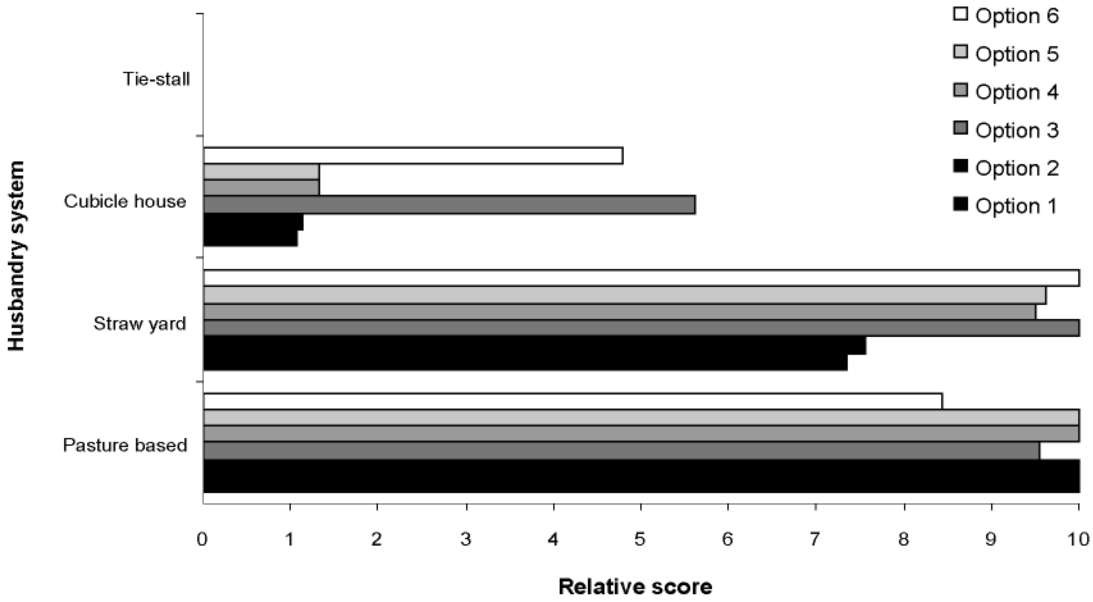
**Figure 2**




The relative husbandry system scores for four different husbandry systems for six different options (zero for the worst and ten for the best system). Option 1: Weighting factors based on weighting scores, equal distribution over levels. Option 2: Weighting factors based on order, equal distribution over levels. Option 3: All weighting factors equal, equal distribution over levels. Option 4: Weighting factors based on weighting scores, proportional distribution over levels. Option 5: Weighting factors based on order, proportional distribution over levels. Option 6: All weighting factors equal, proportional distribution over levels.

COWEL assigned weighting factors from 1 to 17 to the attributes (Table 1). COWEL calculated that the attribute 'number of resting places' is most important for cow welfare (weighting factor of 17), followed by 'feed quality' (weighting factor of 16) and 'negative conditioners and stray electricity' (weighting factor of 15). The least important attributes for cow welfare according to COWEL were the 'dimensions of the walking alleys', 'light intensity during the night', 'the way farmers isolate their cows' and 'herd size' (weighting factors of 1).

The COWEL model can assign a maximum welfare score of 313 (the sum of all the weighting factors) in terms of welfare benefits (Table 2). In this table, the best possible husbandry system received this total welfare score by setting all attributes at the best level. The tie-stall, cubicle house, straw yard and pasture-based system received welfare scores of, 211, 219, 268, and 271, respectively. For example, for the attribute 'number or resting places' this figure shows that the pasture-based system and the straw yard received the highest possible welfare score (more than one resting place per cow is available), while the cubicle house and the tie-stall scored less for this attribute concerning welfare (one resting place per cow).

