Demand-driven Information Requirements Analysis in Data Warehousing [1]

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Abstract

Information requirements analysis for data warehouse systems differs significantly from requirements analysis for conventional information systems. Existing data warehouse specific approaches are reviewed. A comprehensive methodology that supports the entire process of determining information requirements of data warehouse users, matching information requirements with actual information supply, evaluating and homogenizing resulting information requirements, establishing priorities for unsatisfied information requirements, and formally specifying the results as a basis for subsequent phases of the data warehouse development (sub)project is proposed Its components as well as its overall design are based partially on literature review, but mainly on findings from a four year collaboration project with several large companies, mostly from the service sector. While an application of the entire methodology is still outstanding, some components have been successfully applied in actual data warehouse development projects of the participating companies.

1. Introduction

Data warehousing consumes a significant share of corporate IT budgets and can contribute significantly to meeting information management goals. As a consequence, managerial issues related to data warehousing including development project management are increasingly addressed (Watson, Haley, 1997). This paper addresses the support of information requirements analysis as a specific aspect of project management for data warehouse systems development.

During information requirements analysis, specifications are generated that need to be satisfied by the data warehouse system. This phase is therefore generally comparable to the 'requirements' and the 'analysis' phases of development projects for conventional information systems. Being one of the earliest steps of systems development and thus entailing significant problems if faulty or incomplete, requirements analysis should attract particular attention and should be comprehensively supported by effective methods. Hence it is fair to assume that the special nature of data warehouse systems and the importance of this particular phase of systems development justify a specific methodology.

The data warehouse system may support users in different parts of an organization or even in different organizations. Hence, not only have information requirements to be elicited from future users, matched with available information supply, and prioritized. They also have to be homogenized and integrated into the 'global' conceptual data schema of the data warehouse system. Existing approaches to information requirements analysis for data warehouse systems apparently support these activities only partially: Supply driven approaches risk to waste resources by specifying unneeded information structures and by not being able to involve data warehouse users sufficiently (Gardner, 1998) (List, Schiefer, and Tjoa, 2000). Demand driven approaches often suffer from an too abstract specification of regarded management processes, from missing matching mechanisms for information supply and information demand, or from poor support for priority assignment and homogenization of information requirements (Strauch, 2002).

As a foundation for literature review and method development, we discuss to what extent information requirements analysis in data warehousing development projects differs from requirements specification in conventional information systems development (section 2). Key concepts for specifying information requirements are defined in section 3. Since this research is aimed to support real life data warehouse development projects, section 4 summarizes project managers' expectations for an information requirements analysis methodology in large projects. These interviews show that the methodology should be demand-driven, use a multi-stage, hierarchical support, and cover the entire process of

(1) determining information requirements of data warehouse users,
(2) comparing information requirements with actual information supply,
(3) evaluating and homogenizing resulting information requirements,
(4) establishing priorities for non-covered information requirements, and
(5) formally specifying the results as a basis for subsequent phases of the data warehouse development (sub)project.

Based on the experts' requirements, existing approaches are discussed in section 5. To meet the requirements and overcome identified methodology shortcomings and problems, a method is proposed in section 6 that comprises 13 steps: In an initialization phase, targeted users and dominant applications for the (sub)project are identified. During the second, 'as-is'

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[1] This article is based on Winter, R. and B. Strauch: 'A Method for Demand-driven Information Requirements Analysis in Data Warehousing Projects', to appear 2003 in Proceedings of the Hawai'i International Conference on Systems Sciences, IEEE.

analysis phase, actual reports are analyzed, an aggregate information model ('information map') is created, and relevant data sources are analyzed. The third, 'to-be' phase comprises the identification and analysis of business questions for the regarded management processes, a systematic, multi-stage comparison of as-is and to-be information requirements, the establishment of priorities for non-covered information requirements, and alignment of resulting information items with the corporate meta data repository for homogenization purposes. A final modeling phase includes specifying and reviewing the data model(s) as an input for subsequent phases of the data warehouse development (sub)project. Section 7 concludes the paper by summarizing our approach and first application experience.

The proposed method components as well as the overall design of the method are based partially on literature review, but mainly on findings from the competence center 'Data Warehousing', a four year collaboration project of several large companies – mostly from the service sector – and the Institute of Information Management, University of St. Gallen[2].

