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An Approach for Information Quality measurement in Data Warehousing

(Research-in-progress)

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Abstract

High level information quality and the management of ensuring information quality is one of the key success factors for Data Warehousing projects. Data form the basis for analyses, reports and information exchange in complex business networks. Only accurate, relevant and understandable information, which is accessible through all business partners, ensure reliable business networks in long term and thus provide competitive advantages.

In the following research outline an approach for Information Quality Management and particular planing and measuring Information Quality will be described. First, a definition for information quality will be worked out. Based on practical experiences made in several projects, an approach for planing and measuring information quality will be introduced and explained. This concept is based on the method of Quality Function Deployment, which is already accepted in product quality planing. In further research, it is planned to detail this approach and develop a generic model of information quality, which can be used for quality planing and quality measuring in practice. Based on the processes of customer relationship management, the model will be instantiated for specific processes, like internet sales. This practical application of the model will illustrate advantages, problems and solutions of this approach in complex business networks.

1. Business Context

1.1. Data Warehouse – turntable for end-to-end-business process integration

Since business processes even between different companies are more and more tightly connected, a serious need for information exchange is being created. New technical possibilities are enabling and facilitating the information exchange in enterprise networks. E.g. Marketing, Sales, Production and Service are increasingly exchanging information . It's already Best-Business-Practises that companies are mutually sharing purchasing information. Also marketing, sales, production as well as service information are about to be exchanged between numerous enterprises.

- Data Warehousing combined with Internet Technology enables new possibilities of Customer Relationship Management by newly defining the value chain and obtaining the relevant information along the entire process including all partners and customers. New process chains, reduced process as well as other interfaces are being created. These newly developed process chains are much more flexible and competitive then the traditional ones.

- First of all the range of business partners can be significantly increased by providing information at any time, at any location, at any level of detail and according to any individual demand-level. Information is decoupled from the supply chain.

- The manufacturers bright product know-how like product description, configuration possibilities, calculation and pricing features can be shared with the business partners and can be easily integrated into their supply chain. Following that, substantial added-value can be created within the business partner's supply chain: the closer the informational links between companies and customers the higher the partner/customer loyalties. Changing business partners will lead to major (informational) disadvantages and might cause competitive disadvantages. A tight link between the business partners has been developed out of the mutually shared processes.

- Currently available Data Warehouse features enable process screening and to track and analyze the business partner's behaviour: end-customer's behavior and needs can be analyzed and interpreted. Upcoming, potential market changes can be anticipated. Strategies and processes can be adapted proactively instead of reactively.

With the borderless or networked company idea, data warehousing will become key to link back-end with front-end processes and for efficient inter-company communication. Therefore information offered via the internet must be a trusted base for mutual cooperation.

Let's assume the following example: a company wants to share all its product-relevant information like product description, product availability, pricing conditions etc. to business partners and customers in digital format in order to facilitate their processes and to add value to their supply chain. Partners and customers should be able to investigate the product catalogue, to configure solutions, to price them and to derive proposals for their own end-customers. In case the proposal will be transferred into a customer order, purchasing documents should be created automatically via the internet and transferred to retailers or wholesalers who will provide distribution and transport logistics.

After order fulfilment the proposal and the order data should be used in the billing process, since all the data has been already available along the process chain. Furthermore the supplier can significantly add value to his clients by providing them digital information for those process steps where information gathering is very time-consuming and difficult due to different sources and accessibility. All Data required in these process scenarios are available in a Data Warehouse. Fig. 1 shows this business scenario:

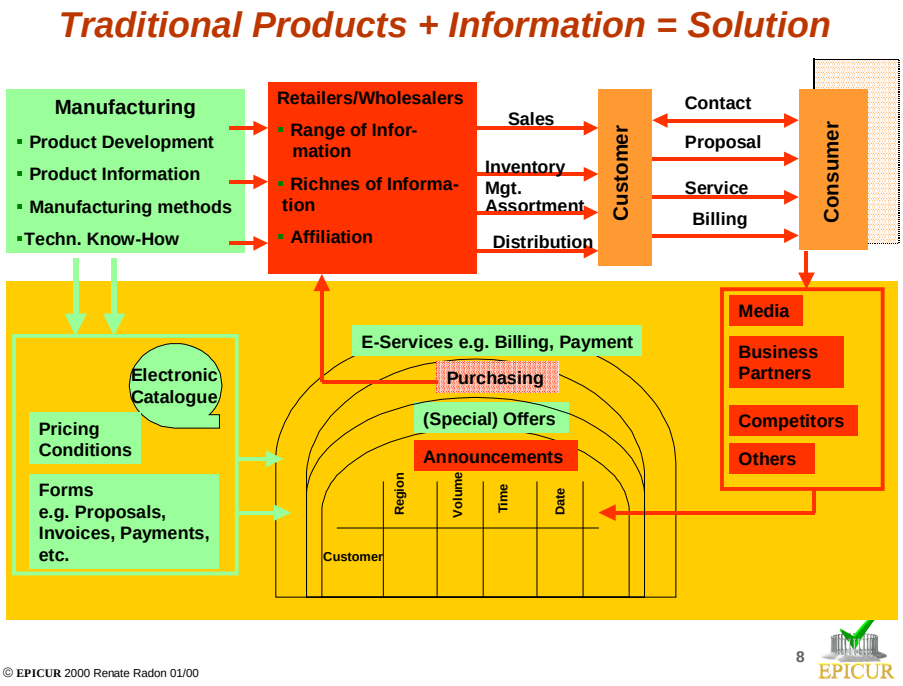

Fig. 1: Data Warehouse as a turntable for inter-company processes

The supplier will play an important role in his partner's supply chain: electronic services based on the supplier's original data will facilitate the partner's business process and will enable to offer new products from the supplier's point of view:

Traditional Products + Information ➔ Solution

This scenario requires comprehensive Data Warehouse functionality from the suppliers point of view in which information quality becomes key for reliable, trusted and sustainable business relations:

- Key information is stored once, centrally, is always up-to-date and accessible at any time
- Standard information regarding forms and procedures can be used in different administrative process steps
- Time-consuming processes like checking price conditions and developing calculation forms are drastically reduced
- The business partners benefit significantly from this electronic services and therefore will develop a close relationship to their suppliers. Changing the supplier will cause additional costs and disadvantages. Furthermore new process chains will be developed.

2. Information Quality in Data Warehousing

2.1. Definitions and Terms

The discussion about information, quality and information quality shows that these terms are complex and still no widely accepted definition exists. There are numerous approaches for defin-

ing information (Wolf 1999) and information quality (Wand, Wang 1996; Tayi, Ballou 1998; Huang et al. 1999), and therefore it is necessary to clarify the terms information and information quality used in this article.

Following the theoretical framework provided by semiotic, the terms signals, data and information are defined in a model with three levels (Wolf 1999). The bottom level comprises characters, symbols and signals and deals with syntactical concerns. Format and the kind of representation is important at this level. The next level, the semantic level comprises data and messages. Data are interpreted signals. At this level, meaning and content are important. The pragmatic level deals with information. Information is data used for a purpose by an information user in situations, where information is needed. In the following, these situations are named information processes covering all processes (decision and operational), where information is needed and processed. The following table shows for each semiotic level terms and definitions used in this article.

Semiotic level	**Term**	**Definition**
Syntax	Signals	Characters, symbols
Semantic	Data	Signals interpreted by user *u*
Pragmatic	Information	Data used for information process *p*

In Data Warehouse Systems, for example, the transmitted and stored characters are based on syntactical rules (e.g. constrains). On the semantical level, these characters are interpreted by using some meta data, where meta data comprises all data describing data itself. Finally the information user uses these interpreted data for information processes by using reports and other queries.

The term quality is as complex as the term information. One approach, which is widely adopted in the quality literature, is focused on the consumer and the product's fitness for use. In this approach quality comprises two aspects. First, quality means characteristics of products which meet customer needs and thereby provide customer satisfaction and second absence from deficiencies that result in customer dissatisfaction (Juran 1998). In summary, high quality means that a product is fit for the use by a customer. It is important to note, that the customer requirements determine the product requirements and only the customer state quality. Thereby product requirements are formed by a sum of single product characteristics. Customer requirements and the related product characteristics are therefore starting point for planning and measuring quality products and systems.

Following this approach, Huang et al. define information quality as information that is fit for use by information users. Information quality dimension is defined as a set of information quality attributes that represent a single aspect or construct of information quality. Based on this definition and empirical studies they develop a framework with four information quality categories and related information quality dimensions (Huang et al. 1999). Information quality dimensions can also be named information characteristics.

IQ Category	**IQ Dimensions**
Intrinsic	Accuracy, objectivity, believability, reputation
Contextual	Relevancy, value-added, timeliness, completeness, amount of information
Representational	Interpretability, ease of understanding, concise representation, consistent representation
Accessibility	Access, security

(Huang et al. 1999)

This framework is of empirical relevance and gives a suitable foundation for further research, but it is defined on a high level. For a clarification it is essential to define precisely information quality characteristics, show the relationships between them and how they relate to user requirements and so contribute to information quality. As shown above, information, data, and signals can be distinguished on different semiotic levels. Thus, a definition framework should consider the different semiotic levels and should show the level specific information characteristics as well as the relations between these levels.