To see where potential improvements for each husbandry system can be made, it is also possible to calculate the welfare risk. The maximum welfare risk was –313 (the maximum welfare benefit was the sum of the weighting factors: 313), and was –102, –94, –45, –42 for the tie-stall, cubicle house, straw yard and pasture-based system, respectively. Figure 3 shows which attributes contribute to these scores, and need to be improved to reduce the welfare risks cows have in those systems. It shows that the cubicle house and tie-stall score lower than the other systems on 'floor type of feed alleys, 'floor type of walking alleys', 'resting area' and 'bedding material in resting area'. There are also differences between these two systems. The restriction of movement and behaviour is greater in a tie-stall compared to a cubicle house, while hygiene and number of drinking places pose a lower risk. A large contributor to the perhaps unexpected low score of the pasture-based system is the Temperature Humidity Index value (heat stress), which can rise considerably during the summer. In both the straw yard and the cubicle house there is a potential risk of poor hygiene. Furthermore, some attributes (mainly management) create welfare risks in all systems. This is, for example, the case seen with dehorning, which commonly occurs and has a relatively large impact. However, not dehorning the cows is not normally possible in current husbandry systems, since it can lead to other welfare problems, such as injuries.

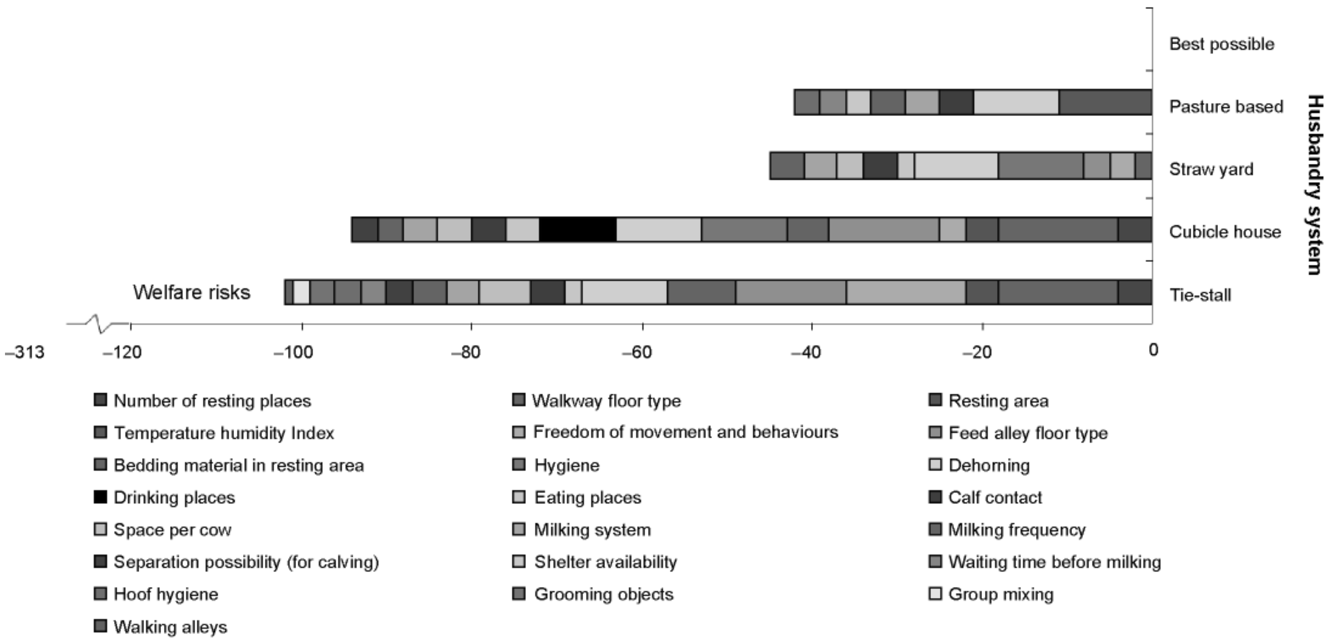
## Discussion

The sensitivity analysis that was conducted pointed out that the best calculation option to be used was option 4 (weighting factors based on weighting scores and a proportional distribution of level scores over levels).

