Requirements on document management systems – recorded using the Analytic Hierarchy Process and transferred into a Quality Function Deployment

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Abstract
By using the Analytic Hierarchy Process [AHP] the precision of the weightings of customer demands can be increased before they are used in a Quality Function Deployment [QFD]. Basically essential are the method of pairwise comparison as well as the assessment of the logic. A problem for a QFD-integration is that the AHP gives relative weightings. Therefore we have created a way of transferring relative into absolute weightings. The complete procedure was successfully realised in a document management-systems [DMS].

Originality/value
One possible methodology to apply AHP before a QFD was presented at the QMOD 2007. Now we have developed this procedure further and have tested it in practice in the prioritization of demands on DM-systems. Additionally, we have tested various methods of transforming the relative into absolute values in order to increase precision.

Purpose
QFD can only lead to exact results if the input mirrors exactly the customers' opinions. The relative weightings won by the AHP certainly represent the preferences more exactly. The next task was to transform these relative weightings in such a way that they can be entered as input into a QFD. On the one hand, this procedure has to be practicable, but on the other hand the loss of precision has to be as small as possible.

Methodology/approach
We have therefore developed a methodology how to transform the relative weightings of the AHP into absolute weightings for a QFD. The suitability of the concept was tested in several customer interviews and the results were processed according to the methodology. The resulting customer requirements can be used to support a concrete

investment decision as well as by developers for new or further development of DM-systems.

Findings

When tested we have found out that the interviews with the help of AHP are accepted very well by customers. We had expected some difficulties concerning the consistency of the answers. However, this was not the case. The procedure was considered very practicable. Furthermore, the precision of the input of the QFD could be increased.

Keywords: QFD, AHP, customer requirements, relative weighting

Paper Type: Research Paper

Introduction

By using the Analytic Hierarchy Process [AHP] the precision of the weightings of customer demands can be increased before they are transferred into a Quality Function Deployment [QFD]. This method used to develop products and services with a view to the customer can only lead to exact results if the input mirrors exactly the customers' opinions. The prioritisation of all QFD parameters on the basis of an absolute evaluation process is deemed currently to be standard. However, as this process does not permit any differentiated evaluation, the significance of the results can only be estimated with some difficulty. The relative weightings won by the AHP certainly represent the preferences more exactly which is mainly based on the hierarchical structuring and pair-wise comparison of all input parameters as well as the assessment of the logic of the weightings.

During the course of a project dealing with the ascertainment, structuring and weighting of demands of an intra-logistical plant, the AHP was successfully employed in 2007 (Crostack, 2007).
Based on evaluations of the requirements made on a Document Management System [DMS], the practical suitability of the method for prioritising customer requirements was to be more thoroughly investigated by using a higher number of surveys.

Additionally, we had to find a way of transforming these relative weightings so that they could be used in a current approach to QFD - for example, in line with the American Supplier Institute [ASI]. On the one hand, this procedure has to be practicable, but on the other hand, the loss of precision has to be as small as possible. The resulting customer requirements can be used to support a concrete investment decision as well as by developers for new or further development of DMS.

Fundamentals

<u>Analytic Hierarchy Process</u>

The AHP is a method developed by Dr. Thomas Saaty to support decision-making where problem-solving involves taking a host of criteria into consideration. Ascertainment and hierarchical structuring of relevant parameters are characteristic as is a level-specific evaluation of criteria and alternatives in paired comparisons. The evaluation of individual paired comparisons resulted in local and global percentages which allow parameters to be ranked. Furthermore, on the basis of the ratio scale used in the evaluation process it was possible to interpret intervals between the element-specific weightings and thus precise statements could be derived from the evaluator's preferences. Furthermore, the AHP provides a theory for checking the inconsistency. It is thus possible to estimate the logics of a partial decision as well as to make a statement on the quality of the overall results (Saaty, 1990).

The AHP is divided up into three phases and a total of eight sequential steps. A brief example allows the most important process steps to be followed.

