IDENTIFYING POTENTIAL BENEFITS OF INFORMATION TECHNOLOGY ON DAIRY FARMS USING AN EXPERT PANEL

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Abstract: Investments in Information Technology (IT) determine the way by which the farm will be supported. In order to set priorities amongst the current available IT applications, the identification of business needs is essential. Therefore potential farm functions and processes are identified by using an expert panel. A methodology is presented that is based on system decomposition principles which makes a formal analysis possible. Two obvious functions in which important potential benefits are expected are roughage production and nutrition. Potential processes which are not associated with these two functions are health care control, detection of subclinical mastitis, milk production control and detection of oestrus and clinical mastitis.

Keywords: Information Technology, Strategic Decision-Making

1. INTRODUCTION

Small differences in livestock production performance result in a significant difference in profit. Hence, modern farming imposes increasing demands on farmers' management skills in order to maintain profit and guaranty continuity of the farm. Consequently, opportunities for effective management decision support are gaining importance.

Recent advantages in information technology (IT) have increased the opportunities for effective management decision support. Nowadays, several applications are available that support one or more processes. In the Netherlands (number of farms implemented the application between brackets) these include on-farm management information systems (4800), pedometers to measure daily physical activity of cows (250) and automated concentrate feeding systems (12800). Moreover, on-line automated parlour systems were adopted for recording of milk production (2500), milk temperature and electrical conductivity of milk (150) (ATC, 1996).

In order to set priorities amongst the current available IT applications, the identification of business needs is essential. Investments should be aligned with these business needs; applications that support the needs with the greatest economic benefit and use the least resources should get the highest priority (Ward, 1990). The assignment of priorities can be accomplished by utilising expert opinions (Kleijnen, 1984).

This paper explores the possibilities for a decompositional approach used as a reference framework for an expert panel from which potential opportunities of investments are identified. The constructed theoretical framework focuses exclusively upon processes relating to the operational management of a dairy farm.

2 MATERIALS AND METHODS

2.1 System decomposition

The constructed Dutch information model presented an efficient reference framework upon which potential factors were evaluated (ATC, 1994). It included the functions, the processes, the information flows and the data, which all were considered to be important for the management of the dairy business (Martin and Leben, 1989).

The model was constructed at the level of the individual dairy farmer, was well documented and was verified with external experts. The development was in close cooperation with research and private companies. The project, initiated as the INformation Stimulating Plan for the agricultural sector (INSP-agro), was financed by the Dutch government and the Farmers' Union (Doeksen, 1993). The different functions and processes of a farm were deducted from basic management concepts (planning,