Even if this article cannot provide a detailed definition framework, it is essential to clarify the term information quality and provide a foundation for further research. In this article an overview of a definition approach, which is part of current research at the Competence Centre 'Data Warehousing Strategy', is given.

Core element is a set of relevant information characteristics based on the three semiotic levels. On the level of syntax, syntactical correctness and consistent representation is relevant. Because this level deals with the exchange of signals between sender and receiver, security and accessibility are located at this level as well. At the semantical level, which deals with the meaning of signals, interpretability, accuracy as well as consistent and complete data values are important. At the pragmatic level all characteristics are located, which are relevant within the application of data for information processes. For example, relevance, completeness of information and timeliness are important. It is important to note, that the superior level includes all characteristics of its sub levels.

Semiotic Level	**Characteristics**
	Syntactical correctness, consistent representation, security, accessibility
	Interpretability, accuracy, consistent data values, complete data values, precise data definitions, objective, believability, reliable, easy to understand
Pragmatic	Relevance, completeness, timeliness

Following the customer focused approach of quality, information quality means characteristics of information which meet user needs and thereby provide user satisfaction as well as absence from deficiencies that result in user dissatisfaction. Information quality means, that the provided information supply corresponds with information requirements in a set of relevant information characteristics. The information requirements are defined by user's needs and expectations for his or her information processes. Information quality also includes data quality and signal quality.

Information quality	$IQ(p,u) := f_c(I^R(p,u) = I^S(p,u))$
f_u	Quality function of user *u*, which assign information quality based on the correspondence of information requirements with information supply.
$I^R(p,u)$	Information requirements for process *p* and user *u*
$I^S(p,u)$	Information supply for process *p* and user *u*

Two problems to determine information quality should be noted. First, the information requirements is not exact and a priori definable. Subjective information requirements, which are determined by information user, and objective information requirements, which are determined by information processes, are only in theory identical (Wolf 1999). Second, it is impossible to identify the function f_u precisely, which means that only experiences can be used to approximate this function. Information quality is determined by the user in the moment of information usage.

For practical use, it is necessary to develop a framework to specify information requirements and measure information supply on an uniform and consistent base. Part of the framework are relationships between information characteristics and user requirements. For the measurement of information quality, a measuring system with measuring methods have to be developed. This is key part of method-based Information Quality Management (IQM) for Data Warehousing, which is introduced in the following.

2.2. Method-based Information Quality Management

Total Quality Management (TQM) is successfully used in manufacturing and states the current research in quality management. Typically for TQM is the orientation on customer requirements and the comprehensive management approach. All activities in the enterprise are integrated in a total quality management concept aiming to continuously improve quality of products, services and processes itself and therefore satisfy customer requirements (Seghezzi 1996).

Quality management includes concepts of quality policy, quality planning, quality control and quality assurance as well as quality improvement. Quality management operates throughout the quality system. Elements of the quality management system are organisational structure, process organisation, standards, guidelines, and rules as well as methods, techniques, and tools.

The current research applies the concept of Total Quality Management to information quality. First results showing that quality management in manufacturing and service industry can be transferred to information quality with some adaptations. Based on TQM, the proposed method-based IQM consists of an organisational structure and a process cycle with processes 'Define', 'Measure', 'Analyse', and 'Improve'. They are continuously applied in an iterative process aiming information quality improvement. The method-based approach provides methods and tools to support these four processes. Besides that, organisational aspects defining roles and responsibilities are considered as well. Guidelines for evaluating and using tools as well as standards are available. In Fig. 2 the method-based IQM is summarized.