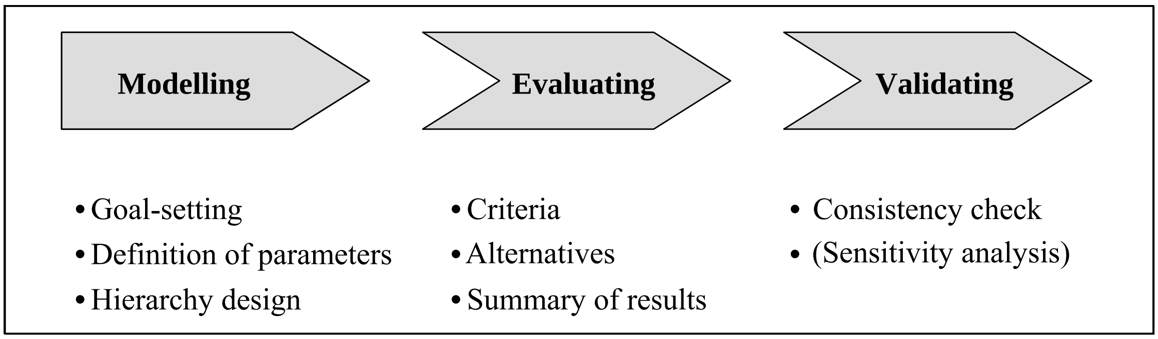

Figure 1: Diagram of AHP steps

This example aims to illustrate customer requirements regarding a travel hairdryer whereby it deals with a pure weighting of criteria which maybe supplemented at any time by an evaluation of an alternative. The criteria under observation and integration into a hierarchical structure can be seen in the following diagram. If several alternatives were to be observed at a later time, then the decision hierarchy would have to be supplemented by a third level.

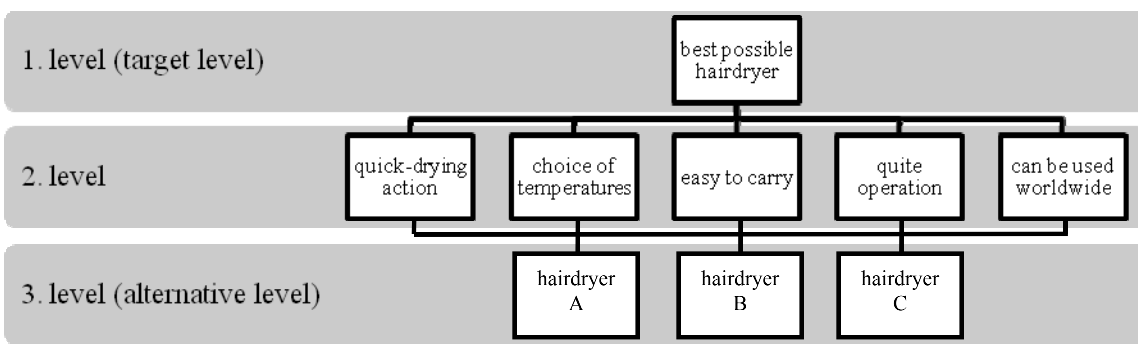

Figure 2: Hierarchy for weighting of requirements on a travel hairdryer

In order to solve the above decision-making problem, all of the criteria involved in the target must be compared in pairs with one another. This requires a total of ten individual evaluations.

A metric scale was employed for the weighting which contained all the numbers between 1 and 9 as well as their associated reciprocal value. For example, 1 stands for equally important and 9 for the largest difference in significance between to compared comparisons.

The results of a partial decision are recorded in matrix notation. The following values are assumed in evaluating requirements on a travel hairdryer.

