Metadata-Driven DSS Framework

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Abstract: *This paper presents a proposed decision support system (DSS) framework based on extended use of metadata to include business concepts, which improves system usability, flexibility, data legibility and provides an enhanced level of integration between various components of the DSS infrastructure in a complex enterprise environment. Firstly, the critical issues of the current decision environment are analyzed.*

Then, the proposed framework and its general architectural model are introduced.

The paper gives charts illustrating the framework operational procedures.

Keywords — Decision Support System**,** Data warehousing, Metadata and Data Mart.

1. INTRODUCTION

Decision Support Systems (DSS) are a specific class of computerized information system that supports business and organizational decision-making activities [1].

DSS can be categorized in many ways. DSS can be divided into data-oriented DSS, model-oriented DSS and process-oriented DSS [1, 2].

A data-oriented DSS uses data base systems as source of the decision support, in contrast to a model –oriented DSS which uses mathematical models to support business decisions and a process-oriented DSS which simulates human decision making processes.

An important class of data-driven DSS is designed for use by enterprises and governmental organizations to analyse data gathered from various internal and external sources in order to provide answers to questions of business/national impact.

Such DSS systems are architected based on data warehouses / data marts infrastructures according to the typical **data warehouse** architecture illustrated in Figure 1 [3, 4, 5, 6]:

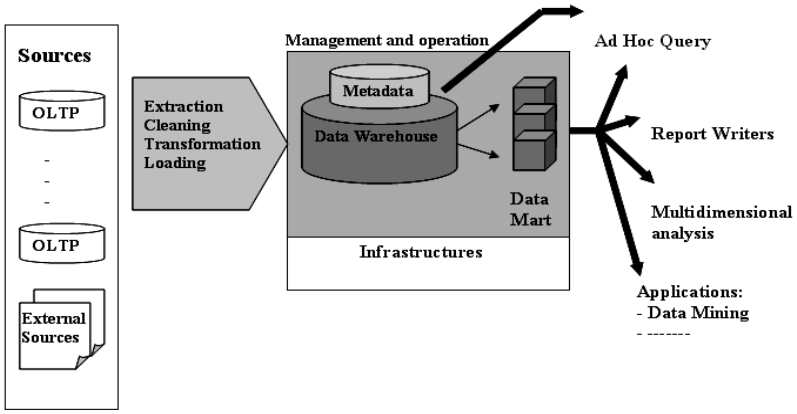

Figure 1: Data Warehouse Architecture

This model uses a Data Warehouse (DW) to integrate and persist data from various data sources.

While Data Marts (DMs) house summary information required by a specific set of users or a specific study.

DWs and DMs are basically architectural options to interface with today's DSS.

The Metadata is a central component of the DSS framework [19]; it allows integration to occur between source systems, the extraction, transformation and load (ETL) processes; the business views, and reports

The primary consumers of the contents of data warehouse are decision makers, knowledge workers and business analysts. Many of the end users are not technically oriented and need a significant amount of support to use a data warehouse effectively.

One method for supporting end users is metadata [7]. Metadata has been described, generically, as "data about data". Metadata have been needed to describe the meaning or properties of data with the aim to better understand, manage, and use that data.

Metadata has been categorized in many ways; for example, technical metadata is used for system operation and maintenance, and business metadata is used for data valuation and interpretation [8].

A second categorization is based on functionality and reflects design and maintenance characteristics abstracted by the metadata.

It identifies six distinct metadata types [9]:

1) Infrastructure metadata that abstracts the components of the system (such as hardware, operating systems, networking, and database servers);
2) Model metadata that abstracts the modelling of data into entities and their relationships: conceptual, logical, and physical . It includes a semantic layer for translating the physical data elements into business terms interpretable by end users;
3) Process metadata that captures information on how data is generated and the transformations it undergoes from source to target;
4) Quality metadata that captures the assessment of the actual data stored in the system;
5) Interface, or delivery and reporting, metadata that captures how business users consume the data.
6) Administration metadata that tracks data usage, including information on users, security, and access privileges to data and applications.

Metadata helps data warehouse end users to understand the various types of information resources available from a data warehouse environment.

However, many data warehouses today do not provide "good" metadata to end users [7, 10, 11].

Metadata Critical issues are partially addressed by research work and products implementations.

Metadata critical issues can be summarized as follows [10, 12, 13,14]:

- Support for all metadata functionalities;
- Support for business metadata;
- Metadata standard formats;
- Metadata exchange and integration.

In this paper we address Decision Support systems that are architected based on Data Warehouses and Data Marts. A framework is proposed based on extended use of metadata to support business metadata [17, 22] with an objective to improve system usability and to enhance the level of integration between the various components of the DSS framework. The proposed approach also defines means to guide and control the loading, refreshing and removal of data in the Data Warehouse.

In the next section, we present the business concept around which the framework is designed. Then, in the sub-sequent sections, we illustrate the proposed framework and its architectural model. Finally we illustrate the framework operational procedures to clarify how the various components of the DSS Infrastructure tie together.