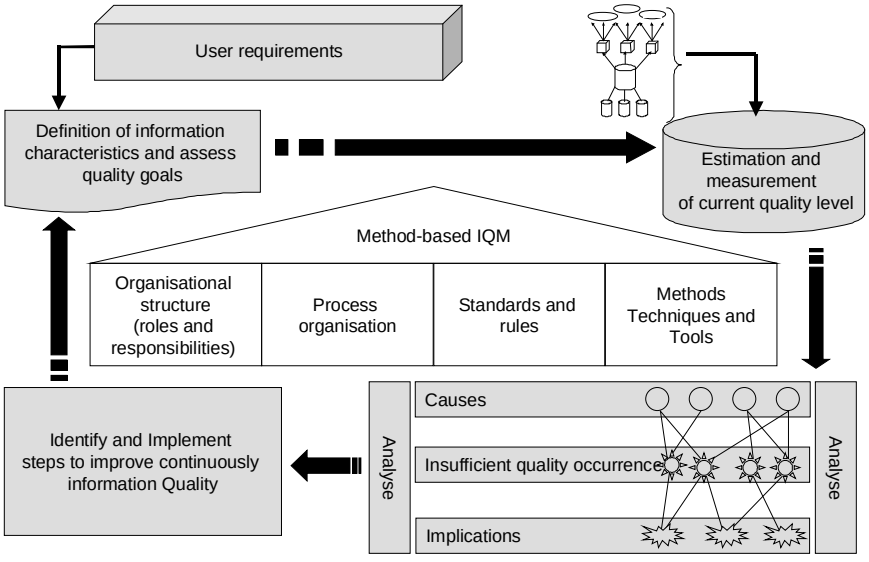

Fig. 2: Method- based Information Quality Management

One example of the method-based approach is the structured analysis of insufficient information quality, which is shown in Fig. 3. Following the three semiotic levels, relations between information characteristics and classes of causes are identified. Identifying these classes, it is possible to propose solution options. For example, technology, design decisions, organisational aspects, and architecture are possible fields for identifying solutions.

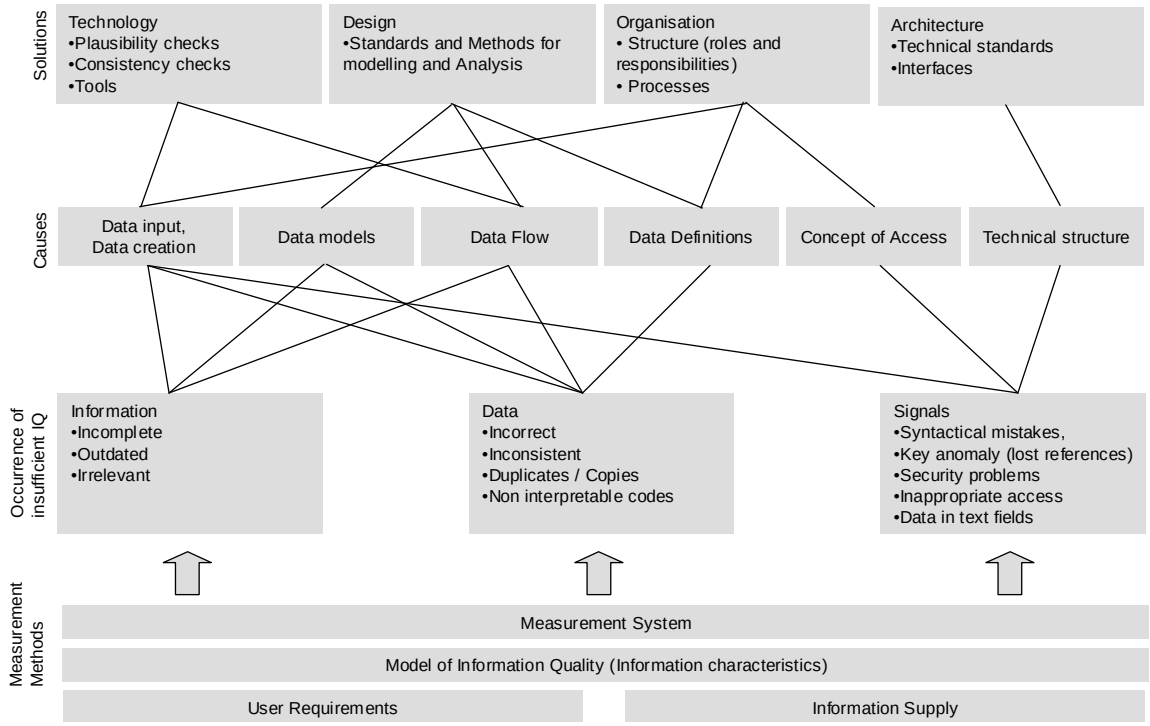

Fig. 3: Method-based Analysis

Key success factor of the method-based IQM is information quality planning and measuring, so that quality goals can be defined and current information quality levels be estimated. This is gaining complexity the more business partners are working together in business networks. Therefore a generic model of information quality with guidelines, standards and measuring methods is necessary.