**Table 2 Welfare benefits of four different husbandry systems per attribute. The best possible system receives all positive welfare points. The total welfare benefit for each husbandry system is presented at the bottom.**

| **Attribute** | **Husbandry system** | | | | |
|---|---|---|---|---|---|
| | **Best possible** | **Pasture based** | **Straw yard** | **Cubicle house** | **Tie-stall** |
| Number of resting places | 17 | 17 | 17 | 13 | 13 |
| Feed quality | 16 | 16 | 16 | 16 | 16 |
| Negative conditioners and stray electricity | 15 | 15 | 15 | 15 | 15 |
| Freedom of movement and behaviours | 14 | 14 | 11 | 11 | 0 |
| Handling | 14 | 14 | 14 | 14 | 14 |
| Resting area (dimension) | 14 | 14 | 14 | 10 | 10 |
| Temperature Humidity Index | 14 | 3 | 14 | 14 | 14 |
| Walkways floor type | 14 | 14 | 12 | 0 | 0 |
| Feed alley floor type | 13 | 13 | 10 | 0 | 0 |
| Light intensity daylight hours | 12 | 12 | 12 | 12 | 12 |
| Tail docking | 11 | 11 | 11 | 11 | 11 |
| Hygiene | 10 | 10 | 0 | 0 | 10 |
| Bedding material in resting area | 10 | 10 | 10 | 5 | 2 |
| Dehorning | 10 | 0 | 0 | 0 | 0 |
| Feed structure | 10 | 10 | 10 | 10 | 10 |
| Drinking places | 9 | 9 | 9 | 0 | 9 |
| Feed quantity | 9 | 9 | 9 | 9 | 9 |
| Water quality | 8 | 8 | 8 | 8 | 8 |
| Shade availability | 8 | 8 | 8 | 8 | 8 |
| Calf contact | 8 | 4 | 4 | 4 | 4 |
| Eating places | 8 | 8 | 6 | 4 | 6 |
| Lower critical temperature | 6 | 6 | 6 | 6 | 6 |
| Milking system | 6 | 2 | 2 | 2 | 2 |
| Space per cow | 6 | 6 | 3 | 2 | 0 |
| Water quantity | 6 | 6 | 6 | 6 | 6 |
| Predictability of environment | 5 | 5 | 5 | 5 | 5 |
| Hoof trimming | 4 | 4 | 4 | 4 | 4 |
| Milking frequency | 4 | 0 | 0 | 1 | 0 |
| Separation possibility (for calving) | 3 | 3 | 3 | 0 | 0 |
| Diurnal rhythm | 3 | 3 | 3 | 3 | 3 |
| Hoof hygiene | 3 | 0 | 3 | 3 | 0 |
| Air quality | 3 | 3 | 3 | 3 | 3 |
| Shelter availability | 3 | 0 | 3 | 3 | 3 |
| Grooming objects | 3 | 3 | 3 | 3 | 0 |
| Udder hygiene | 3 | 3 | 3 | 3 | 3 |
| Waiting time before milking | 3 | 0 | 3 | 3 | 0 |
| Noise | 2 | 2 | 2 | 2 | 2 |
| Group mixing | 2 | 2 | 2 | 2 | 0 |
| Isolation by farmer | 1 | 1 | 1 | 1 | 1 |
| Herd size | 1 | 1 | 1 | 1 | 1 |
| Walking alleys (dimensions) | 1 | 1 | 1 | 1 | 0 |
| Light intensity night time hours | 1 | 1 | 1 | 1 | 1 |
| **Total welfare benefit** | **313** | **271** | **268** | **219** | **211** |

**Figure 3**




Welfare risks for four different husbandry systems (a tie-stall, cubicle housing, straw yard, pasture-based system). The sequence in the bars (starting at zero) matches the legend from left to right.

The welfare scores based on the actual weighting factor (options 1 and 4) or based on the order of the attributes (options 1 and 5) did not give a large enough difference. This is due to the fact that the weighting factor decreases gradually as the order of the attribute increases when the attributes are sorted by weighting factor (as in Table 1). Options 3 (all weighting factors equal and an equal distribution of level scores over levels) and 6 (all weighting factors equal and a proportional distribution of level scores over levels), show a different pattern than the other four options. Both these variants were calculated with the underlying assumption that the weighting factors for all attributes are equal, ie all attributes are equally important for cow welfare. As can be seen in Table 2, the weighting factors were important in calculating the total welfare effect of a husbandry system (total of all individual weighting factors multiplied by the level scores of their attribute) and if we would set all weighting factors even, this would be less indicative. Consequently, it would be accurate to use the actual weighting factors and therefore options 2, 3, 5, and 6 were eliminated. Between option 1 and 4, a small difference was found. Choosing for a proportional distribution of the level scores creates a model that takes small or large differences in welfare effects between the levels into account. Therefore, we considered option 4 as the best option to be used in the COWEL model.