2. THE BUSINESS CASE MODEL

2.1 BUSINESS CONTEXT

The DSS systems under this research are characterized as follows:

- The decision support process is dependent on the availability of data originated from external as well as internal sources.
- In most cases, data is originated from external sources, and not owned by the organization . On request the source data is acquired and used.
- Source data is structured. However references to unstructured data are needed in order to address various types of resources such as internet resources, and documents resources.
- The answers to business questions necessitate analysis, studies, and presentations that may long for several days, and weeks, so time for collecting and transforming data is not a critical factor.
- It is important for the studies with long duration, to have from time to time updated data from originating sources.
- Business Questions to be answered require special environment that include data, models, and tools.
- Many decision support groups are working simultaneously to conduct several studies. Each study requires a subset of source data logically modelled via a common data warehouse schema.
- Results of various studies represent enterprise knowledge that must be archived for reuse in newly posed questions.

2.2 THE BUSINESS CASE CONCEPT

From business perspective a Business Case (BC) represents a study undertaken by a decision support group to answer a question of business interest.

A BC comprises of all tasks and means necessary to deliver results, which are the foundation for taking decision(s) for an individual problem.

A BC is an evolving business object and has a lifecycle.

A BC is initiated by a decision request, and follows a four stage decision support process [6, 16] as shown in Figure 2:

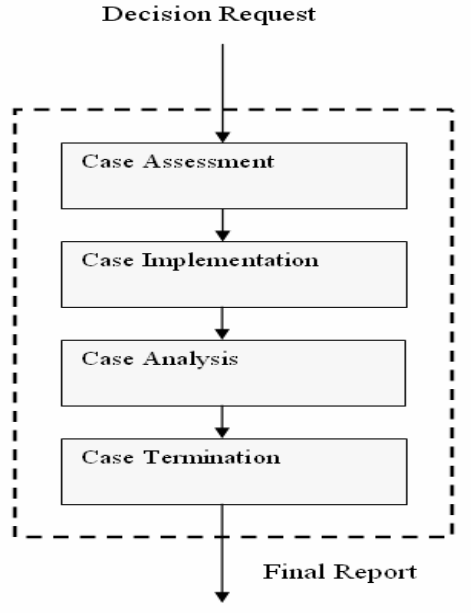

Figure 2: The DSS Process

1) BC assessment.

- BC initiation and forming of BC team.
- Clearly identify the subject, the objectives and the scope of the BC.
- Get a clear picture of the requested results, business rules to apply and the analysis methods, techniques and related tools to use.
- Identify the required data on which the analysis will be based

2) BC implementation.

- Prepare a complete environment for actually performing the analysis. This includes modeling, data downloading and transformation.
- Develop and implement any analytical applications using the related tools and analytical models.

3) BC analysis

- Perform the actual analysis.
- Produce the requested results.
- Generate the final report.

4) BC termination

- Archive the BC
- Clean-up the BC working environment.

Each BC is considered on its own a project, and is managed according to the standard project management methods.

2.3 The BC representation

The main idea is to make the business case explicit in the DSS framework information architecture as illustrated in Figure 3.

Assuming the pre-existence of an enterprise data warehouse;

The BC is represented in the metadata repository, and then a mapping from the business metadata to the schema of the data warehouse is built [15]. When a decision request is raised, a customized data mart with data populated from the data warehouse can be automatically generated with the help of this built-in knowledge

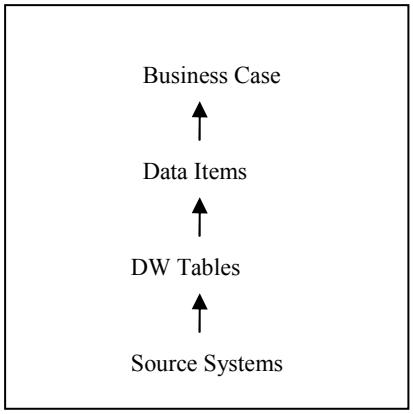

Figure 3: Information Architecture

The BC is modelled and described as follows:

- BC name, BC description.
- Associated subject areas.
- Associated data items

Data items is a logical layer of the DW that contains the definitions of business views, usually on the DW schema [18, 20, 21].

A data item (DI) is described in the metadata repository from different perspectives:

- Analyst view (item name, description, subject area, refresh rate, data fields, etc.).

- Where to tackle it (DW modeled data tables and source data tables).
- How to produce it in the DW and BC environment (acquisition, loading and propagation procedures).

Data items are extremely useful for DSS activities. The metadata repository indexes data items under a subject area hierarchy, allowing the Knowledge Workers and Decision Analysts using the system to quickly find items relevant to their Business Cases.

Business cases and Data items are used to guide and control the loading, refreshing and removal of data in the DW.