2.3. How to measure Information Quality?

Information quality means, that the provided information supply corresponds with the information requirements in a set of relevant information characteristics. Information quality is assigned by a quality function f_u, which assign information quality based on the correspondence of the provided information supply with the information requirements. To determine information quality, two questions have to be addressed:

- How to develop a framework to specify information requirements and measure information supply on a uniform and consistent base? The framework should be based on relevant information characteristics and should consider the semiotic levels.
- How to approximate the quality function $f_{u,}$ to obtain a 'good' estimation for expected and realised information quality?

The framework builds the foundation for gathering and structuring user requirements. These requirements can be transferred through related information characteristics into quality goals. The specified information characteristics and their appropriate measuring methods giving the possibility to state current quality levels and compare information quality of different systems and alternative solutions. By the comparison in time, it is possible to identify quality trends and

evaluates the effect of quality improvements. The framework also provides the foundation for cost benefit analysis for quality improvements and further developments.

Currently, there are different approaches for measuring information quality. On the one hand, information quality can be measured with subjective perceptions from information users. On the other hand, there are approaches developing measuring systems on the basis of quality characteristics (mostly intrinsic information quality characteristics like for example completeness and correctness). But as of today no generally applicable and objective measuring system is available yet.

Huang et al. are suggesting a measuring system consisting of three categories (Huang et al. 1999). First, a metric that measures individual's subjective estimates of information quality is suggested. This metric consists of a simple, understandable questionnaire. The user is questioned about his or her estimation of information quality in their context of using. Second, a metric that measures information quality along quantifiable, objective variables that are application independent is proposed. Examples of objective variables are given as correctness, completeness and consistency. However, as the example of completeness shows, application independency is not obviously given. Third, a metric that measures information quality along quantifiable, objective variables that are application-dependent, is suggested. This third measurement needs knowledge about information, their application and their formats.

Idea of current research at the Competence Center 'Data Warehousing Strategy' is to develop a general, generic framework which brings user requirements and information characteristics together. To reduce the complexity, the framework is divided in the three semiotic levels. With the help of some method, the framework is then specified for specific information processes. Finally, it is necessary to develop methods for assigning values to information characteristics and so measure information quality in a constant and consistent way.

One accepted method for planing quality in the manufacturing sector is Quality Function Deployment (QFD), which was introduced by Akao in Japan in 1966 (Akao 1990). QFD is a method for quality planing, which has the customer requirements as there primary focus. With the structured procedure of QFD, it assists to define customer requirements and then translating these requirements into design targets and major quality assurance points to be used throughout the manufacturing process. The method is used by mixed teams continuously from the product development through the product's conception to the manufacturing itself. It consists thereby of four phases. In phase one, quality characteristics are derivated from stated customer requirements. The next phase breaks these quality characteristics down to each component of the product. In phase three, from these component specifications, requirements for the production process are developed. The final phase defines tools for production and quality inspection to ensure the required production process. QFD could so be used as starting point for the development of a framework to specify information requirements, associate information characteristics and measure information supply. Thus, the concept of QFD will be introduced and applied to information quality in Data Warehousing in the following.

Experiences in USA and Japan showed that QFD in principle is applicable to service and software industry. The method is also applicable to information quality (Redman 1996), but there is still lack of fundamental research and applications in praxis of QFD for information quality. The current research approach is focussed on QFD as a method for quality planning and measuring

information quality in Data Warehousing. In the first step a framework for user requirements and information characteristics is developed. Based on this research it is planned to use the framework as a measuring system for information quality. The framework can also be used to support the planning of Data Warehousing Systems by providing quality characteristics for components of Data Warehouse Systems. Based on these component specifications the necessary information process can be developed. Finally, based on the QFD method it is possible to define and select tools for Data Warehouse Systems and quality inspection.

Core instrument of QFD is the 'House of Quality', which is used as the main documentation of results and concepts throughout all phases of QFD (Saatweber 1997). The main fields are shown in Fig. 4.

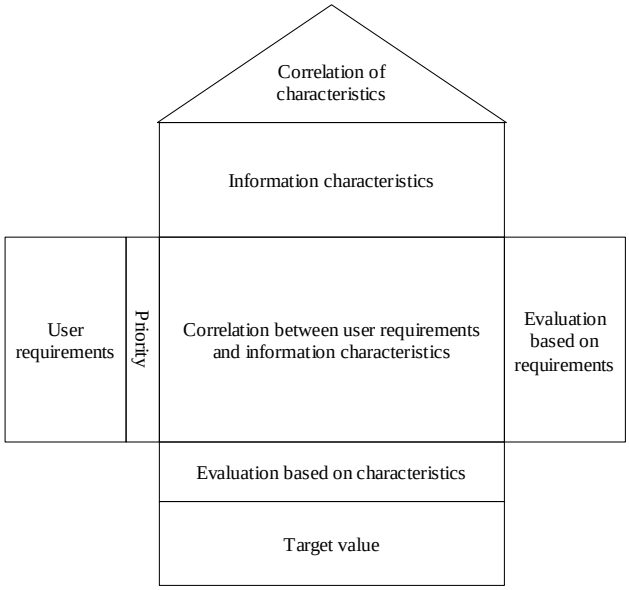

Fig. 4: The 'House of Quality'