	R1	R2	R3	R4	R5
R1	1	3	1/3	1/3	1/4
R2	1/3	1	1/6	1/3	1/6
R3	3	6	1	1	1
R4	3	3	1	1	1/3
R5	4	6	1	3	1

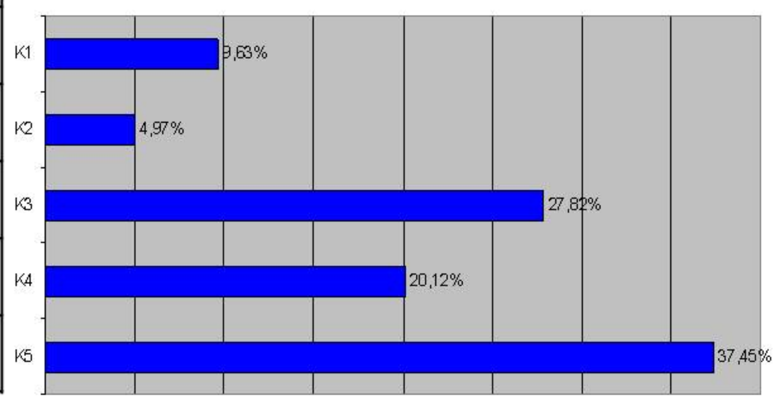

Figure 3: Criteria priorities matrix and criteria priorities

Accordingly, for example, R1 is somewhat more important than R2, however somewhat less preferred than R3, R4 und R5. The other lines may by interpreted using the same schema. All of the element-specific preferences may now be derived from the above matrix. Saaty was able to prove mathematically that the associated inherent vector matrix represents the relative weightings of the compared elements.

This may be attributed to the characteristics of the priorities matrix:

- All of the diagonal elements show the value 1
- The diagonal serves as a reciprocal axis of reflection
- The number of lines and columns is identical and agrees with the number of elements compared

The relative weights gained by determining the eigenvector are as follows for the example given: EV = [0.0963,0.0497,0.2782,0.2012,0.3754]T. The above bar chart was created on the basis of these values and clearly shows the relationship between individual criteria. For example R5 = 4 R1. Verbally, R1 is thus less important than R5.

In addition to the classical scale evaluation of criteria and alternatives, it is also possible to standardise individual values to 100% by integrating quantitative values directly. This would lend itself, for example, if the noise level of various travel hairdryers were to be compared with one another.
If the basic decision-making problem is structured so that the decision-making hierarchy has more than two levels, the results of individual decisions must be consolidated.

Viewed formally, all of the local eigenvectors at level n + 1 are summarised into one matrix and multiplied by the respective eigenvector of level n. This results in a consolidated vector which in turn must be multiplied by the vectors of levels n + 2 which have been consolidated into one matrix. This algorithm is repeated until the consolidated vector for the lowest level which represents the desired final result has been determined.

In order to determine the logics of a concluded partial decision, the so-called Consistency Ratio [C.R.] is determined. In the example, this is 4% and thus clearly below the threshold value of 10% as required by Saaty. Man's cognitive skills limit his ability to make consistent decisions - a low degree of inconsistency must consequently be permissible. The larger the number of paired comparisons, the more difficult it becomes for the evaluator to place weightings logically. A survey carried out by the US American psychologist, George Miller, showed that man is not able to consider more than five to nine items of information at the same time (Miller, 1956). An important ruling for the hierarchical design is derived from these findings – i.e. for each partial decision not more than seven parameters should be taken into consideration.

In comparison to absolute evaluation methods in the run-up to QFD, AHP displays numerous advantages. The set-up of the evaluation techniques ensures that the observed customer requirements are independent of one another and meet the same dimensions. Furthermore, the interviewee is forced to make a differentiated weighting as contradictory evaluations are revealed by a high inconsistency factor. Moreover, not only can the intervals between the individual preferences be interpreted but also their relationships can be interpreted and a sensitivity analysis can be carried out.
The drawback is that weighting via AHP is considerably more time-consuming and requires a higher concentration as does an absolute evaluation procedure. As to how far this has an effect on the motivation of the interviewee was looked at during individual questioning and is explained at the end of the concept description.

DMS

The Document Management Software is digitalised for database-supported administration and electronically generated documents are used. The exclusive administration of scanned records is known as document imaging. Solutions which administrate scanned and original digitally generated data are being increasingly sold under the term Documented Related Technologies [DRT]. If the system comprises all structured and unstructured documents of a company, it is usually referred to as Enterprise Content Management.

The functional scope and focus of DMS may vary considerably depending on the producer and the number of acquired software modules. The following diagram shows the typical life-cycle of a document. All of the phases shown here can be supported using a DMS.