2.4 BC ACTIONS

A BC is an evolving business object and has a lifecycle. Figure 4 illustrates the state chart of a business case

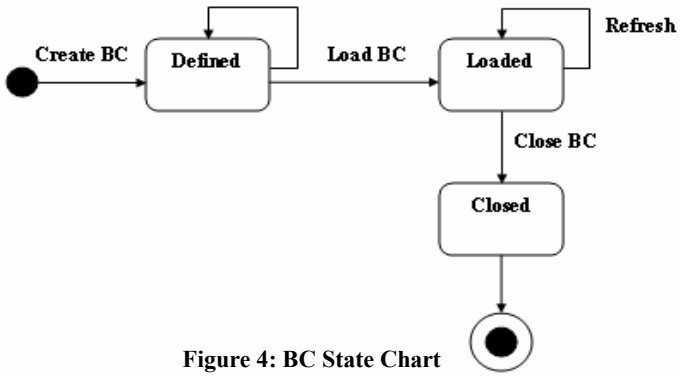

Figure 4: BC State Chart

The Knowledge Workers and the Decision Analysts can perform the following primary tasks:

1) Create a Business Case

The purpose of "Create Business Case" is to:

- Open a new business case.
- Define the business case metadata: name, description and related subject areas.
- Associate the business case with the required data (structured and unstructured)..

2) Load a Business Case

The purpose of "Load Business Case" is to:

- Download into the DW the data required by the business case.

- Create the related working environment.
- Copy the related parts of the DW into a Business Case Working Environment or shortly a BCWE (to initialize its Data Mart).

3) Refresh Business Case

The purpose of "Refresh Business Case" is to

- Update (refresh) the data in the DW and BCWE related to the business case.

4) Close Business Case

The purpose of "Close Business Case" is to:

- Package all data from the BCWE into a file and archive this file as a document under a Document Management System (DMS).
- Delete the BCWE and Delete from the DW the data associated to the business case which is no longer needed by other business cases.

3. THE ARCHITECTURAL MODEL

The purpose of the proposed DSS infrastructure is to provide the decision support groups (Knowledge workers, Decision analysts …) with data marts populated with appropriate data, for them to conduct a variety of analysis and presentation activities in support to the decision making.

The DSS framework consists of many components. These components integrate together around the extended metadata repository in order to finally present the needed data in a structured and effective form to facilitate the decision making process.

The components of the DSS infrastructure are illustrated in Figure 5. The figure clearly shows that the main components are:

- Metadata Repository (MDR)
- Data Warehouse (DW)
- Business Case Working Environment (BCWE)
- Collection Engine (CE)
- Interfaces to unstructured files and Document Management System (DMS)
- External Data Sources Interface

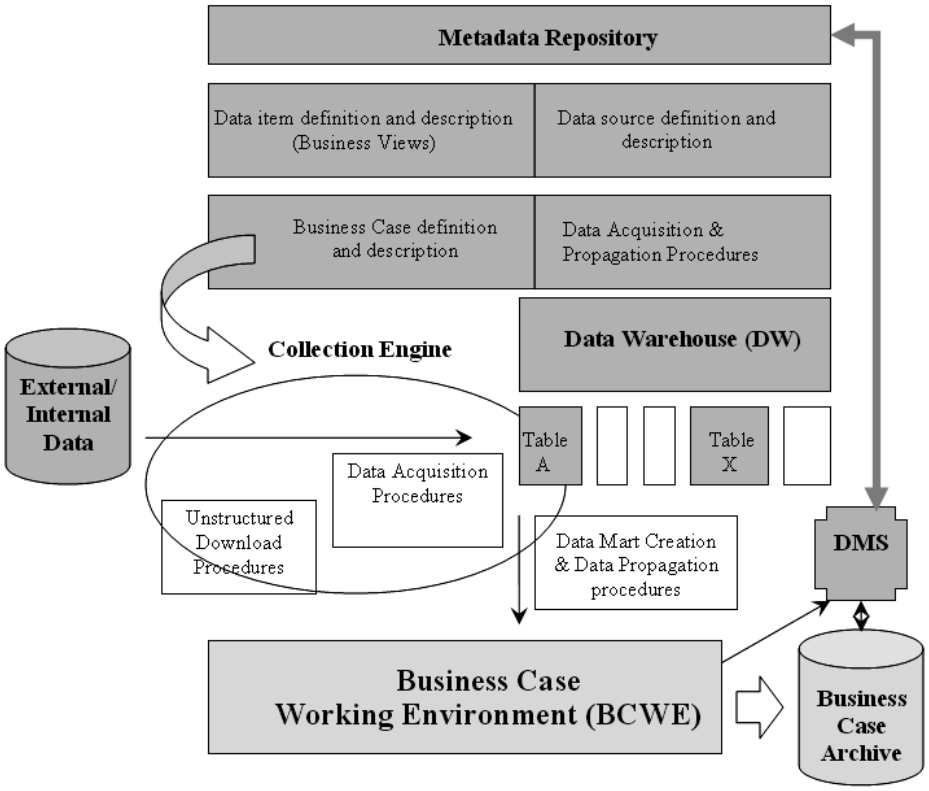

Figure 5: Components of the DSS Infrastructure

3.1 METADATA REPOSITORY (MDR)

The MDR is the repository of metadata of all data sources of interest. In addition it contains metadata specifically related to the DW. The MDR contains all the definitions of the data items, their associations with the various data sources, and the different data transformation steps required to transform the source data into the DW model.