User requirements are stated on the left side. These are organised by category and by hierarchical levels. Here it is important to address subjective and objective requirements of information. The user states for each requirement its priority as a rating from one to five (one means lowest priority and five the highest). A simple way to rank these requirements is to compare the requirements in pairs. Information characteristics are stated in categories and hierarchical levels on top of the matrix. These characteristics are meaningful and measurable criteria, which are related to user requirements and building the basis for measuring information quality.

Based on the user requirements and information characteristics, relationships between these are worked out in discussions between users, business and Data Warehouse people. The intensity of the correlation should be identified (strong [9], medium [3] , and weak [1]) and listed in the correlation matrix. This matrix helps to understand and visualise the relations between user requirements and information characteristics. A ranking of the information characteristics can be calculated by multiplying the correlation value with the priority of user requirements. High ranking are important for the overall information quality and therefore should be consider carefully.

A second object of the QFD-method is to state target values for the stated information characteristics. For this, the matrix is extended to include the evaluation of current solutions. A user focused evaluation is stated on the right side of the correlation matrix. On the bottom of the matrix there is an evaluation focused on information characteristics. For evaluation an integer scale between one (unfit/not fulfilled) and fife (excellent/fulfilled) could be used. Two separated evaluations, one focused on user requirements and a second focused on information characteristics, help to validate the correlation matrix and derivate realistic target values for information characteristics.

It is important to keep the amount of information in each matrix at a manageable level. This can be done by splitting the matrix in three levels based on semiotic. A separated 'House' for syntactical issues, one 'House' for issues related to semantic and one for issues related to pragmatic. Fig. 5 shows a simplified example of the 'House of Quality' for semantic.

				Priorities	Information characteristics											
					Data Values				Meta Data							
									Codes				Descriptions			
					Empty fields	Used default values	Incorrect values	Duplicates	Codes without description	Varying codes	Redundant used codes	Non-unique codes ("two in one")	Fields without known default values	Synonyms	Inconsistent data description	Fields without precise description
User requirements	Interpretability	Precise data definitions														
		Easy to understand														
		Consistent interpretability	No synonyms													
			Compatibility of definitions between systems (Integratability)													
		Codes	Standardised, known default values													
			Codes only where appropriate													
			Interpretable codes													
			Standardised codes													
	Data Values	Accuracy (correct compared to real world)														
		Consistent														
		Complete	Optional fields filled in													
			Obligatory fields filled in													
		No Redundancy (Copies, Duplicates)														

Fig. 5: 'House of Quality' for semantic

The completed 'House of Quality' for each level have to be integrated in a 'Model of Information Quality', which combines the three semiotic levels. For this, the relation of user requirements between different levels have to be identified. This can be done by comparing user requirements between syntax and semantic and then between semantic and pragmatic. The result should be stated in two correlation matrixes with values between one and nine (strong [9], medium [3] , and weak [1]).

The completed 'Model of Information Quality' structures user requirements and information characteristics for each semiotic level and states relationships between them. With appropriate methods to measure the value of each information characteristic, the 'Model of Information Quality' builds the basis for measuring information quality. The model also provides a uniform and consistent documentation for quality planing in Data Warehouse Systems and the basis for further analysis to determine the causes and implications of insufficient information quality.

3. Information Quality in Customer Relationship Management Processes

Customer Relationship Management Processes are supporting Marketing, Sales and Services. Fig. 6 illustrates standard business processes in each of the functions. The processes are closely interlinked with each other as well as with the back end processes in the ERP-systems. Data Warehouse forms a strong platform to enable and facilitate information exchange. Any of them can rely on Data Warehouse Information and should be offered via the Web.