2. Requirements analysis for data warehouse systems

2.1. Data warehouse systems vs. conventional information systems

Data warehouse systems differ in various aspects from conventional information systems:

- The data warehouse system is a conglomerate of the data warehouse database(s), data marts, extraction systems, transformation / cleansing systems, selection / aggregation systems, meta data management system, etc. Such a complex and expensive component of corporate IT infrastructure can only be developed incrementally (Inmon, 1996, p.96) (Devlin, 1997, p.304) (Gardner, 1998, p.58) (Cognos 2000) (SAS, 2000). Except for 'quick wins', sustainable return on investment occurs only in the long term and needs the entire infrastructure to be regarded as a whole. In contrast, the business case for conventional information systems can usually be better isolated from the underlying infrastructure and paybacks should exceed investments after three years at the latest.
- All data in the data warehouse system originate from the company's transactional information systems or from external sources. In contrast to a conventional information system that supports specific business processes or even specific access / distribution channels (e.g. call center, electronic commerce), the data warehouse system cannot be developed 'on the green'. Instead, numerous interfaces and connections to existing systems throughout the organization or even beyond have to be considered.
- Particularly in early stages of the development project, the future users of a data warehouse system have difficulties to express their information requirements (Connelly, McNeill, and Mosimann, 1999, p.7) (Gardner, 1998, p.55). In contrast, conventional information systems are usually developed based on extensive, consistent specifications.
- Data warehouse development projects involve several organizational units so that their success depends on top management support. In contrast, conventional information system development projects can often be linked to specific organizational units that serve as application owners.

Data warehouse systems are developed incrementally, regarded as long term projects including significant infrastructure investments, are closely linked to many other information systems, cannot be 'owned' by specific organizational units and, what may be most important, can usually not be developed based on a comprehensive set of requirements specifications. Systems development support methodologies – and in particular the requirements analysis phase – have to reflect these specific properties.

2.2. Information requirements analysis for data warehouse systems vs. requirements analysis for conventional information systems

Requirements analysis for conventional information systems means to elicit necessary and desirable systems properties from prospective users and / or project sponsors, homogenize requirements, assign priorities to requirements (i.e. separate necessary from 'nice to have' systems properties), and derive a conceptual schema that represents necessary requirements independently from the systems' implementation (Gane, Sarson, 1977) (De Marco, 1979) (Yourdon, 1989). Data warehouse systems are developed to support decision makers and / or knowledge workers. Due to the uniqueness of many decision / knowledge processes, the missing structure of many decision / knowledge processes and the refusal of decision makers / knowledge workers to disclose their processes in detail, the required input for data warehouse requirements analysis

[2] Partner companies of the Data Warehousing competence centers (1999-2002) are AGI (now swissscom IT services, -2000), ARAG, Credit Suisse (from 2000), Deutsche Post (-2000), Mummert Consulting (from 2001), plenum Consulting (-2000), Sanitas (-2000), swisscom (-2000). Swiss Life, Swiss Re (from 2001), UBS (from 2000), VBS (-2000), Winterthur Insurance, Württembergische Insurance (now W&W). For project details and published results see http://datawarehousing.iwi.unisg.ch

can usually not gathered correctly and comprehensively (List, Schiefer, and Tjoa, 2000, p.24). Section 3 provides a framework to differentiate between various information concepts that proved useful to analyze such situations.

Data warehouse systems should not only support actual information needs by decision makers and / or knowledge workers, but should also provide a means to meet future, presently unknown information requirements (Gardner, 1998, p.55). If the collection, homogenization, selection and specification of current information requirements in a data warehousing context was already problematic, the specification of future information requirements seems to be completely impossible (Connelly, McNeill, and Mosimann, 1999, p.7) (Gardner, 1998, p.55). The analysis of information requirements for data warehouse systems cannot only be based on information demand, but must also be guided by current and future information supply – because these seem to be more stable, more concrete and better accessible.