The MDR is also a repository for the definitions of the various Business Cases that have been conducted by the DSS System, and the information about which data items were used by those Business Cases.

The CE will use the MDR stored data about: business cases, data items, data sources and transformation procedures to download data into the DW and to

initialize the business cases working environment with parts of the DW as required by the active business cases.

As a conclusion, the Metadata Repository can be divided into three main areas:

1) Data sources metadata

It holds information about the data sources. A data source is represented in the MDR through a set of entities that describes the source, its databases and application systems. Source databases are described in detail to the data table and data field levels.

This area in the MDR supports the data discovery process to understand the meaning and properties of data available in the disparate data sources and to conclude the plans and procedures for its extraction and integration into the DW.

2) Business Cases metadata

It holds information about the business cases: Definition, association with data items and subject areas, references to unstructured files and status.

This area in the MDR will be used by the CE to identify the data items required for the active business cases, and to keep track of their status.

3) DW metadata

It describes data items from different perspectives:

- Analyst view (item name, description, subject area, refresh rate, data fields, etc.).
- Where to tackle it (DW modeled data tables and source data tables).
- How to produce it in the DW and BCWE (loading and distribution procedures).

This area in the data dictionary will be used to guide the loading, refreshing and removal of data in the DW and its further update into the BCWE. The MDR describes the DW data model, which is normalized Relational model The basic functions provided to support and use the MDR are:

1) Content management functionality, to manage the contents of the MDR, that allows to add update and delete meta data describing DSS available data and objects.

2) A metadata browser /search engine functionality, this will be the front end for users to search and access the MDR contents in order to identify the needed data items for a business case.

3) BC status management functionality, to initiate the requests of changing BC status:

Request to define a new BC, Request to load a BC, Request to refresh a BC, and Request to close a BC.

3.2 DATA WAREHOUSE (DW)

The DW is a logically modeled database into which data can be loaded as required by the active business cases. The MDR contains a description (metadata) of the DW data model.

The definition of the DW schema is an ongoing effort. An initial schema may be developed for an initial set of data sources. Additions and modifications to this schema occurs whenever new sources are available.

The DW is generally divided into the following:

1) Modeled Data Tables (DW Tables)

The Modeled Data Tables represent a clean, usable model of the Data Warehouse. Multiple Source Data Tables may have been used to define the data in the Modeled Data Tables.

2) Modeled Data Views (Data Items)

This layer of the DW contains the definitions of views, usually on Modeled Data Tables. The MDR Data Items mostly refer to these Modeled Data Views. Each view defines a set selected from a Modeled Data Table representing a distinct Data Item. Modeled Data Views are extremely useful for DSS activities.

The actual data contained in the DW vary depending on the business cases currently being processed by the analysts. It can be empty if no work is currently under way; it could contain the complete set of data defined in the MDR or any subset of data as defined by the business cases with the status loaded.

The data currently loaded in the DW is refreshed as defined in the MDR (e.g. daily or once a week, etc). Data is purged when all business cases referencing it have the terminated (closed) status.

3.3 BUSINESS CASE WORKING ENVIRONMENT (BCWE)

As a general rule, a separate working environment is created for each business case. The Business Case Working Environment (BCWE) is a data area that is created for each Business Case, when that Business Case is loaded.

It initially contains the actual data as requested when defining the business case in the format most suitable to the business case. The format could, for example, include transformation of the DW tables into a different physical data model to enhance the performance of a specific tool to be used for analysis.

Furthermore it contains files with unstructured data that belong to the business case.

The Knowledge Workers and the Decision Analysts working on that Business Case can then access the data in the BCWE and apply a variety of data analysis

techniques using the proper tools and then present the data and/or the results using proper drawing, charting and presentation tools.

The analyst has manual control over the refreshing of his data (e.g. he can choose to work on the original data version that was placed in the working environment when it was first established or he can decide to manually rerun the transformation routine to refresh the data after is has been refreshed in the DW).

Once the Business Case work is completed, the Collection Engine archives the whole contents of the BCWE, and then deletes the BCWE.

An old Business Case may be later loaded back using an 'import' utility.

3.4 COLLECTION ENGINE

The Collection Engine is the "glue" that interfaces the various components of the DSS Infrastructure together. It ties-in the DW with the MDR and the BCWE.

The Collection Engine (CE) is the component of the DSS infrastructure that is responsible for updating the data in the DW and in the BCWE as needed. To this end, the CE has access to internal and external (remote) data sources in order to update the DW data. Internal data includes data originated from internal sources. Remote data sources can be accessed directly through Gateways or by importing media to be loaded in a staging area then in the DW. The CE can refresh data in the DW on demand and then propagate it to the requesting BCWE. The CE is responsible for other tasks, such as access to internal sources and archiving of the BCWE when a business case is closed. The CE gets its requests from the Business Case user interface Applications. The collection engine consists of three components:

1) The collection engine driver, which accesses the MDR to determine which data items are to be loaded for a specific business case and starts a three passed loading operation:
   - Initiate the data access and transformation routines that perform the data load operation into the DW. Data items that already reside in the DW will not be reloaded.
   - Once DW data loading for a business case is complete, the data mart creation routine is invoked to populate the business case's working environment.
   - To provide any unstructured data defined as part of the business case, the unstructured download routine is also started.