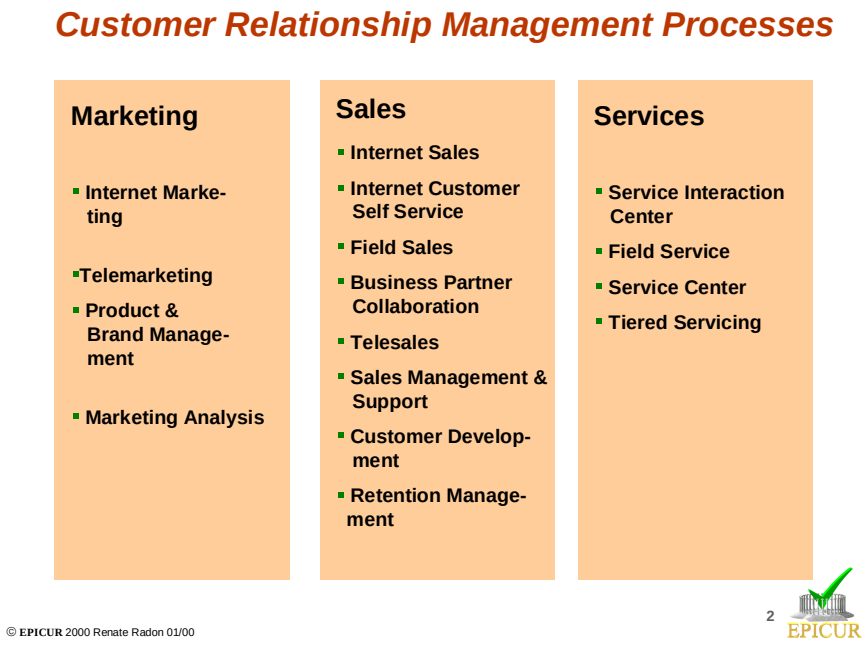

Fig. 6: Classification of CRM-Processes

3.1. Internet Sales as an example for CRM-processes

The following example concentrates on Internet Sales: Interactive sales dialogues based on customer profiles support online product/solution configuration, pricing functionality and purchasing once the solution is checked for consistency and suitability. The standard business process consists of the following process steps:

Product Configuration including consistency checks:

- In the first step, the knowledge base is loaded. Product-related data like material master data, bill of materials, classification data like classes, characteristics and values, as well as dependencies like procedures, actions and preconditions are prepared for presentation and selection. E.g. if a PC should be configured all relevant configuration data for screens, keyboards, loudspeakers, processors etc. is being loaded.
- In the second step, characteristic values are assigned to the header material. E.g. the individual PC is 'tailored' according to customer request: customer-individual screen, keyboard, loudspeakers and processors are being selected and assigned to the customer-specific product.

- In the third step, the customer's choice is checked for completeness. In case inconsistencies have occurred, they have to resolved. E.g. if the processors selected do not meet certain pre-conditions, the customer-specific configuration can not be further processed. Resolving inconsistencies can initiate an iterative cycle between step one and three until the configuration is finally consistent.
- In the forth step, the consistent configuration is displayed with its individual product structure. A customer-specific product has been developed.
- In the fifth step, the configuration can be further specified interactively by navigating through the multi-level product structure until the final product is entirely described. E.g. key-board details can be further specified. A customer-tailored, consistency checked bill of material has been created. It can become part of the customer's purchase order and later on of the materials requirement planning in the supplier's process chain. It can also form the basis for pricing and invoicing later on.

Pricing

- In the sixth step, the configuration is saved and can be used for pricing simulations in subsequent steps.
- In the seventh step, the configuration can be priced according to customer-specific pricing conditions. Product-related, customer-specific and perhaps seasonal pricing conditions can be combined to finally calculate the proper price. In case, pricing does not meet the customer's expectations the configuration process can be restarted at step two until it finally meets the customer's requests.

The diagram in Fig. 7 illustrates the process with detailed information input and output at each step:

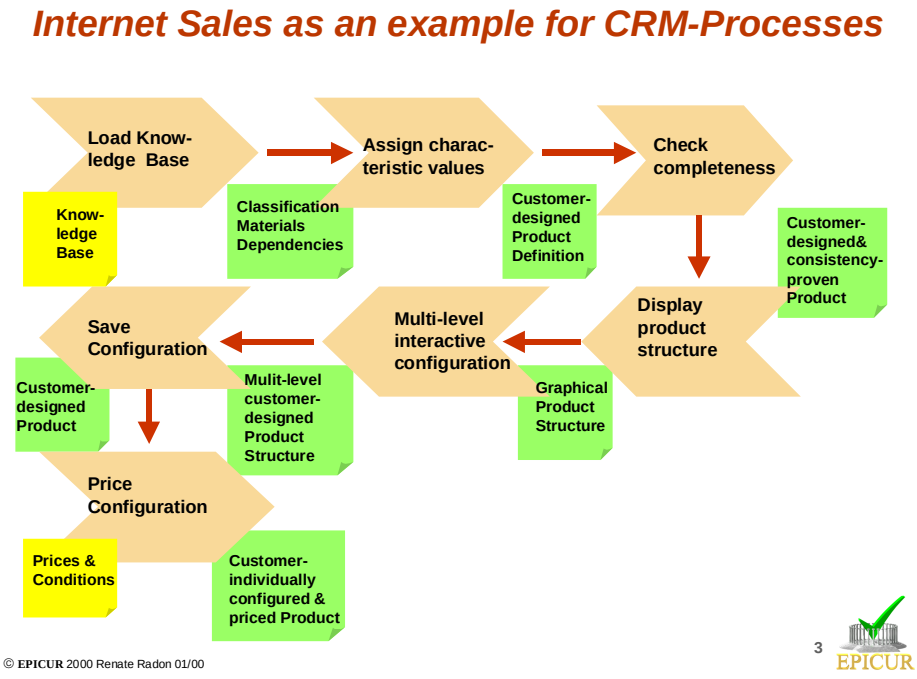

Fig. 7: Internet Sales process chain

In order to provide high level quality information throughout the entire process chain, information quality characteristics have to be assigned to the specific information input and output of each step.

3.2. Quality characteristics in the internet sales process

To meet these targets the information offered must fulfil quality characteristics on any of the three semiotic levels syntax, semantic and pragmatic: In the following section we are trying to give examples for each level according to the table below.

Semiotic Level	**Characteristics**
	Syntactical correctness, consistent representation, security, accessibility
	Interpretability, accuracy, consistent data values, complete data values, precise data definitions, objective, believability, reliable, easy to understand
Pragmatic	Relevance, completeness, timeliness

Syntax –level:

Three key elements can be identified on this level:

- Syntactical correctness and consistent representation
- Secure and individualized accessibility
- Easy accessibility

Since lots of information is shown to public, access security must be guaranteed. Furthermore access and security are a prerequisite to generate a trustful relationship with the various partners of the business network. Information therefore must be accessible at any time and in the most reliable way. Individualized accessibility and individual-tailored information is necessary to provide exactly the information the business partners need. Individualization emphasis customer loyalty and forms a sustainable part in the customer relation. Individualized accessibility means that the customers are presented only those parts for configuration that are working and certified for the particular location. E.g. voltage must always be defaulted according to the country the customer is most likely to live. Additionally, target-group optimization enables individualization of offerings, facilitates forecasting, shopping basket analysis, profitability analysis etc. If target-group optimized accessibility is available, tools to generate insights about customers can be easily applied.

As a matter of fact, syntactical correctness and consistent representation is also a key element on the syntactical level in order to create trustful business relationships.

Semantic - level

The following three key elements can be identified on this level:

- Interpretability
- Easy to understand
- Consistent, complete and accurate data values

Is the data presented interpretable, easy to understand, and consistent? The data presented should meet the business partner's specific data requests. E.g. pricing conditions should be perceived as transparent, fair and easy-to-calculate. Currency is also an information that should be consistent and accurate. Misinterpretations must be avoided. Since pricing and currency are competitive issues, interpretability becomes an extremely important quality characteristic. Furthermore consistency and accuracy form an essential part in trusted business partnerships. Key questions to be answered are:

- Can the business partners trust in the data presented?
- Is the data accurate, objective and reliable?

This is extremely important in case purchase orders or bids and proposals should be developed out of the supplier's data. Product catalogues, configurations and pricing conditions must meet the needs of accuracy, objectivity, believability and reputation. Since the data is used in the partner's/customer's supply chain, trust in the suppliers reputation is key to business success.

Information - level

The following key elements can be identified on this level:

- Completeness
- Timeliness, Up-to-date
- Relevancy

Key questions to be answered are: Is the Data presented complete and up-to-date? Does it meet the needs of relevancy, value-added, timeliness, completeness and does it provide the required amount of information? E.g. are the catalogues and configuration options updated timely? It is essential that the latest products and offerings are immediately shown to the business partners. Since all partners involved want to gain competitive advantage out of the joint Data source the needs mentioned above must be fulfilled. Latest-edge-offerings will add-value to all parties involved: on the one hand the suppliers are showing their competence and on the other hand the partners can generate additional business by making attractive offerings.

As the example shows, quality in Data Warehousing becomes a key success factor especially if the information is shared with external partners: it will be used to develop new, cross-company processes and to facilitate key business processes of the partners – trust in the information offered is key to business success. Reliable measurement methods must be integrated into an efficient meta data management from the very beginning in order to guarantee a high quality standard.

4. Acknowledgements

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