The objective of this study was to develop a semantic model to assign welfare scores to existing and new husbandry systems for dairy cattle based on scientific evidence and thereby supporting the design of new, welfare-friendly systems. In fact, this means that the attributes serve more or less as a brief of requirements related to cows' needs. For example, the attribute 'bedding material', consists of five levels: as on pasture (with dry areas), as on deep straw/sand, as on mattresses, as on mats, and as on concrete. This does not suggest, however, that you should provide access to a pasture to ensure a perfect bedding for resting, but it suggests that the type of bedding should be equally comfortable as lying in the pasture, to ensure the same quality in terms of welfare.

We have shown that it is possible to develop a model, in which current and future dairy cattle husbandry systems can be assessed on animal welfare. There are some striking results concerning the top levels of some attributes. For instance, concerning the resting area, the best level is a free resting area without obstacles (Bartussek *et al* 2000), which means that cubicles (even if they are large enough) are a welfare risk. Moreover, the attribute 'freedom of movement and behaviour' has as best level 'the cow is free to move and behave as and when she wants both indoors and outdoors' based on research by Ketelaar-De Lauwere *et al* (2000) which shows the importance of free choice at any time for being either indoors or outdoors for dairy cattle. Furthermore, the best level of the attribute 'space per cow' is set at a minimum of 360 $m^2$ based on the spacing behaviour of cattle (Kondo *et al* 1989), which is not a space allowance currently being practised.

COWEL is currently the most extensive semantic model containing as many as 2,343 statements from 476 references. COWEL uses scientific statements concerning attributes and levels in order to calculate welfare scores. It must be stressed, however, that it was not possible to link a statement to every level of an attribute. In such instances, the level received neither a positive nor a



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negative weighting and the weighting score (not the level score) was set at zero. For a number of attributes (10), a limited amount of statements on the levels were found in the literature (eg 'light intensity during night-time' and 'walking alleys'). This could result, in some cases, in low weighting scores for these levels and therefore also a lower weighting factor for the entire attribute. On the other hand, for other attributes and levels, many statements were found in the literature (eg 'feed quality', 'bedding material', 'cow-calf contact' and 'handling'). However, if attributes are described extensively in the literature, it does not necessarily follow that they automatically receive a high weighting factor. This depends on the effect of a level of an attribute on welfare: the maximum value (effect) per weighting category (animal-based welfare indicator) contributed to the total score of a level thus leaving lower scores per weighting category unused. More statements could, however, increase the possibility of finding more extreme effects. According to Bracke (2008), the number of statements is related to the weighting factor. A higher number of statements resulted in a high weighting factor. This can possibly be explained by the need of the sector and/or society to conduct research on certain subjects. The importance of attributes with a low weighting factor and a limited amount of underlying statements may thus have been underestimated by the model. However, the weighting factor of these attributes did not conflict with practical and scientific expectations and experiences. Nevertheless, if, in the future striking new literature about some subjects is found, it would be extremely easy to add this information to COWEL.

In the future, COWEL can be further improved by taking interactions between attributes and more management characteristics into account, and aspects about natural behaviour and positive welfare (eg grooming, social contact and playing). A validation of the model against expert opinions, experimental or practical results will improve the outcome and reduce uncertainty.

A final note is that we decided to exclude animal characteristics from being attributes in the model. One reason for this is due to the fact that the model is made for designing new husbandry systems. Future animal characteristics are not known and moreover animal characteristics are hard to measure. Another reason to exclude animal characteristics is because the model is concerned only with dairy cattle with a shared genetic background (Holstein or partially Holstein cattle). The weighting categories used in the model, however, do concern animal parameters. It could be of use to upgrade this model towards a model that integrates animal characteristics into the attributes. For example, the cubicle dimensions that are within welfare limits according to the current model are probably different for other (larger or smaller) breeds.

## Conclusion and animal welfare implications

COWEL can successfully rank husbandry systems on a welfare scale. Moreover, it provides detailed insight in the relative importance of husbandry attributes. The model gives the best results with weighting factors based on weighting scores in combination with a proportional distribution of level scores over levels. COWEL is a useful tool in designing new, welfare-friendly husbandry systems and thereby it supports one aspect, ie animal welfare, of sustainable development of dairy cattle systems.

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