The driver is also started periodically to review if any data currently residing in the DW is to be refreshed (e.g. daily, weekly or monthly) and to start the data access routine accordingly.

If the data item that currently resides on the DW is no longer accessed by any loaded business case, it is purged from the DW.

2) The data access routines that, based on the parameters defined in the MDR, perform the data load operation.

3) The data transformation routines that define the procedure of moving data from the DW to the business case's working environment.

The CE keeps a database updated with information about its operation for tracking its own progress and for communication purposes with the CE Administrator.

3.5 INTERFACES TO UNSTRUCTURED DATA AND DMS

The DSS infrastructure has interfaces to unstructured internal / external data sources.

The MDR is able to store references to unstructured documents, which are of interest to particular business cases. Once a business case is identified it keeps the IDs of these selected documents, and the CE downloads such files in the BCWE. The user can access these documents from the BCWE during the BC analysis phase.

On the other hand when a BC is closed, the collection engine packages the whole data of the BCWE into a file and stores it as a document on long term storage through DMS.

3.6 EXTERNAL DATA SOURCES INTERFACE

The collection engine is able to access external data sources to use their data in populating the DW and the BCWE. To fulfill this task, the CE uses transformation procedures stored in the MDR.

Access to external structured data can be implemented by two means; the first is by using Gateways. The second is through the traditional way of extracting data at the location of the origin onto long term optical media, loading them into an intermediate staging area and finally transforming them into the DW.

4. OPERATIONAL PROCEDURES

This section describes how the various components of the DSS Infrastructure tie together. The description goes though the various steps of a decision support scenario clarifying the role of each of the DSS Infrastructure components.

Illustration of the DSS Infrastructure Operations

4.1 INITIATING BUSINESS CASE

- During the assessment (initiation) stage for a new case, the business analyst is able through the browsing / search services provided by the MDR to

survey old business cases, nd existing data items. The browsing / search services provide business end users with a more intuitive navigation method or view of the information stored in the data warehouse.

-The business analyst can start a new business case by:

- Copying the definition of an old business case, then customize this definition based on the scope of the new business case.
- Create the new business case from scratch, but with a good idea about the appropriate data items for this new case.

- The meta data services used during the business case initiation step are:

- **The Browsing facility provided by the MDR**
  Purpose: To view the detailed data about the previously defined business cases/ data items in a structured manner.
- **The Search facility provided by the MDR**
  Purpose: To search in the MDR for the business cases and/or the data items related to one or more subject areas.

4.2 DEFINING BUSINESS CASE

- The MDR Database is used to manage business cases and their relationship to required data items.
- As illustrated in Figure 6, the analyst can define a new business Case using metadata services.

A reference to the Business Case is stored in the MDR.

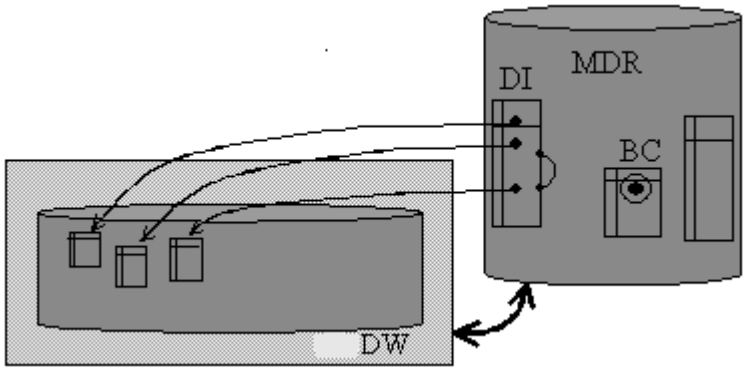

Figure 6: The Definition of a Business Case

- The basic data of the new business case is mainly:
  - BC_ID.
  - BC_NAME.
  - BC_DESCRIPTION.
  - BC_ASSOCIATED SUBJECT AREAS.

- Other basic data such as: BC_ID, BC_OWNER_ID, BC_SECURITY LEVEL, BC_DATE_OF_CREATION, etc.