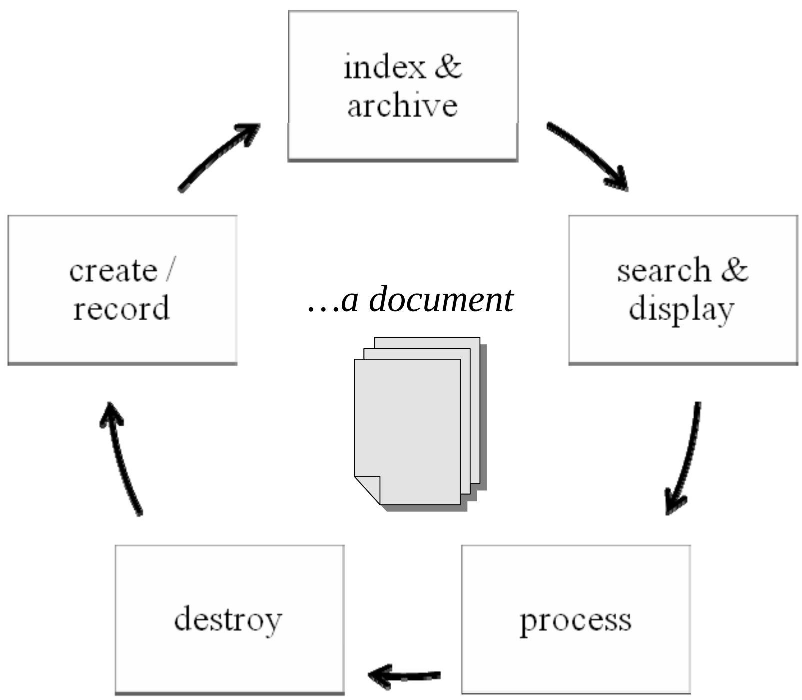

Figure 4: Document life-cycle

The cycle begins with the creation of an internal document or the recording of an external document. Analogue documents must first be digitalised so that they may be administrated by means of a DMS. Before archiving, features which clearly identify the document in question must be noted. This type of indexing allows the archived documents to be retrieved and displayed at any time. Using the processing function documents may for example, be amended, passed on or copied. Processing and the destruction of documents both depend on User Rights and the type of document. The procedural steps Search and Display as well as single processing functions can be carried out in reverse order and as often as required. If wanted, the documents can be automatically deleted on a previously defined date.

Costs for storage, internal and external transport, printing and copying of documents can be drastically reduced by the continuous employment of a DMS. Furthermore, there are also other advantages which cannot be immediately quantified - such as increased ability to provide information to internal and external customers. Because of the long procurement and introductory phases, additional costs incurred for hardware and high training expenses DM solutions are currently found mostly in larger enterprises and organisations.
These incurred costs however are not the only reason why many decision-makers in medium-sized companies hesitate. Those responsible often have neither the necessary expertise nor the time to carry out consistent project planning parallel to their daily business activities. In addition to testing AHP, the following in-depth discussed concept aims also at creating a qualified requirements profile. Additionally, the consolidated individual results may be used for customer-directed (advanced) development of DM software for SMEs.

Concept on structuring and weighting of customer requirements by means of AHP

The concept of prioritising requirements using an AHP is broken down into a total of eight steps as can be seen in the following diagram. All customer-specific components are shown against a grey background. The first two and the last process steps are in contrast carried out just once, independent of the number of interviews. The individual concept phases are explained in more detail, as follows.