3. Key concepts for defining information requirements

As a foundation for discussing related work and a framework for developing a methodology, we have to define the various information concepts found in organizations:

- ***Information requirements*** is defined as the type, amount and quality of information that a decision maker or knowledge worker needs to do his / her job. In most cases, information requirements cannot be specified exactly, vary with different tasks, vary in time, or depend on the decision makers / knowledge workers frame of mind (Picot, Reichwald, and Wigand, 1996, p.106). While ***objective information requirements*** comprise all information that actually is relevant to fulfill his / her respective tasks, ***subjective information requirements*** denotes all information that the decision maker / knowledge worker believes to be relevant.
- Usually decision makers / knowledge workers articulate only a portion of their information requirements so that ***information demand*** can be defined as a subset of (subjective) information requirements (Picot, Reichwald, and Wigand, 1996, p.106). But information demand may also go beyond subjective information requirements when information is collected as a precaution or as a means of power (***pseudo information provision***) (Schneider, 1990, p.226).
- ***Information supply*** is defined as the entirety of information that is available to a decision maker / knowledge worker at a certain point in time and at a certain (work)place. Information from internal as well as external sources is comprised.
- ***Information provision*** is derived by intersection of information demand and information supply. ***Information state*** is derived by intersection of objective information requirements and information supply. Hence, information state is a subset of information provision.
- By comparing information supply on the one hand and subjective (objective) information requirements on the other hand, ***subjective (objective) information oversupply*** and ***unsatisfied subjective (objective) information requirements*** are derived, respectively.

Figure 1 illustrates graphically how the various concepts of information demand, information supply, and information provision are related.

[Insert Figure 1. "Key concepts for defining information requirements (Strauch, 2002, p.70)" here]

4. Expert requirements for data warehouse information requirements analysis

In several workshops of the data warehousing competence centers at the Institute of Information Management, University of St. Gallen, data warehouse project managers from various large companies (see footnote 2) have identified the following requirements for an effective methodological support of the information requirements analysis phase in data warehousing projects (Strauch, 2002, pp.78ff):

- **Multi-stage, hierarchical approach:** To avoid wasting resources and guide the specification process, the matching of information demand and information supply should start on an aggregate level and should be refined later.
- **'Information map':** As one of the results of the information requirements analysis, a document should be created that represents where data are sourced from, which organizational units use which data, which data relate to which concepts, which concepts are homonyms or synonyms, etc. on an aggregate level.
- **'As is' information provision:** It must be documented (and is a necessary input for creating the information map) which source systems provide which data in which quality.
- **'To be' information state:** By analyzing actual and projected overlaps of information supply and information demand, the 'to be' information state is planned to meet not only actual, but also projected information requirements.

- **Assignment of priorities:** Since limited resources allow only selected unsatisfied information requirements to be covered by the data warehouse system, evaluation criteria have to be developed and coordinated which then allow for deriving priorities.
- **Homogenization of concepts:** Data from different operational sources can only be integrated if the underlying semantic concepts have been homogenized.
- **Integration with subsequent development phases:** In order to create results that are reusable in subsequent phases of the data warehouse development project, models for information requirements representation should be aligned with – or even be identical with – models used for data warehouse design and / or data mart design. Therefore project managers prefer conceptual models for multidimensional data.
- **Documentation of meta data:** Information requirements analysis creates valuable meta data that should be directly transferable into the meta data management system instead of having to be manually recorded and integrated in subsequent phases of the data warehouse development project.

The proposed methodology is designed to meet these requirements and to support the systematic specification of current as well as future information requirements.

5. Existing approaches to data warehouse information requirements analysis

A large number of approaches to information requirements analysis have been developed both by academia and companies / consultants. Beiersdorf (1995, p. 71ff) describes not less than 28 techniques and technique combinations for information requirements analysis. Most of these techniques, however, have been developed for supporting the development of conventional information systems and are therefore only partly suitable for data warehousing projects.

Like Business Systems Planning (IBM, 1984), Information Engineering (Finkelstein, 1989) (Martin, 1989) or the method of critical success factors (Rockart, 1979), most methods combine specific elements with basic components like interviews, questionnaires and job analyses which of course are also applicable for data warehouse development projects. But as a whole, they do not meet the requirements described in section 4 sufficiently (for a detailed discussion see Strauch, 2002, pp.77ff).