- The status of the business case is initialized to the "DEFINED" state.
- All the business case basic data is stored in the MDR.
- The meta data services used during the business case definition step are:

- **Define a new business case**
  Purpose: To create a new business case and to insert the basic data escribing it in the MDR

4.3 Identifying the Required Data

- All the data allowable in the DW is described in the MDR as data items.
- As illustrated in Figure 7, the association between the Business Case and the selected Data Items is stored as relationship in the MDR

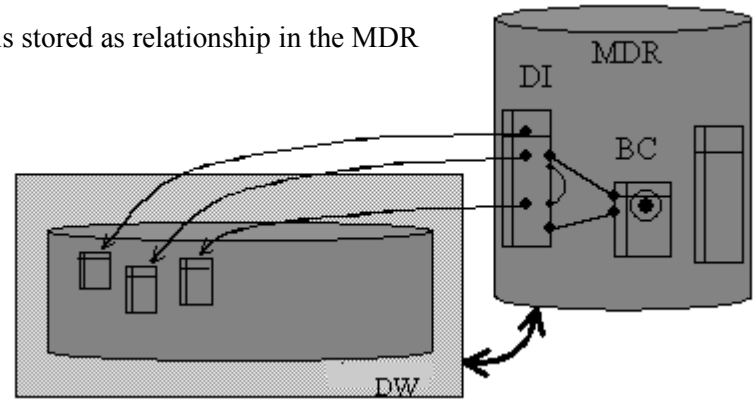

Figure 7: Identifying the Required Data for the Business Case

- The meta data services used during this step are:

- **Identifying the Required Data for the Business Case**
  Purpose: To insert in the MDR the data describing business case association to data Item**s.**

The list of data items related to the subject areas of the designated business case is displayed, and the business analyst selects the required data items from this list.

4.4. IDENTIFYING UNSTRUCTURED FILE REFERENCES (UFR)

- References to unstructured documents, which are of interest to a particular Business Case is stored in the MDR.
- Using metadata services, the business analyst can associate unstructured files to a business case.
- The meta data services used during this step are:

- **Identifying unstructured file references**
  Purpose: To insert in the MDR the data describing unstructured files sed by a business case.

The analyst activates the DMS menu, and selects the required unstructured files, and enters the URLs of any required internet resources. The name and type of the designated files are stored in the MDR.

4.5. SOURCING DATA TO THE DW

- As illustrated in Figure 8, the next step is to make the data of the selected data items readily in the DW. By default, the data is not retained in the DW.
- This step is activated by a request to load a BC triggered through the MDR GUI interface.
- In this case, the Collection Engine automatically undertakes this task in the background.

The Collection Engine uses instructions that are previously stored in the data item description in the MDR.

- These instructions specify which data sources to access and how to transform the data in these sources in order to make the required data accessible in the DW.

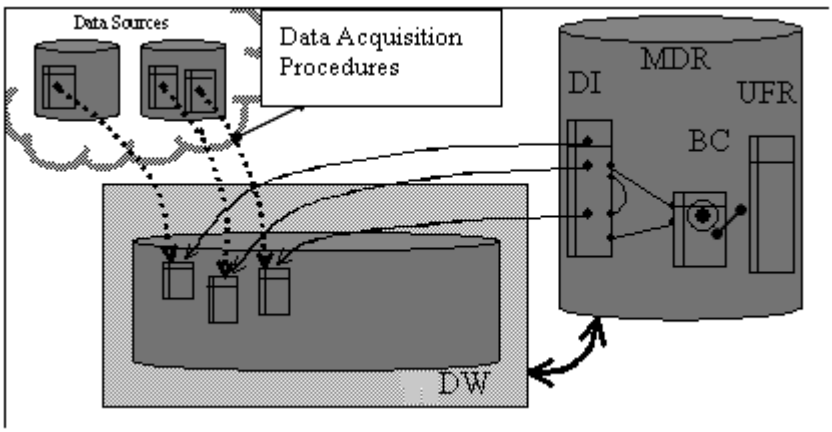

Figure 8: Sourcing Data to the DW

- The meta data services used during this step are:

- **load a business case**
  Purpose:- to issue a request to the collection engine (CE) for loading a BC, -to download data items requested by the business case into the DW, and to create the BCWE and initialize with data items from the DW.

4.6. PREPARING A BCWE

- Preparing the BCWE means downloading BC structured and/or unstructured data and implementing necessary analysis tools.
- As illustrated in Figure 9, preparing a BCWE comprises the following:

a. Loading Structured Data

After the Collection Engine has made available in the DW data for all the selected data items, it creates a BCWE and then the Data Mart which is a part of the BCWE is initialized. This consists of the following actions:

- Create a user in one of several databases especially prepared previously for that purpose. This user represents the Business Case and all data relating to the Business Case is stored in this user's schema.
- Replicate the data of the selected data items from the DW into the schema of that newly created user.

b. Accessing NON-Structured Information

- Download into the BCWE the unstructured files referenced by the BC.

