

# **Information systems development methodologies for Data-driven Decision Support Systems.**

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## Abstract

The sum of small and big decisions made in all levels of companies determines its performance. Also, the quality of the decisions can be improved when there is information available to help decision makers in their task. All this has motivated the development of specific types of information systems aimed to provide the information necessary in the different levels of the company to support structured and semi-structured decision making. This research will be focused on a specific group of information systems to support decisions that make intensive use of historic data integrated from multiple sources; Data-driven Decision Support Systems (DDSS). On the other hand the features of the systems to support decisions together with tasks and techniques that are unique for these systems demanded the creation of specific development methodologies to perform the development process. In response to that demand, several proposals have been elaborated but there is no consensus in the field. Currently there is a debate around two development methodologies that are analysed on this paper. After the analysis of the proposed methodologies a case study organization with experience on the development of DDSS will be analysed. The research aims to understand and present the development process carried out in the organization to develop DDSS. In the analysis the influence of the existing methodologies and other sources, like traditional development methodologies and standardization is included. Finally a proposal to improve the development of DDSS in the case study organization is presented. The proposal is generated in the light of the existing methodologies and other particular proposals that deal with single tasks on the development process.

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Lastly, I offer my regards and blessings to my wife, who patiently accompanied and encouraged me during this exigent process.



## **Declaration**

No portion of the work referred to in the dissertation has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

## Glossary

CDM: Corporate Data Model

DBMS: Data Base Management Software

DIS: Data Item Set

DDSS: Data-driven DSS

DSS: Decision Support Systems

ESS: Executive Support systems

ETL: Extraction, Transformation and Load

ERM: Entity Relationship model

MIS: Management Information Systems

OLAP: Online Analytical Processing

RUP: Rational Unified Process

TPS: Transaction Processing System

UML: Unified Modelling Language

## 1. Introduction

In the last 40 years many organizations have introduced computer-based Information systems to support business processes and provide information to its members. However the way that information flows in organizations has changed, it is now possible to grant access to more people and encourage information sharing and cooperation. The new strategy around information and processes allows performing tasks simultaneously and speeding up decision making. Information technology has become a sound source of tools that help managers of different levels in the organization to complete their roles in monitoring, planning and forecasting. Those tools provide support to functions related to information dissemination, linking the different organizational levels and allocating resources (Laudon and Laudon, 2009; Avison and Fitzgerald, 2006).

With the provision of information to all levels of organization, decision making is not anymore limited to management. Decisions of different size and type are made in all levels of organization and the quality of all the decisions made, determine the success of the company. To support employees in the important responsibility of making decisions, a specific group of information systems has been designed, they include: Management Information Systems (MIS), Decision Support Systems (DSS) and Executive Support systems (ESS) (Laudon and Laudon, 2009). From this classification this research will focus on DSS. This kind of information systems for decision support are interactive computer-based systems with the purpose to help decision makers to use communications technologies, data, documents, knowledge and/or models to identify and solve problems (Power, 2007). The use of the different tools or components leads DSS into a more specific classification; Power (2002) categorizes DSS using these criteria in his framework. The different categories are summarized in Table 1, it includes:

Category	Main tool or component
<b>Communications-driven DSS</b>	Decision rooms, two-way interactive video, white boards, bulletin boards, chat rooms and email systems.
<b>DDSS</b>	Historical data, Online Analytical Processing, and reporting tools
<b>Document-driven DSS</b>	Document storage and processing technologies
<b>Knowledge-driven DSS</b>	Business rules and knowledge bases
<b>Model-driven DSS</b>	Algebraic, decision analytic, financial, simulation, and optimization models

Table 1: DSS Categories

Communications-driven DSS: this type of DSS is intended to assist the solution of problems by decision makers that are working in a group; communication technologies and decision process models are used for this propose, they include decision rooms, two-way interactive video, white boards, bulletin boards, chat rooms and email systems.

Data-driven DSS, DDSS from now on: in this category the emphasis is in the analysis of large collections of historical data. Data is structured and access can be provided using Online Analytical Processing (OLAP) and ad hoc reporting tools that allow users to visualize and manipulate data in different levels of aggregation. Data warehouses and business intelligence systems are included in this category.