Although it seems to be obvious that matching information requirements of future data warehouse users with available information supply is the central issue of data warehouse development, only few approaches seem to address this issue specifically. Based on whether information demand or information supply is guiding the matching process, demand driven approaches and supply driven approaches can be differentiated:

- **Demand driven approaches** are aimed to determine information requirements of data warehouse users. According to Hansen (1997, p.319), end users alone are able to define the business goals of the data warehouse systems correctly so that end users should be enabled to specify information requirements by themselves.
  However, end users are not capable to specify their objective, unsatisfied information requirements because their view is subjective by definition, because they cannot have sufficient knowledge of all available information sources, and because they use only a business unit specific interpretation of data (Strauch, 2002, p.115). Moreover, end users can often not imagine which novel information the data warehouse system could supply (Gardner, 1998, p.55) (Connelly, McNeill, and Mosimann, 1999, p.7).
- **Supply driven approaches** start with an analysis of transactional source systems in order to reengineer their logical data schemas. By selecting items from the consolidated data schema, information requirements can then be specified by end users. The data schema subset can directly reused as input for the data warehouse data schema.
  However, these approaches risk to waste resources by handling many unneeded information structures. Moreover, it may not be possible to motivate end users sufficiently to participate because they are not used to work with large data models developed for and by specialists (Gardner, 1998, p.55).

A special type of demand driven approaches is to derive information requirements by analyzing business processes in increasing detail and transform relevant data structures of business processes into data structures of the data warehouse (Böhnlein, Ulbrich-vom Ende, 2000). The data warehouse systems regarded in our research were developed to support exclusively decision processes. For decision processes, however, a detailed business process analysis is not feasible because the respective tasks are often unique and unstructured or, what is even more important, because decision makers / knowledge workers often refuse to disclose their processes in detail.

6. Proposed methodology

The experts' requirements to information requirements analysis in a data warehousing context (see section 4) call for a demand driven approach. Since the business process oriented approach is not applicable if the data warehouse system has

to support decision / knowledge processes, we focus on a 'conventional' demand driven approach. Of course the proposed methodology should overcome the shortcomings listed in section 5, i.e. a multi-stage approach has to be taken, users have to be supported in specifying objective (and not subjective) information demands, novel information (e.g. information from sources that users might not be aware of) has to be included, the homogenization of information requirements has to be supported, selection and priority assignment mechanisms have to be provided for project management, and aggregate as well as semi-formal specification documents have to be created.

Several data warehouse development projects in participating companies (see footnote 2) were analyzed in order to identify best practices for information requirements analysis. While no procedure met all of the above requirements, many companies developed appropriate solutions for certain activities. Moreover, a common, consistent sequence of activities was observed that includes two different supply-demand matching steps: After some initialization activities, information requirements for regarded decision processes were first matched with available information on an aggregate level. Based on that aggregate match, requirements then were brought into a priority sequence, the most important requirements being elaborated in more detail and then homogenized. A second matching activity then was used to synchronize information supply and information demand on a full level of detail. In a final modeling phase, information requirements (and appropriate meta data) is transformed into a format that can be reused in subsequent development phases.

[Insert Figure 2. "Activity model for the proposed methodology (Strauch, 2002, p.172)" here]

Figure 2 illustrates the proposed structure and sequence of activities. The functional assignment of analysis activities to 'as is' (phase 2) and 'to be' (phase 3) makes clear that, while on different levels on detail, both 3.2 and 2.3&3.6 are matching activities. In the following, activities are described according to their assignment to 'initialization', 'as is analysis', 'to be analysis', and 'modeling' phase. However, it should be noted that the actual sequence of activities (see Figure 2) differs from the sequence of their description in the text.

6.1. Phase 1: Initialization

Activity 1.1: Identify targeted users

Since usually an incremental approach is used for data warehouse development in general (see section 2.1), it is necessary for each cycle to identify targeted users or targeted decision processes of that cycle. E.g., a development cycle for data warehousing in a bank could target 'only' reporting for securities transactions.

Activity 1.2: Identify dominant application type

Depending on the type of users (e.g. middle management vs. knowledge workers) and the type of analyses (e.g. regular reporting vs. drill-down analyses of exceptions), different types of analytical applications are deployed. E.g., analysts usually prefer to use OLAP tools for flexible information analysis, while upper management favors exception reports or balanced scorecard systems to convey aggregate information (Strauch, 2002, p.173). The dominant application type[3] has to be identified because this specification has implications on which data models are used, which source systems are relevant, and which decision processes have to be regarded.