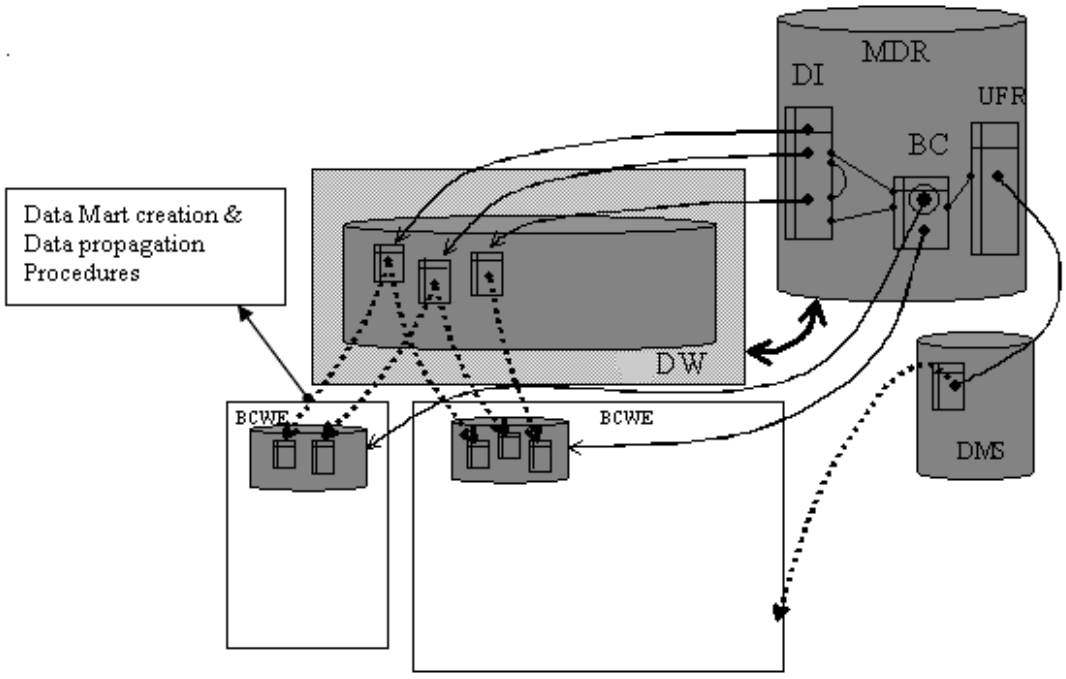

Figure 9: Preparing a BCWE

- After the successful completion of the BCWE preparation, the status of the business case is changed to the "LOADED" state.

- The meta data services used during this step are:

- **load a business case**
  Purpose:-to issue a request to the collection engine (CE) for loading a BC,
  -to download data items requested by the business case into the DW, and -to Create the BCWE and initialize with data items from the DW.

4.7. PERFORMING THE DATA ANALYSIS

- The foundation for the data analysis is a BCWE.
- BCWE consists of one (or more) data mart(s) and other files that may be produced by the analysis.
- The Data Mart is initialized by the private copies of the required data items.
- As illustrated in Figure 10, Analysis tools will be used to perform the different analysis required by the business case.
- When the analysis is finished a report documenting the findings is created

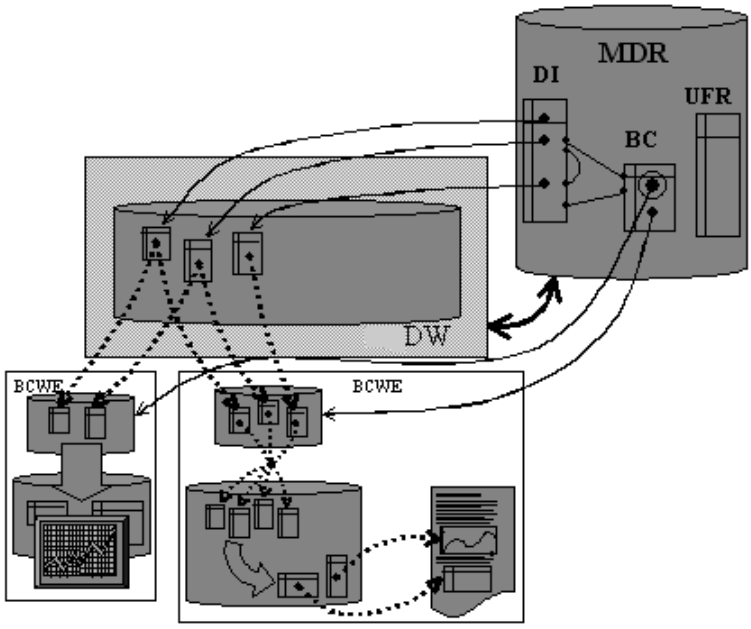

Figure 10: Data Analysis

4.8. REFRESH BUSINESS CASE

- From time to time, especially if the duration of the Business Case analysis is too long, the user may be working with data that is already out of date, and therefore may need to update (refresh) the data in the BCWE.
- In this case, the user requests the CE to Refresh the Business Case.

- Refreshment of data items may be carried out for one or more data items without affecting already loaded data for the business case.
- The meta data services used during this step are:

• **Refresh Business Case**
Purpose: To refresh data items of an active business case in DW and BCWE, this function is triggered through the MDR GUI interface, and Periods of refreshing are set in advance (in the description of data items) and stored in the MDR.