Document-driven DSS: this kind of DSS provides support in gathering, retrieving, classifying and managing unstructured documents; the managed documents are for example policies and procedures, product specifications, catalogs, and important correspondence. A variety of storage and processing technologies are integrated in document-driven DSS for document retrieval and analysis.

Knowledge-driven DSS: also known as expert systems they intend to include business rules and knowledge bases to be able to recommend an action to the user using problem-solving expertise. The expertise in this kind of information systems contains knowledge about a particular domain, understanding of the situation and the ability to propose solutions.

Model-driven DSS: “use algebraic, decision analytic, financial, simulation, and optimization models to provide decision support...They are designed so a user can manipulate model parameters to examine the sensitivity of outputs or to conduct a more ad hoc ‘what if?’ analysis” (Power and Sharda, 2007: 1044).

From the different kinds of DSS presented the research will be narrowed to the development of DDSS, in literature this kind of information Systems is also referred to as Data warehouse or Business Intelligence systems (Power and Sharda, 2007; Negash and Gray, 2008).

Despite all the benefits that can be expected from the introduction of Information systems in organizations DSS and other information systems development projects have faced a low success rate (Giorgini et al., 2005). One of the responses that companies have opted to use is the introduction of development methodologies, when using a development methodology companies aim to obtain: a better product, a better development process or a standardized process (Avison and Fitzgerald, 2006). Development methodology is defined by Avison and Fitzgerald (2006:568) as:

...a recommended means to achieve the development, or part of the development, of information systems based on a set of rationales and an underlying philosophy that supports, justifies and makes coherent such a recommendation for a particular context. The recommended means usually includes the identification of phases, procedures, tasks, rules, techniques, guidelines, documentation and tools. They might also include recommendations concerning the management and organization of the approach and the identification and training of the participants.

Varieties of methodologies appeared from practitioners’ experience and academics research, in early stages they were applied as part of consultancy work or cooperation between researchers and organizations, eventually they became products and were perceived by some organizations as the solution of all their problems with the development of information systems. After More than 20 years working with methodologies it has been proved that this is not the case, although difficulties do not stop some companies to use methodologies successfully, differently to the

early use of methodologies companies' approach is now more critical and open minded (Avison and Fitzgerald, 2006).

In the development of DDSS as in the rest of information systems development projects the correct use of a development methodology would help to increase the chance of success, however a review in two of the most influential authors in the field namely Ralph Kimball and William Inmon shows no convergence with the most used methodologies. Both Kimball et al. (2008) and Inmon (2005) propose different lifecycles and there is not recommendation or usage of the visual modelling techniques from the set that is widely used by practitioners and recommended by several methodologies.

## **1.1 Shape and scope of the study**

The purpose of this research is to explore the literature and analyse the software development methodologies that have been proposed for the development of DDSS. The different features of DDSS, the techniques used and task performed during the development process led to the development of specific information systems development methodologies. It is within the scope of this research to analyse the most important methodological proposals for the development of DDSS. Besides the analysis of a case study organization with experience in the development of this type of information systems is carried out with the objective of understanding how the development of DDSS is performed in practice and what the influence of the proposed methodologies is. Besides, the influence of other elements shaping the development in the case study is included. Finally it is from the interest of the research to propose strategies to improve the development process in the selected case study organization using the analysis of the methodologies and other proposals that deal with single tasks of the development process.

## **1.2 Chapter Outline**

The research report is organized into five chapters outlined as follows:

### **Chapter 1: Introduction**

This chapter is an introduction to the study; it highlights the background and objectives, the research questions, the research method and possible use of the study.

## **Chapter 2: Literature Review**

Chapter 2 contains the literature review; in this part of the paper the analysis of the existing methodologies for the development of DDSS is carried out. On this chapter the important features of development methodologies on the existing debate are drawn from the analysis. Besides, other proposals that deal with single tasks on the development of DDSS are briefly presented.

## **Chapter 3: Methodology**

This chapter provides background about the context from where the research questions were drawn and presents what the aims of the study are. On this chapter an adaptation of the framework used to analyse methodologies is presented. The adapted framework is used latter to analyse the DDSS development process on the selected case study organization.