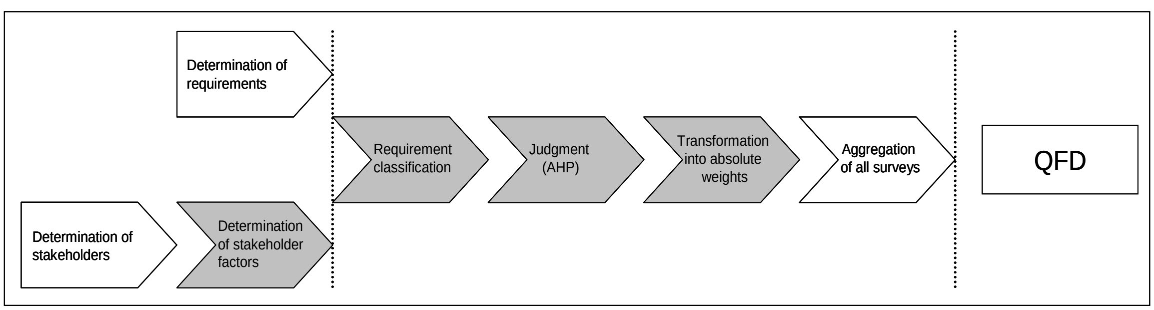

Figure 5: Process of requirement-structuring and weighting

Determination of customer requirements on a DMS

The requirements catalogue on whose basis individual customer interviews are carried out comprises a total of 65 requirements which have been determined through comprehensive research in professional literature, journals, investigations and guidelines, as well as product descriptions. Thirteen types and four super-ordinate subject blocks have been allocated to the individual requirements. The following table illustrates the structural set-up of the catalogue.

Table 1: Breakdown of requirements on a DM software

Block A	*General*	A1	User-friendliness
		A2	Qualification of software producer
		A3	Service
Block B	*Technical properties*	B1	Flexibility
		B2	Safety
		B3	Capacity
		B4	System performance
Bloc C	*Functionality*	C1	Recording and indexing
		C2	Research
		C3	Advertisement
		C4	Processing
		C5	Administration
Block D	*Cost-efficiency*	D1	Total costs

The list comprises only such requirements which do not represent a compulsory K.O. criterion, but which can likewise be estimated as being relatively important or absolutely unimportant. Requirements which, for example, must be archived in accordance with legal provisions have consequently not been taken into consideration.

Furthermore, only the contents of those criteria are observed which refer to the above-named basic functionality of DMS. As the interviewees are potential customers, the requirements focus is on classical systems. For the same reason, the majority of problems dealt with were user-related. Requirements made on storage media, scanners, monitors, printers and other peripheral devices were not taken into consideration as they do not have a direct connection to concrete software solutions.

Determination of stakeholders and associated factors

Persons with a justified interest in the activities of an institution or enterprise are referred to as stakeholders. The requirements of stakeholders depend on the respective perspectives. The following stakeholder groups were included in the DMS survey:

- *Management (S1)*
  - Stakeholders who take decisions on the implementation of a project from a commercial perspective
- *IT experts (S2)*
  - Stakeholders who take decisions on the implementation of a project from a technical perspective and/or take on the administration of software ,
- *Users (S3)*
  - Stakeholders who use the software in their daily business life

Depending on the preference of the person responsible different weighting factors can be allocated to individual stakeholders. These may be globally defined or can vary according to requirement block and requirement type. Basically, this can be all absolute and relative evaluating procedures e.g. also AHP.

Stakeholder-related classification of requirements

The weighting of requirements is broken down into two steps. It must first be clarified whether the requirement is absolutely important, merely advantageous or absolutely unimportant from the point of view of the evaluator. This classification alone ensures that the requirements assessed using AHP have a comparable dimension. Must-have requirements are so significant, that it is absolutely unacceptable that they are not met. Can-have requirements are also beneficial for the customer and must be specified in more detail in a second step using AHP. Meeting an absolutely unimportant requirement however does not provide the customer with any additional benefit and is thus not acknowledged. All of the criteria thus affected can be therefore deleted from the requirements catalogue. As several stakeholders are involved in the evaluation the weighted average is taken to determine the overall classification of a requirement. The following applies:

$$a_i = W_{i,1} * g_{i,1} + W_{i,2} * g_{i,2} + \dots + W_{i,n} * g_{i,n}$$

// a_i: requirement i, W_i: requirement-related stakeholder weighting; g_i: stakeholder factor

Hierarchisation and relative weighting of can-have requirements

All requirements which have been classified as advantageous can now be weighted using AHP. Hierarchisation picks up the breakdown in the requirements catalogue. Blocks A to C are integrated on the second level i.e. below the objectives. The requirement types are shown on the third level. Which criteria flow is incorporated in the fourth level depends on the concrete results of the requirements classification and is thus variable.