4.9. CLOSING AND ARCHIVING A BUSINESS CASE

- Once a Business Case no longer needs to be active, it should be closed.
- The user initiates via the MDR services a request to close a Business Case.
- In response, the Collection Engine exports all the data from the BCWE into a file. It packages this file, and stores this on long term storage using DMS services.
- The exported database includes a copy of all the data stored in the schema of the Business Case user. This includes all the selected data items, as well as any additional tables created during the analysis phase.
- Data that is not stored inside the relational database such as, the final report of the Business Case, possibly in addition to other word documents, resentations, etc. can be part of this package.
- After archival, the Collection Engine deletes the BCWE and therefore the replicated data.

Furthermore, if the data in the DW is not used anymore by any other active Business Case, then the Collection Engine can delete that data too, so that it is not available anymore in the DW except if sourced again from the relevant data sources due to a new Business Case.

- This step signals the end of the DSS process for a Business Case.
- Delete unused data from the DW When a data item is no longer being used in a business case, it should be wiped out from the DW. The CE will decide if a data item is needed or not for other business cases based on a counter associated with the data item. Initially this counter is set to zero. This counter is incremented each time a business case associated to the data item is activated. It is decremented when an associated business case is closed. If the value of the counter is zero, this indicates that the data item is no longer needed.
- After the successful completion of the BC close operations, the status of the business case is changed to the “CLOSED” state.
- The meta data services used during this step are:

- **Close a business case**
  Purpose: - To close and archive a business case, - to delete data associated to the business case from DW, which is no longer needed by other business cases, to delete the business case working environment, and to set the business case status to "CLOSED".

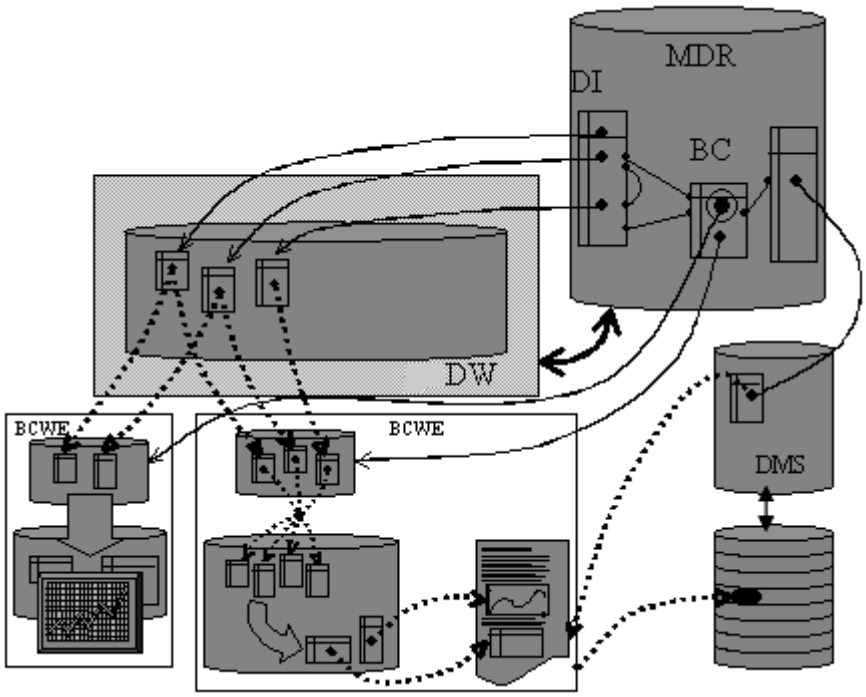

Figure 11: Business Case Archiving

5. COMPARISON BETWEEN THE PROPOSED FRAMEWORK AND THE CURRENT DSS ENVIRONMENT

The proposed framework provides many tangible advantages with respect to current DSS environment:

(1) It provides a single and unified repository of meta data that comprises meta data for business users in addition to technical meta data. The business views stored in the MDR (in terms of data items) play an important role during the assessment stage of a new business case.

They are used to guide the business analyst to find out the appropriate data required for a new business case.

(2) It provides an enhanced level of integration between the various components of the DSS infrastructure. As illustrated in section 4, Metadata usage turns to exchanging data between the DSS infrastructure tools. The meta data repository model is the central hub of the environment. It is the one place where integration occurs between operational source systems; the data warehouse; and the business case working environment.

(3) It provides explicit means to guide and control the loading, refreshing, removal of data in the data warehouse tied to events related to the life cycle of DSS studies.

The requests of changing BC status:

Request to define a new BC, Request to load a BC, Request to refresh a BC, and Request to close a BC, are the major events that control the actual data contained in the DW

(4) It provides a common repository to collect the definitions and results of various DSS studies that represent enterprise knowledge, which encourage reusability in newly posed business questions. The business analyst may start a new business case by copying the definition of an old business case, then customize this definition based on the scope of the new business case.

6. CONCLUSION

The proposed framework is a step forward to defining a generic framework derived by a metadata repository that supports both business and technical metadata.

It is important to note that in this paper, we approached one of the metadata critical issues, which is the integration of business metadata in the metadata repository model.

Other critical issues highlighted in section 1, remain to be investigated.

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