Also on this chapter the details of the case study organization are presented together with the rationale for its selection. Besides, the sources of information for the research are spelled out together with the collection and analysis methods used.

## **Chapter 4: Results and evaluation**

In this chapter the finding of the analysis of the collected data is presented. The analysis of the DDSS development method in the case study organization using the adapted framework is carried out in this part of the paper. The factors that shape this method are explained and a proposal to improve the method in the company is presented.

## **Chapter 5: Conclusions**

In this chapter, an answer to the research questions is presented, the limitations of the study are exposed, and a reflection on the use of the selected framework is carried out. Finally the conclusions drawn from the research are illustrated.

## 2. Literature Review

Software development methodologies are a response to the high complexity of software development process. The situation is not likely to improve because the more information systems are developed in a company the more backward support will be necessary, companies will ask for more complex functionality and more interdependency issues will arise (Mattison, 1996). Software development methodologies are the response from the engineering mindset to face the complexity of this process (Nerur et al., 2005). Different motivations take companies to introduce methodologies, Avison and Fitzgerald (2006) show three main categories of rationale; a better product, a better development process or a standardized process.

The aim of this chapter is to make a consistent analysis of the methodologies proposed to develop DDSS. The chapter starts with the presentation of the framework used for the research. From the analysis of the methodologies, the features that are important in the current debate of the topic arise and are presented. Also other proposals that are not methodologies but deal with specific tasks/phases of DDSS development are presented, they are useful for the research because they might help to fill the gaps existing in the complete methodologies for specific situations.

### 2.1 Relevance of specific development methodologies for DSSS

For long time researchers have highlighted the need for a different development approach for DSS. Around thirty years ago Sprague (1980) had already pointed out two important reasons: the lack of a single comprehensive theory of decision making and the rapid change in the conditions faced by decision makers. Authors of much more recent publications (Inmon et al., 2008) agree with Sprague (1980) when he says that the end users of DSS system are unable to define in advance the systems requirements: from Inmon's point of view, business analysts that use DSS work in "mode of discovery" and he highlights their mindset with a phrase from the users side: "[w]hen I see what the possibilities are, then I will be able to tell you what I really want" (Inmon et al., 2008:9). This is one of main the features that generated different proposals to the development of DDSS. For example, researchers have proposed whether to postpone the definition of requirements to a later stage (Inmon, 2002) or to find a different strategy to define



requirements using business processes as the starting point (Kimball et al., 2008) or using the goals of decision makers to identify the needs (Giorgini et al., 2005). The proposals generated from these different starting points are completely different and there is still no consensus of a widespread methodology (Luján-Mora and Trujillo, 2004).

Now that the relevance of methodologies to develop DDSS has been presented, the framework used to analyse the methodologies will be introduced. The framework will serve to analyse de existing methodologies and will be the tool to analyse the case study organization.

## 2.2 A framework for comparing methodologies

The use of a framework will facilitate a more comprehensive description of the existing methodologies for the development of DDSS. Although the purpose of this research is not to compare the methodologies it has been considered adequate to use the framework proposed by Avison and Fitzgerald (2006). It is originally proposed for the comparison of development methodologies but as stated by its authors the framework “gives a set of features that prove to be a reasonable guide when examining an individual methodology and when used as a basis for comparing methodologies” (Avison and Fitzgerald, 2006:598). Seven elements are included in the framework: Philosophy, Model, Techniques and tools, scope, outputs, practice and product. The elements are summarised in Table 2.

Element	Summary
<b>Philosophy</b>	Principles that underlie the methodologies
<b>Model</b>	Abstraction mechanism to represent the problem and the solution
<b>Techniques and Tools</b>	Procedures to undertake the different phases of development
<b>Scope</b>	Systems Development Lifecycle coverage
<b>Outputs</b>	Extent of definition of partial and final outputs
<b>Practice</b>	Who uses the methodologies? Where does the methodology come?
<b>Product</b>	What ones gets in case of buying the methodology