An AHP software is recommended for customer evaluation as this allows a simultaneous evaluation of results and determination of inconsistencies. For example, ExpertChoice could be considered – a US American software solution, developed in direct cooperation with Saaty (ExpertChoice, 2008).

As was the case for requirements classification, the AHP weightings of individual participants must be aggregated to give an overall result whereby the stakeholder factors in each case should be taken into account. Again, the weighted arithmetical average is used to consolidate the stakeholder-related weighting. Global priorities are calculated by multiplying the consolidated local values with the global weight of the superordinate criterion in each case. The use of a spread sheet analysis programme is recommended should the AHP software not support direct stakeholder integration and factor definition.

If in relation to a requirement type only one requirement is defined as advantageous, its benefits cannot be determined by means of AHP. As it is not possible to carry out a paired comparison, the absolute weight must be ascertained using an absolute evaluation method.

Conversion of relative to absolute weights

In order to be able to use the QFD strategy in accordance with ASI, the relative weightings must be converted into absolute figures. All requirements which have been declared as absolutely essential and absolutely negligible in the classification can be integrated directly into a QFD. As for the nine-element evaluation scale for the can-have requirements, all must-have requirements should be allocated the value 10 and all unimportant criteria the value 0.

The priorities of the can-have requirements determined by means of AHP are present in the form of relative numbers because of the method used. In order to obtain a uniform evaluation profile, these numbers must now be allocated into figures from 1 to 9. The person responsible must decide whether in principle the highest relative priority is to be automatically given the number 9 or whether the absolute priority is explicitly asked for.

Furthermore, the mathematical link existing between the relative and the absolute values must be determined. A linear relationship is one possible strategy which could be picked up for the customer surveys. The absolute values in the fourth column apply to the above example.

Table II: Variants for transforming relative into absolute values

Requirements	Relative values	Factor analysis		Absolute. values V1		Absolute values V2
R5	37.54%	1		9		9
R3	27.82%	1		7		9
R4	20.12%	2		5		8
R1	9.63%	4		2		6
R2	4.97%	8		1		2

The following formula was used in calculation. Mathematically, it is standard on the highest reading of 9.

$$a_i = \frac{w_i * W_{max}}{w_{max}} \qquad // \; w_{max} = 37.54\ \% \text{ und } W_{max} = 9$$

The AHP permits a verbal interpretation of the intervals between individual priorities. If the most important criterion (R5) is set in relationship with all of the criteria weightings, this will result in the factors listed in the third column in the above Table. It thus emerges that R5 is just as important as R3 and a little more important than R4. Furthermore, it can be seen that R5 is more important than R1 and significantly more important than R2. In relationship to the AHP interpretation, the differences between the first three absolute values is the most strikingly clear factor.

If a customer had directly weighted a requirement as absolute and would be of the opinion that R5 is only a little more important than R4, he might have selected the 8 or the 7 instead of the 5. The question therefore arises as to how suitable a linear distribution is for converting relative priorities into absolute priorities.
Another possibility is to determine the absolute values by means of a factors analysis. The conversion table on whose basis the absolute values in the last column of the above Table were determined are shown as follows:

Table III: Factor-based conversion table

Factor differences	1	2	3	4	5	6	7	8	9
Absolute values	9	8	7	6	5	4	3	2	1

A graphical comparison in comparison with an ideal typical linear curve is shown in the next Figure and results in an interpolation of interfaces between the relative and absolute values from R1 to R5. The slight deviations in the first variant from the linear curve can be attributed to the figures having been rounded off to whole numbers.