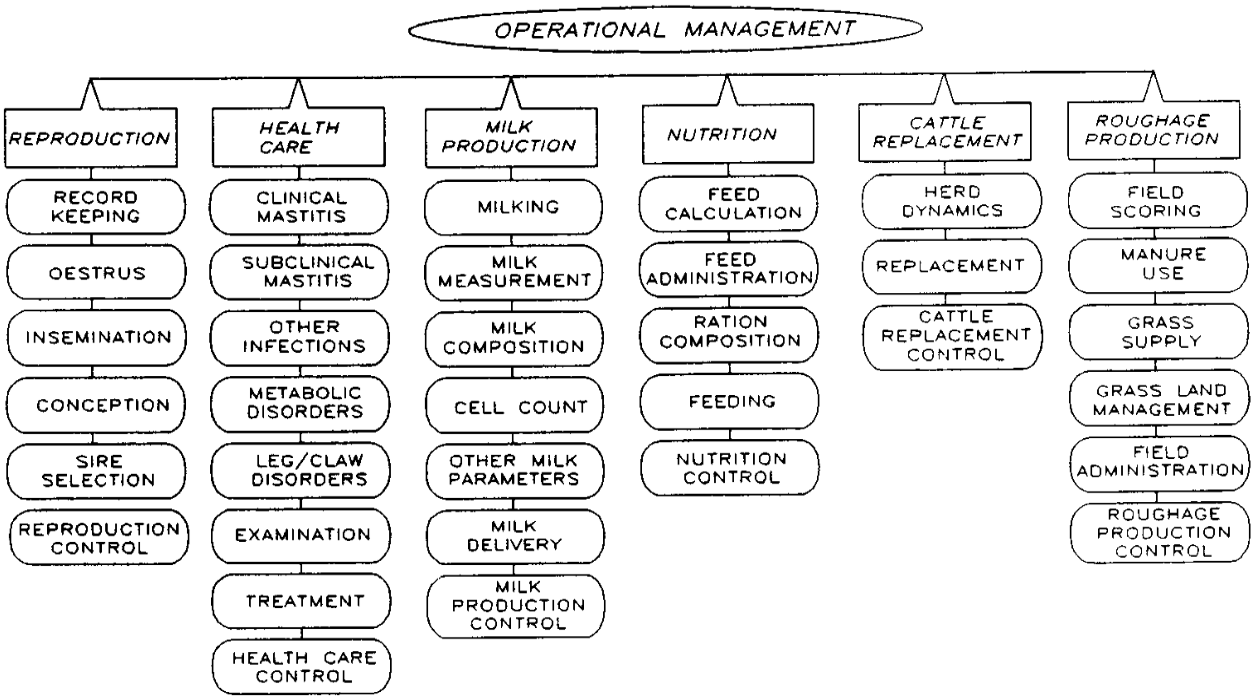

Figure 1: System decomposition

operation and control). Every function was decomposed into processes. Management of a farm was divided into: a strategic planning function, a tactical planning function, various operational functions and an overall control function. In case of a dairy farm the operational function included the processes reproduction, health care, milk production, nutrition, cattle replacement, roughage production, fixed assets administration and cash administration.

The available information resulting from IT applications are mainly used to support the operational management decisions related to the physical process. Decisions concerning pasture, livestock and its control may affect all of the main areas of the farm. Therefore, this research focuses exclusively upon the operational management of a dairy farm and consequently business needs are particularized to these underlying processes (Figure 1).

2.2 Eliciting subjective knowledge

In the current research Delphi is confined to identifying the potential factors being considered. The Delphi technique is an iterative instrument that is used for systematically eliciting and aggregating human judgements when experimental or observational data are not available (Linestone and Turoff, 1975). The procedure is characterized by: 1) the use of a formal questionnaire; 2) anonymous personal answers; 3) determination of a statistical group answer; 4) sharing information of the participants; and 5) repetition of the investigation.

In this study, data from an expert panel was obtained through a written two-round Delphi survey. A panel of experts working in dairy IT agribusiness was selected. The questionnaire suggested that the panel member was investigating an average Dutch dairy farm. An extensive description of the farm characteristics was provided. It was stressed that no IT applications were implemented yet on the farm.

In the questionnaire the experts had to rate A) the current status of farm performance and B) the opportunities to improve farm performance within the next 10 years. The experts had to divide 100 points between the 6 functions incorporated in the information model. With the two assignments the relative importance of each function for the current (A) and the opportunities to improve the technical and economic results (B) of the reference farm was quantified. Supplementary, a further distinction was made between the associated processes within a function. In total, 2*(1+6)=14 different sets were evaluated with 100 points each: 2 time perspectives (current and potential performance); 1 set of functions and 6 sets of associated processes. The experts were asked to motivate their numerical answers. In Delphi-II, the participating experts were re-surveyed for re-estimating their personal numerical answers with the help of the statistical group values evaluated from the first investigation (means and ranges). Motivations for relatively higher and lower judgements were added to the numerical answers. The second questionnaire was aimed at either achieving a consensus or clarifying those aspects over which most dissension existed.

3 RESULTS

At the first stage, a group of 25 experts was originally contacted to participate. Of the 19 experts who replied to the initial questionnaire, 17 completed the follow up. Some descriptive statistics obtained from the final Delphi questionnaire are summarized in Table 1. The importance of the functions included in the information model are described for both time perspectives: the current status of farm performance and for the potential performance. The functions are ranked in order of potential importance as perceived by the experts. Ranks were computed in a descending order within experts (the highest score was given rank 1) and summarized per function. The overall rank sum was equal to 19*(1+2+...+6) =399 for each of the two independent evaluated time perspectives. In general, the initial and final ratings were given in multiples of 5 on the 0 to 100 scales, a discrimination among the functions and processes more precisely seldom occurred. On the used scale from 0 to 100, the absolute ratings ranged from 0 to 70. The interquartile range was considerable narrower with a minimum of 5 points and a maximum of 19 points for the function production in case of the current performance. With a rank sum of 46, meaning an average rank per expert of 46/19=2.42, roughage production was considered as the function with the highest potential for improvement.