Table 2: Framework elements

### 2.2.1 Philosophy

This feature is regarded as a set of principles underlying the methodology, It is considered one of the most important aspect because on its light is that the selection of areas to cover, the orientation and participation choices are made. Philosophy is all “the underlying theories and assumptions that the authors of the methodology believe in” (Avison and Fitzgerald, 2006:568), it contributes to the methodology a series of unwritten aspects and believes that complements the methodology and enhances its applicability. Philosophy is broken down in four factors: Paradigm, Objectives, Domain and Target. The Paradigm might be Science or System. The ‘Objective’ of a methodology might be aimed to develop an information system or it can be broader to analyse and change other elements in the organization. The ‘Domain’ refers to the choice of analysing a particular problem or start with a broader view of organization as a whole. Finally the ‘Target’ refers to the applicability of a methodology of any kind of information systems or particular types.

### 2.2.2 Model

The model is the mechanism used in the methodology to make an abstraction and represent important elements of the information system and the organization. It serves as communication tool and allows to take the essence of the problem between different phases (e.g. design to implementation). It has been categorized in different types: verbal; analytic or mathematical; Iconic, pictorial or schematic; simulation.

### 2.2.3 Techniques and tools

Techniques support the “Collection, collation, analysis, representation or communication of information about systems requirements and attributes” (Avison and Fitzgerald, 2006:315). Techniques influence analysts’ understanding of a problem; using different techniques to solve a problem situation can lead to different solutions. Techniques include: Rich pictures, Entity modelling, Normalization, and data flow diagramming.

Tools are software packages used for the development of information systems, analysts use tools to support specific parts of the development process. Tools are designed to support

specific techniques or complete methodologies. For the development process one can find tools aimed to collaboration, communication, drawing and coding.

#### **2.2.4 Scope**

The scope refers to the stages of the information systems development life cycle that are covered by the methodology. In this framework is also recommended to review the level of detail in which the stages are covered.

#### **2.2.5 Outputs**

Outputs refer to what is delivered at each stage and at the end of the whole process. They tightly defined to guide analyst or loosely defined to be more flexible.

#### **2.2.6 Practice**

The measurement of practices is made according to three sub-elements, first the background (Commercial or Academic), second the user base (taking account of the type of users) and third participants in the methodology (Users or specialists).

#### **2.2.7 Product**

If someone decides to buy the methodology as a product, does it include any software, training, customer service, and consultancy?

The different elements of the framework that have been just presents will serve as the mechanism to analyse the methodologies that have been proposed to develop DDSS in the next section.

### **2.3 Methodologies description and comparison**

In the field of DDSS there are two fundamental proposals (Breslin, 2004; Arnott and Pervan, 2005); they were first presented by Inmon and Hackathorn (1994) and Kimball (1996). Subsequent proposes are aligned to one of them, or use them as a starting point. Besides when the definition of methodology presented in chapter 1 is used to search in literature for proposals specifically aimed to the development of DDSS it can be said that relatively few

complete proposals have been put together, consequently the two methodologies have been selected to be described using the selected framework as a starting point for the research.

### 2.3.1 Kimball life cycle

#### Philosophy

The fundamental concepts of this methodology are explicitly stated and reinforced with the practices recommended. Kimball et al. (2008:2) introduces his proposal with them:

- Focus on the business.
- Dimensionally structure the data that's delivered to the business via ad hoc queries or reports.
- Iteratively develop the overall data warehouse environment in manageable lifecycle increments rather than attempting a galactic Big Bang.

The principles shape different features of the methodology; the first principle makes this methodology a demand-driven one in the classification proposed by Giorgini et al. (2005). All design work comes after the definition of business requirements and they are used as the main input for the task. An additional feature that comes from the focus on business principle is that it intends to be simpler and engage end users (Breslin, 2004).

Dimensional modelling drives the strategy for logical and physical design to a mindset where redundancy avoidance and transaction processing speed loses importance. What is the priority for the design team is simplicity and query response speed over big amounts of data.

Iterative development of the enterprise DSS, an iteration of the proposed lifecycle intends to create one or several dimensional models referred to as star schema that addresses the information needs of a specific business process. According to the authors this strategy allows the results to be achieved faster, and different business processes to be worked on independently and asynchronously (Kimball et al., 2008).