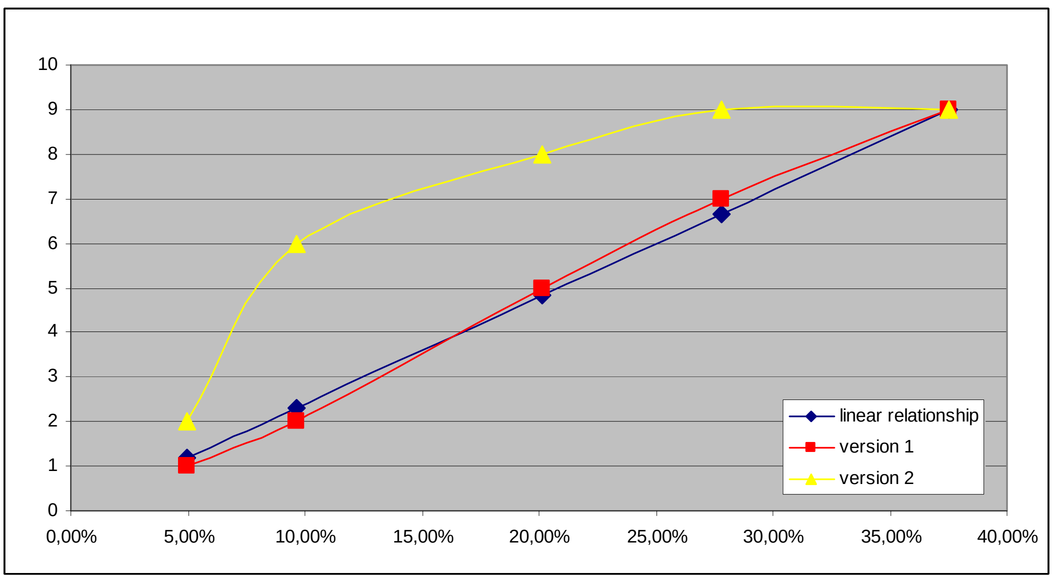

Fig. 6: Variants for converting relative scale values into absolute scale values

The first variant is used for evaluating individual customer surveys as the calculation steps can be easily automated and the second variant cannot be universally applied. When scales comprise fewer than 9 elements it would be possible to make conversions in accordance with the above schema, for example. Other conversion procedures are currently being investigated by the Chair for Quality Management, which reflect as real a connection as possible between the relative and the absolute weightings in order to minimize loss of accuracy incurred by the transformation.

Results of AHP interviews

Peculiarities of individual results

During the course of a survey, 5 interviews each with 3 stakeholders were carried out in accordance with the previously described schema whereby various sectors and corporate sizes were deliberately addressed in order to investigate whether different parameters are reflected in diverging requirement profiles. In detail the interviews involved a forwarding company (C1), a trading company / service providers (C2), a Catholic day care and educational centre (C3), a tax consultancy / solicitors chambers (C4) and a non-profit and independent professional association (C5). All the customer surveys followed the classical flowchart. In the case of C2, the interview was additionally carried out in a team in order to investigate the impact of the method on the end results.

What is noticeable is the fact that the stakeholder weightings determined by those responsible differed greatly. One preferred in principle the dominance of a stakeholder such as the perspectives of the management. Others distinguished between the competences of those involved. Again others allocated all stakeholders the same weight. In addition, the possibility of determining various weightings depending on the requirement type was also perceived.

Regarding the deviation rate, individual surveys diverged in many ways. The evaluation showed that regarding requirement classification, differences for C5 of approximately 50% were the lowest, and with approximately 80% the highest for C1. C1 also displays the highest level of deviation in the AHP survey where 60% of relative weightings deviate by more than 0.2 from each other. In comparison, divergences of smaller than or equal to 0.2% were determined for more than 80% in the case of C4.

Where deviations were very high, those participating were advised to repeat their decisions as a team in order to find a common consensus as the average value in this case is only limitedly significant.

Although AHP was unknown to all of the participants, an open and uncomplicated handling of the method was observed. This was reflected in the inconsistency values which on the whole were very small. In all, 165 partial interviews were carried out, three quarters of which were concluded with 0% inconsistency. An inconsistency of between 10% and 20% was only observed in just about 5% of partial decisions.

Most notably, it was seen that the participants were well able to handle a high number of paired comparisons – something which because of the required level of concentration was not thought possible. The two-part set-up of the survey (requirement classification and AHP evaluation) was well received by the participants and did not lead to any flagging in motivation in the second part of the survey.