In order to test significant differences between rank sums, Friedman's two-way analysis for block designs was performed for a main-effects analysis of variance. In this test, direct comparisons between experts were not made. The test rejected the hypothesis of no differences between functions ($\alpha=0.05$) for both time perspectives. Subsequently, multiple comparisons were executed for comparing individual functions. Any two functions whose rank sums were more than 15.7 and 15.2 points apart could be considered as unequal ($t_{0.95}$), for the ratings of the potential and current performance respectively. According to this test, only nutrition was not significant different from the function with the lowest rank sum (roughage production) in case of the potential performance. Yet, nutrition and health care were not different from each other. The following combinations were also different: health care with reproduction; health care with cattle replacement and production with cattle replacement. Comparison of the individual rank sums showed that the current performance of nutrition and cattle replacement were significant different from all included functions. Moreover, health care and production were different from each other. Other differences between functions were not significant.

A main-effects analysis of variance on ranks for the processes included per function, rejected the null hypothesis in all cases. However, with this analysis no

Table 1: Descriptive statistics for the farm functions included in the information model.

	Potential performance				Current performance			
	Rank sum	Quartiles			Rank sum	Quartiles		
		25%	50%	75%		25%	50%	75%
1 Roughage production	46	20	25	30	68.5	10	17.5	20
2 Nutrition	47	18	20	30	38.5	20	20	25
3 Health care	62	10	20	25	72.5	10	15	20
4 Production	72	10	15	20	55	11	20	30
5 Reproduction	80.5	5	10	15	68.5	10	15	25
6 Cattle replacement	91.5	5	10	12	96	5	10	10
	---- +				---- +			
	399				399			

comparisons could be made between processes allocated in different functions. In order to translate the scores of the processes into the results of the information model as a whole, the individual scores of the processes were multiplied by the overall scores of the corresponding functions per expert. The multiplication explicitly assumed linearity of the obtained scores. In addition, the overall scores were adjusted for the expected values (Table 2). Negative adjusted scores occurred if the actual score was lower than the expected score (which assumed an indifference of the importance of the processes). The overall rank sum for the two independent evaluated time perspectives was equal to $19*(1+2+...+35)=11970$. Similar to the previous analysis it was tested whether the rank sums could be considered as unequal. Numerous processes were scored statistically different from each other. Ration composition, oestrus, milking, feeding and clinical mastitis were regarded as most important with respect to the current performance (sum ranks are respectively 140, 148.5, 177.5, 182.5 and 216). Since this study was focused upon potential processes, only these components of the information model were further analyzed. Grassland management was considered as the process with the highest potential for improvement (rank sum 172). Eleven other processes were not statistical different from grassland management. The Mann-Whitney test (or Wilcoxon test) for unpaired measurements was applied in order to test statistical difference between current and potential performance per process for these twelve processes. The two-tailed test pointed out that the scores in case of potential performance of health care control and nutrition control increased in comparison with the current performance at a significance level of $\alpha=0.05$.

In the course of the Delphi process, the experts re-evaluated the numerous ratings on the functions and processes in the information model. The evolution of the degree of agreement among the experts, that is the convergence of

Table 2: Adjusted descriptive statistics for the farm processes included in the information model.

	Potential performance				Current performance			
	Rank sum	Quartiles			Rank sum	Quartiles		
		25%	50%	75%		25%	50%	75%
1 Grassland management	172	22	142	522	262	-128	55	213
2 Health care control	193	-68	137	242	390.5	-158	-108	-8
Manure application	193	-28	222	472	242.5	-58	52	222
4 Nutrition control	193.5	-33	167	417	352.5	-33	117	267
5 Feed calculation	197	42	117	267	237	-108	67	267
6 Feeding	209	-33	117	417	182.5	-33	117	267
7 Ration composition	218.5	-33	117	467	140	107	242	567
8 Subclinical mastitis	226.5	-58	42	192	310.5	-158	-43	92
9 Milk production control	240.5	-38	62	162	327.5	-88	-38	62
10 Oestrus	241	-153	82	322	148.5	22	222	522
11 Clinical mastitis	248	-158	92	192	216	-58	92	192
12 Field administration	248.5	-78	22	282	325.5	-178	-68	122
13 - 35 Other processes; Total:	9389.5				8835			
	---- +				---- +			
	11970				11970			