However some imprecise applications of this strategy has led to the creation of isolated and incompatible sources of information, To guide the overall design over the iterative approach

the methodology includes an architectural proposal, the “data warehouse bus architecture” allows a smoother integration of each business process DSS to the overall system.

## Model

The first phase in Kimball’s methodology where models are used is the “Business Requirements Definition”. In his proposal Kimball recommends Interviews and facilitated sessions, he offers detailed procedure and recommendations on how to interact with users. However the model used to record business requirement is of the verbal type in the categorization of the models in Avison and Fitzgerald framework. This choice from Kimball contrasts with Avison and Fitzgerald (2006) that state that most of the models used in the field of information systems development are Iconic, pictorial or schematics.

Data warehouse bus architecture in Figure 1 shows a model to support the strategy that link the parts of the information system, since the business requirements definition is built to ensure that each part conforms to the whole and that development is being undertaken on top of previous efforts. The matrix shows the process and the dimensions that will be useful for data analysis in each process (Kimball et al., 2008).

BUSINESS PROCESSES	COMMON DIMENSIONS							
	Date	Product	Store	Promotion	Warehouse	Vendor	Contract	Shipper
Retail Sales	X	X	X	X				
Retail Inventory	X	X	X					
Retail Deliveries	X	X	X					
Warehouse Inventory	X	X			X	X		
Warehouse Deliveries	X	X			X	X		
Purchase Orders	X	X			X	X	X	X

Figure 1: Sample data warehouse bus matrix (Kimball et al., 2008)

It is in a later phase in the development where the strongest argument of Kimball approach comes in to scene, this phase is called dimensional modelling and the model is dimensional model. “Dimensional modelling is a logical design technique for structuring data so that it’s intuitive to business users and delivers fast query performance” (Kimball et al., 2008:234). According to the author simplicity in this model allows that business user can easily understand the design and efficient navigation of the software in the database. This model has been adopted by a great deal of proposals since Kimball first used it for this purpose (Kimball, 1996), besides important companies that develop DBMS (Data Base Management Software) have selected this approach to include specific functionality for DDSS; this is the case of analysis services of Microsoft SQL Server.

The elements of the model represent measurements and its context; they are recorded in the transaction processing systems during the normal execution of business processes, Measures are commonly numerical values and are called facts in the model. “Dimensions describe the “who, what, when, where, and how” context of the measurement” (Kimball et al, 2008:235), they are divided into independent logical groups. Using these two elements the business processes are represented with a fact table that contains numeric measurements, surrounding the fact table the dimensions are connected to represent the context. Figure 2 shows an example of a high level dimensional model.



Figure 2: High level dimensional model example (Kimball and Ross 2002)

## **Techniques and tools**

It has been just mentioned that the dimensional model is the most important in Kimball's approach; it drives the development after the definition of business requirements. The author proposes a technique called "Four-step Dimensional Design Process" to complete the design of the model.

### **Step 1: Choose the business Process**

Business requirements are elicited in the light of business processes, priority is also assigned to each of the business process according to the opportunities and management interest during the business requirement definition phase. For this reason this step is limited to select the next process to be modelled in the prioritized list.

### **Step 2: Declare the Grain (Level of detail)**

In this step the design team decides or states what exactly represent a row in the fact table, the grain or level of detail in the fact table should be fixed clearly to a business measure event; it is to be done in business terms. The decision of grain is important because the grain defines the minimum level of detail available for this business process. Kimball recommends to include the lowest level of detail available in the source TPS, because from this grain any level aggregation is possible however if a higher level is selected it limits analyst.

### **Step 3: Identify the dimensions**

Taking as inputs the grain and the dimensions available in the bus matrix the design team will be able to identify which of them fit for the fact table. The dimensions included define the perspectives available for analysis however they should make sense with the grain.

### **Step 4: Identify the facts**

In this step the design team decides what measures to include, it is important that those measures make sense with the grain. Kimball et al. (2008:301) states that "the facts should be

truth to the grain”; for example if the grain is the products in a purchase, then the product price would be a correct measure not the total value of the sale.