It was noted in the C2 team survey that it could be carried out considerably more quickly than the individual interviews. The discussions were very lively and constructive, although not uniformly distributed. As those responsible said, this was not because of the hierarchical differences between the participants but was due to the general divergences in a willingness to communicate. This clearly shows how important it is in these survey variants to select a suitable team. On the whole, the level of agreement was notably high so that the moderator needed only to put forward a few proposals in the matter of compromise.

A comparison of the results of both survey variants clearly shows that in the second method, considerably more requirements were declared as being absolutely essential. In the AHP survey, slight differences were likewise determined but did not allow any tendencies to be derived. In all, the end result of 57% agreed completely. Only one of the requirements was evaluated totally differently. All of the participants agreed that group decisions should be used as a basis for possible selection decisions as these reflect better the needs of a company than the consolidated overall results from the first variant.

Overall results

As previously described the results of all the individual interviews were consolidated to one overall result. If this is done using arithmetical mean values, a tendency to higher scale values is noted. None of the requirements is absolutely unimportant according to this evaluation. In view of a differentiation strategy, the small overall number of low weightings is however of little benefit for software development.

However, the differences between individual weightings which in part were considerable are not surprising in view of the varying motivation regarding the introduction of a DMS. A cluster analysis should show whether consolidation of results from customers with similar prerequisites provide a different picture or not.

On the basis of the company or organisation size, the number of locations, the type and volume of documents to be administrated, the business process and similar comparison criteria it may be assumed that C1 and C5 as well as C2 and C4 would need to require mainly the same things of a DMS. If the average deviation between two customers is determined, it can however be seen that C4 and C5, C3 and C5 as well as C1 and C4 are closest to each other. A comparison of C1 and C5 as well as C2 and C4 shows that in contrast to the previous assumptions there are clear differences in requirements. It can thus be seen that the requirements made on a DMS can only be suggested to a limited extent on the basis of the named parameters.

Conclusion

Even if the previously discussed results of the low number of surveys allow merely a cautious interpretation, the scattering coefficients confirm the observation that the successful sale of standardised DMS software is only possible under extreme difficulty. Customer requirements vary greatly so that improved marketing would appear only to be possible through making individual alignments. However, for reason of fierce competition these must be implemented in as little time and with as few costs as possible. The essential prerequisites for successful marketing of DM systems are a modular software setup, the option to align it to diverging customer requirements plus continuous technological progress.

Regarding the creation of a sound requirements profile the developed concept was positively assessed by all participants. As the participants lacked specialist knowledge about it, the pre-defined requirements catalogue was judged to be very helpful. Those responsible were now able to shortlist the numerous offers available on the basis of the end results. Furthermore, the determined data permit the option of selecting those providers who implement the requirements with the highest priorities best. This can also be done by using AHP.

The successful execution of the pilot project showed that the previously explained concept is suitable for structuring and weighting customer requirements.

Although the AHP was totally unknown as a method of setting priorities it was well received by all the participants - a fact confirmed by the overall low rate of inconsistency - particularly in view of the high number of paired comparisons. Furthermore, this demonstrably shows that the interviewees had no problems in accepting the increased time required. It was noted therefore that increased time and efforts in carrying out the surveys was justified by the increased quality of the requirements weightings.

Converting relative weightings into absolute weightings allows the consolidated requirement priorities to be integrated directly into QFD whereby it is recommended using a method which is practical and at the same time ensures as accurate a conversion as possible seeing that the latter is only limited in the case of linear transformation. A further method was therefore presented which allows conversion on a nine-element scale to provide considerably more precise values and is yet easy to use.

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Prof. Dr.-Ing. Horst-Artur Crostack, born 1945, graduated from the Technical University of Hanover with a Master's degree in mechanical engineering and received a PhD at the Institute for Applied Material Sciences in Bremen. In 1978, he qualified as a university lecturer at the chair for Physical Manufacturing Methods of the University of Dortmund and was appointed to the chair for Quality in 1980. Additionally since 2006, he has been the speaker of the collaborative research centre 696 "Logistics on Demand" and he is also in charge of two of the sub-projects.

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