ratings on the ordinal scales, was approximately measured by the proportions of the ratings within 2.5, 5 and 10 points of the median and the average absolute difference between ratings and medians. In the second round the proportion of the ratings that was within the interval [median-2.5, median+2.5] increased with 0.01 (Table 3). The trivial increasing proportions and declining average absolute difference between ratings and medians, indicated that the experts were rather persistent in their opinions. Little agreement was sought among the experts, a better overall consensus could not be achieved by appending more rounds. The general lack of convergence justified the inclusion of the two experts opinions in the analysis who did not respond to the second questionnaire.

A cross-validation was used to investigate the possible impact of the group composition on the results. The sample in the second round was split into two subsamples of 9 and 10 participating experts in a random fashion. For each subsample, the median ratings were computed and compared with those of the original overall sample (Table 4). In addition, the absolute median difference was calculated by comparing the subsample medians with the total medians per evaluated function, process and time perspective. The final

Table 3: Analysis of round effect.

	Rounds I	Rounds II
Proportion of ratings within 2.5 points of the median	0.31	0.32
Proportion of ratings within 5 points of the median	0.62	0.64
Proportion of ratings within 10 points of the median	0.85	0.86
Average absolute difference between ratings and medians	7.17	6.77

Table 4: Analysis of sample size effect.

	Subsample I	Subsample II
Percentage of medians within 2.5 points of the corresponding total medians	0.73	0.84
Percentage of medians within 5 points of the corresponding total medians	0.95	0.96
Percentage of medians within 10 points of the corresponding total medians	0.99	1.00
Average absolute median difference	1.81	1.55

median ratings would be somewhat different if only a subset of the group of experts had participated. However, the analysis indicated that these differences are relatively small, as suggested by a high percentage of medians within a narrow range and the low value of the average absolute median difference. Therefore the obtained medians were rather insensitive to the size of the group of experts.

4 DISCUSSION AND CONCLUSIONS

In this report the Dutch information model was used as a reference framework to analyze business needs. However, the allocation of associated processes to the functions was somewhat arbitrary and the processes were not completely independent from each other. Despite these shortcomings, the empirical results obtained from the expert panel showed that the group could identify business needs.

There were two obvious functions in which important business needs were expected, namely roughage production and nutrition. Potential processes which were not associated with these two functions were health care control, detection of subclinical mastitis, milk production control and detection of oestrus and clinical mastitis. The relative importance of health care control and nutrition control in case of potential performance increased in comparison with the current performance.

IT applications that support the identified business needs should get high priorities. In the subsequent research only these IT applications are evaluated. Reducing the number of IT applications and related farm processes would allow a more in-depth and refined study and enhance the ability to formulate a model to quantify the technical effects by a follow-up workshop.

5 OUTLOOK: MATHEMATICAL EVALUATION OF DECISION ALTERNATIVES AND SCENARIOS

The long-term objective of the current IT research project is to quantify the important technical and economic effects of potential IT applications in order to construct a flexible simulation model. The model will be used to support farmers' decision making with respect to IT investments. Several techniques of modelling (for example optimisation models and Monte Carlo simulation), provide a mathematical basis to evaluate decision alternatives of IT implementation. Incorporating technical impacts of IT applications, based on experts opinions and literature, could elucidate possible future situations in farming systems.

For dynamic processes, such as IT investments, impacts of a strategic plan for an individual farm over a given time horizon are interesting. Stochastic dynamic optimisation enables to determine the investment policy that maximizes the present value of expected net returns over a given planning horizon. At the beginning of the planning horizon, the model starts with a farm without any IT applications. The model will determine and quantify the optimal combination of a stepwise implementation of applications for an individual farm and is able to include uncertainty on the input-output relationship.

Monte Carlo simulation is a technique that also can support investment decisions for farmers over time. In contrary to the dynamic optimisation models, simulation models will not optimize the investments over a given planning horizon. This approach is applied for sensitivity analysis where the optimality of certain decisions alternatives is checked against alternative scenarios. Moreover, farmers' own-defined strategies could be analyzed and compared.

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