## Scope

Avison and Fitzgerald (2006) identified nine stages of the information systems development life cycle: strategy (Planning), feasibility, analysis, logical design, physical design, programming, testing, implementation, and maintenance. It has been warned that methodologies following a spiral lifecycle might not be well assessed using these nine stages. The life cycle proposed by Kimball has a variety of activities that cover most of the stages. It can be seen in Figure 4 that after the definition of business requirements the lifecycle is divided in three main tracks, they converge in deployment to finish with maintenance and a loop to represent the incremental nature of the methodology.

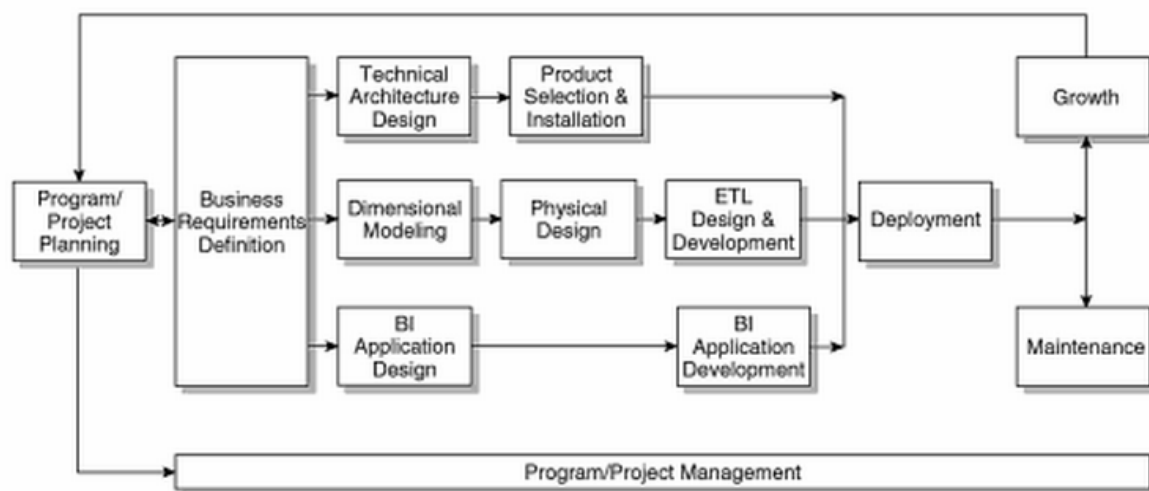


Figure 3: The Kimball Lifecycle diagram (Kimball et al. , 2008)

Table 3 contains the scope analysis according to what has been indicated by Avison and Fitzgerald (2006) that should be covered on each of the stages and what is indicated in the methodology.



Phase	Tasks in Kimball Lifecycle	Level of detail
<b>Strategy</b>		not included
<b>Feasibility</b>	Program/Project Planning	Detailed Only technical feasibility, specifically data feasibility is addressed
<b>Analysis</b>	Business Requirements Definition	Detailed
<b>Logical design</b>	Dimensional Modelling BI application design	Detailed
<b>Physical design</b>	Physical design	Detailed
<b>Programming</b>	ETL Design and Development. BI application Development.	Detailed
<b>Testing</b>	ETL Design and Development. BI application Development. Deployment	Detailed
<b>Implementation</b>	Deployment	Detailed
<b>Evaluation</b>	Program/Project Management	Detailed
<b>Maintenance</b>	Maintenance	Detailed

Table 3: Scope analysis for Kimball Lifecycle

## Outputs

This methodology covers the different development stages with one or more task; the outputs for every task are well specified and in most of the tasks contain guides and procedures. The output for the lifecycle is a working piece of software to support decision making concerning a business process.

## Practice

Background: The origin of this methodology is commercial, according to its authors it arose from their experiences in the development of DSS. It is noted that many lessons have been learnt from their participation in the roles of vendor, consultant, IT project team member and

business user in hundreds of projects, besides their techniques have been refined over the years and with the interaction with other practitioners (Kimball et al., 2008).

User base: There is not much reference in journals to support how many users have adopted this methodology; one figure that can give an idea is the number of registered users in the forum of the author web site, currently there are 1310 registered users (KimballGroup, n.d.). Besides there is an online community of people that have attended to the courses the KimbalGroup offers.