6.2. Phase 2: 'As is' analysis

Activity 2.1: Analyze actual information supply

The most important source of information on actual information supply is to analyze those reports that are regularly used by relevant users. By creating an inventory on these reports, the included information and the underlying data models, two goals can be accomplished: Not only can information requirements more easily matched to available information, and the selection of appropriate reports can be supported. The created meta data also support actual and future data warehouse development activities (Becker, Holten, 1998, p.484).

[3] Observed types of analytical applications were reporting systems, managed query environments, executive information systems, decision support systems (including data mining and other techniques), OLAP systems, and transactional application support (including portals).

Activity 2.2: Create aggregate information map

In order to guide the matching process of information supply and information demand, an aggregate 'information map' is derived. Input for this activity are the meta data gained by report analysis. The 'information map' is basically a data schema of the relevant information subjects on an aggregate level.

Activity 2.3: Analyze source information systems

An accurate analysis of relevant data sources (i.e. selected transactional systems or their interfaces) is inevitable to ensure a sufficient level of data quality. Efficient data quality control is necessary to guarantee the data warehouse's successful implementation and acceptance by users (Watson, Haley, 1998).

6.3. Phase 3: 'To be' analysis

Activity 3.1: Analyze information demand

A growing number of companies uses so-called 'business questions' (see e.g. Connelly, McNeill, and Mosimann, 1999) to analyze decision processes and identify respective information requirements. Business questions are typical questions that are relevant to the regarded users / decision processes and that can not or not sufficiently answered by using existing information systems. We often observed that not missing information was the primary problem for decision makers or knowledge workers – in most companies, all information is available somewhere. Instead, it is important to identify the 'right questions' (Schwaninger, 1994, p.142). The data warehouse system has to supply the information to answer these business questions. A concrete method for identifying relevant business questions and deriving respective information demand can be found in (Strauch, 2002, p.187ff). Figure 3 illustrates how the results of this activities are documented.

[Insert Figure 3. " Documentation of information demand analysis (Strauch, 2002)" here]

Activity 3.2 Match aggregate information supply and information demand

Information demand for regarded business questions (from activity 3.1) is matched against the aggregate information map (from activity 2.2) to create a first, rough-cut analysis of unsatisfied objective information requirements. Based on this analysis, it has to be decided in subsequent activities which unsatisfied information requirements should be provided by the data warehouse system.

Activity 3.3: Assign priorities

Usually not all information requirements identified in activity 3.2 can be satisfied entirely within the regarded data warehouse system development cycle. For assigning priorities to information requirements, we found approaches based on development costs, implementation time, capacity of the development team, data security aspects, privacy aspects, desired information granularity, desired refresh frequency, data quality aspects, data quality costs, and combinations of these criteria.

Activity 3.4: Increase level of detail

Since the initial match of information supply and information demand is done on an aggregate level, a refinement activity is necessary. For those information requirements that have been selected in activity 3.3, data sources are analyzed and transformation rules are specified. In addition, it is specified which data are to be provided at which aggregation level / granularity and how often these data have to be refreshed (Strauch, 2002, p.176).

Activity 3.5: Homogenize information requirements

Data provided by a data warehouse system must be associated with clearly defined semantic concepts in order to have meaning for – and can be utilized by – the users. Unfortunately, the semantic meaning of many data is often not uniform throughout large organizations. Inconsistencies and, as a consequence, acceptance problems are inevitable when e.g. 'gross income' in one unit of an airline is understood as effective payments including security levies, insurance charges and taxes, while for other units of that airline extra charges are not comprised in gross income. The semantic meaning of data must therefore homogenized within the organization to avoid consistency and acceptance problems.

Activity 3.6: Review priority assignment

The homogenized specification of the most needed and / or most practicable unsatisfied information requirements that is created by activities 3.3, 3.4 and 3.5 can now be reviewed in the light of an accurate analysis of the relevant data sources (from activity 2.3). Information requirements are re-assessed based on supply costs (for external data), costs of extraction /

transformation processes, expected quality levels, practicable supply service levels, etc., thereby creating a final priority sequence of detailed, homogenized information that should be provided by the data warehouse system.