Participants in the methodology: The methodology encourages participation of experts in dimensional modelling but what is different of other methodologies is that it encourages since its principles the participation of business users, the is recommended not only in the definition of business requirements or other traditional user functions but also in the dimensional modelling where business users make part of the “core modelling team”. Business users may need training to understand dimensional modelling but the main input required from them is a “solid understanding of information requirements and the types of analysis to be supported” (Kimball et al., 2008: 290)

## **Product**

There is nothing like a licence to have access to this methodology however a series of resources have been made available in the official website (KimballGroup, n.d.), among those resources one can find Books covering the lifecycle and other important pieces like dimensional modelling or ETL development (Kimball and Ross, 2002; Kimball and Caserta, 2004; Kimball et al., 2008), articles published in the website and related journals, a forum to discuss issues in the use of the methodology and obtain advice from the authors, Training courses covering several areas of the methodology, a user group for course attendees and consultancy from the authors for companies.

### 2.3.2 Inmon's Seven Streams Approach

#### Philosophy

Inmon's architectural proposal includes all information systems and their databases of an organization in a whole; the architecture defines this set as the Corporate Information Factory. It is divided in four levels: Operational, Atomic data warehouse, Departmental and individual. The operational level contains companies TPS (Inmon, 2002). Inmon's approach is much more complex restricting end user participation (Breslin, 2004).

#### Model

Corporate entity-relationship diagram (Corporate Data Model, CDM in short) is created in the same way that is done for the design of TPS databases. First a model is created for each department that will use the DSS; entities with their attributes and the relationships between them are explored and refined. Secondly a corporate model is created adding up the departmental ones (See figure 5).

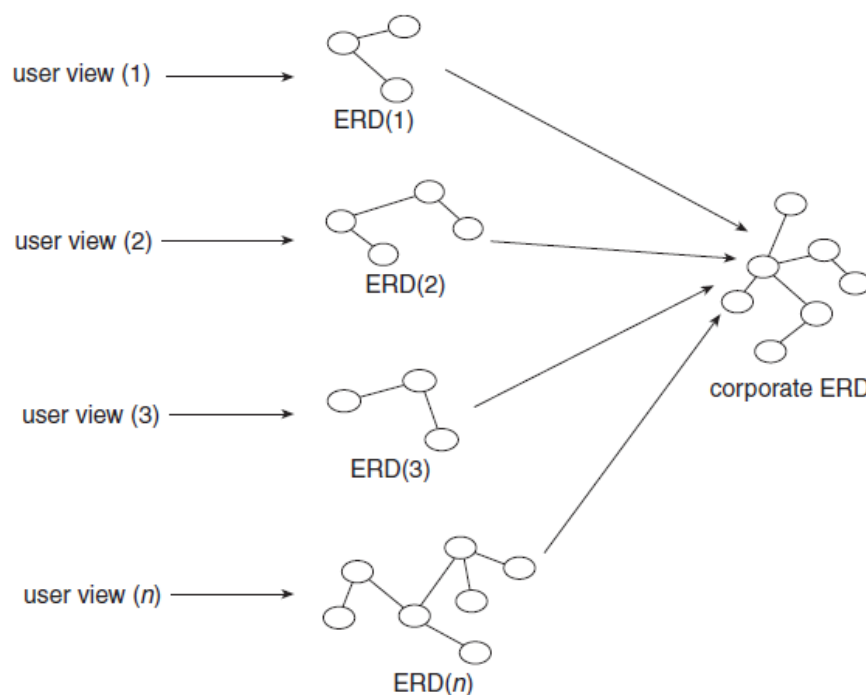


Figure 4: Corporate ERD (Inmon, 2002)

Corporate Data Item Set (DIS) Entity-relationship diagram: for each entity in the CDM one DIS is created, it is used to “identify the attributes of data in a data model and the relationship among those attributes” (Inmon, 2002:96). Four components constitute the DIS: the primary grouping of data, the secondary grouping of data, the connector data, and the type of data; all groupings contain attributes and keys for each entity. Primary grouping of data contains attributes that exist only once for each entity, Secondary grouping contains attributes that can exist multiple times for each entity; it is possible to have multiple of these groupings. The connector represents the relationships identified in the ERD. Finally the type of data grouping contains supertype and subtype classification of data.