6.4. Phase 4: Modeling

Activity 4.1: Create data schema

Being the main deliverable of the information requirements analysis, the data schema serves as a foundation for subsequent systems development phases as well as a meta data source of utmost importance. For modeling the data schema, an appropriate data model must be selected. While general purpose semantic data models (e.g. entity relationship model) are widely used for modeling data schemas of conventional information systems, specific semantic data models for multidimensional have only begun to gain acceptance for modeling data schemas of decision oriented systems. This is due to the fact that many data models for multidimensional data are not truly conceptual because they do not completely abstract from certain, often proprietary, properties of tools or from certain implementation characteristics (Schelp, 2000, p.2). Although semantic models for multidimensional data are far from being perfected, it is not advised to use general purpose semantic data models: These models have been developed to preserve the consistency of volatile databases by appropriate design (e.g. avoiding redundancies) (Schelp, 2000, p.2). In contrast, databases for decision / knowledge work support are mostly non-volatile and certain redundancies may be desirable, e.g. for performance reasons.

As a consequence, information requirements for data warehouse systems should be specified using a semantic model for multidimensional data, e.g. ADAPT (Bulos, 1998), ME/R model (Sapia, Blaschka, Höfling, and Dinter, 1998), or DFM (Golfarelli, Rizzi, 1998). For several reasons discussed in (Strauch 2002), we choose the 'Kubenstrukturmodell' (cube structure model) developed by Schelp (2000) to specify the data schema of information requirements. A cube structure graph is illustrated in Figure 4.

[Insert Figure 4. "Cube structure representation of information requirements (Strauch, 2002)" here]

Activity 4.2: Evaluate data schema

Since, at least when it comes to homogenized, company wide models, data schemas are usually developed by method specialists and not by end users, the resulting requirements specifications must be reviewed by targeted data warehouse users. If significant interpretation gaps are identified or business changes have occurred, this activity may trigger a backtrack to activity 3.1.

6.5. Other methodology components

Although the identification of activities including their structure and their sequence represents the core of method engineering (Brinkkemper, Lyytinen, and Welke, 1996), there are several complementary method components that need to be developed: (Heym, Österle, 1992)

- a set of ***document types*** used to represent the results of certain activities
- a set of ***techniques*** used to support the creation of documents and / or the execution of certain activities
- an ***organizational model*** that specifies which activities are performed and which activities are supervised by which organizational roles
- an ***information model*** that specifies all information objects relevant for an activity, represented in a document, or created by a technique as well as the relationships between these information objects.

For the methodology proposed in this paper, these method components can be found in (Strauch, 2002).

7. Conclusions

The activity model proposed in this paper represents the core component of a comprehensive methodology for information requirements analysis for data warehouse systems. All described activities were observed in – and applied by – several large companies in real life data warehouse development projects. They have been integrated, homogenized, brought into a consistent sequence, and complemented by additional methodology components. When viewed as a whole, the methodology meets all requirements that project managers demand for a consistent, practicable, and scalable support of data warehousing projects in large companies (see section 4): The analysis is focused and compatible with a 'cyclic' overall data warehouse development strategy, the synchronization of information demand and information supply is done in a two-step, hierarchical procedure, end users are involved in the specification process at several occasions and in an appropriate form (e.g. 'business questions'), semantic inconsistencies in large, decentralized organizations are addressed, and priority as-

signment is supported. Main deliverables of the requirements analysis are a data schema using a semantic model for multi-dimensional data, and meta data reusable both in subsequent development phases in for data warehouse operations.

However, our experience with data warehouse projects in large companies shows that a comprehensive application of a rigid methodology is rare, even if only a specific project phase is addressed. Often the use of certain methods, models or tools of varying quality and rigidity is dictated by some company standards, or development projects are managed in a decentralized manner deploying different, often incompatible method components. In some cases there is no methodology used at all, and information requirements analysis is done informally, incompletely, without involving end users and / or not at all ('supply driven' or 'infrastructure' approach).

The proposed methodology has not been yet applied as a whole. However, first experience with applying its components in real life projects allow to expect that significant reuse potentials can be realized and that the manageability and documentation of this often fuzzy phase of data warehouse development can be increased dramatically.

In some cases, major components of the methodology have been applied in isolated data mart projects and not – as intended – throughout all projects in data warehousing. Even though reuse synergies and many other benefits of the proposed approach cannot be exploited if applied only to isolated sub-projects, realized benefits of this engineering approach to requirements analysis in a data warehousing context may lead to a broader acceptance and more complete application.

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