The Physical model is based on the DIS, it should contain besides the attributes identified in the previous level the key attributes. The diagram with different components is shown in Figure 5.

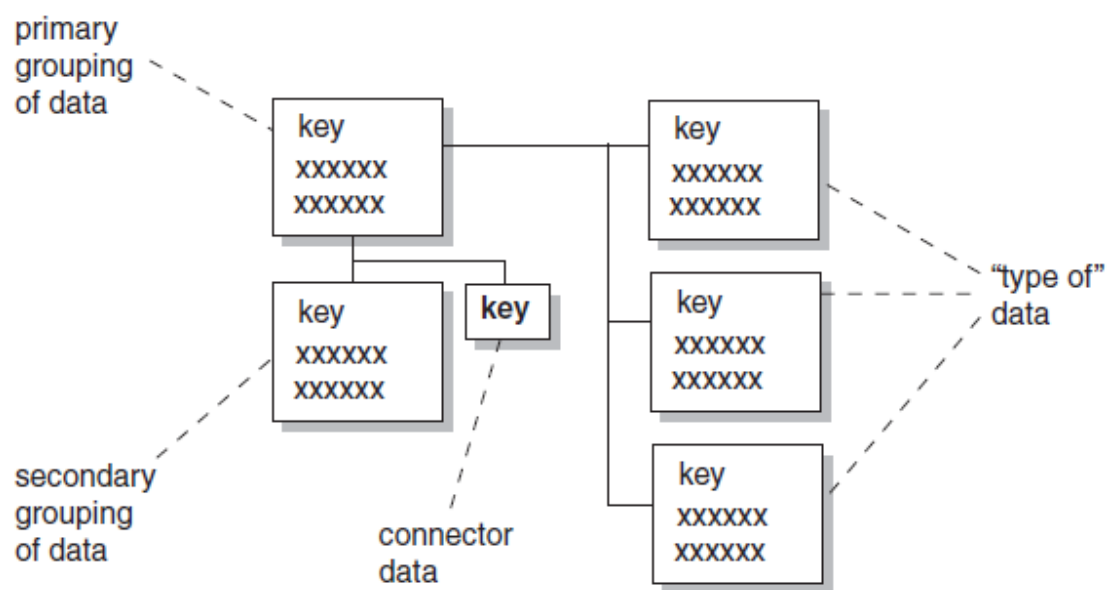


Figure 5: Data Item Set model with components (Inmon 2002)

## Techniques and Tools

The CDM (Corporate Data Model) is created integrating the views of the users; it includes the entities within the “scope of integration” and is created using traditional database modelling

techniques. According to Inmon the resulting diagram represent the requirements of the business because in his proposal process modelling is not relevant for DSS. The model is a view of the organization that emphasizes in its data aspects (Avison and Fitzgerald, 2006); the importance of CDM reflects the supply-driven orientation of the proposal.

The CDM is the starting point for any other data model in the company; to create a model for the DDSS, Inmon (2002) indicates a series of changes to the CDM. The first change is the elimination of data that is “purely” used in TPS, secondly the time is included in the model (time-stamped data), and third the inclusion of derived data is made.

After this series of activities have been done another technique is applied to finalize the design of the DSS database. It is named stability analysis and is aimed to determine the susceptibility of change of attributes and group them based on results. To perform the analysis, the attributes or a table from the CDM are split in three groups: frequently changes, sometimes changes, and seldom changes. The final result of the process is a model that groups data of similar characteristics.

For each entity in the CMD one DIS is created.

Then the physical model is created, this activity is done “extending the midlevel data model to include keys and physical characteristics of the model” (Inmon, 2002:98), besides some work is done in relation to the database performance, on this step granularity and partitioning of data is decided.

Techniques for physical design include: table merging, array creation (e.g. create a month array), denormalization for optimal access, data separation (with access disparity probability), introduction of calculated data, creative index creation, and management of referential integrity.

## Scope

The seven streams approach illustrated in Figure 6: Seven Streams Approach (Inmon et al. 2008) does not fit well in the scope explanation proposed in the framework because it follows an iterative approach; however an attempt to map the different streams to the phases in traditional development has been made in Table 4.

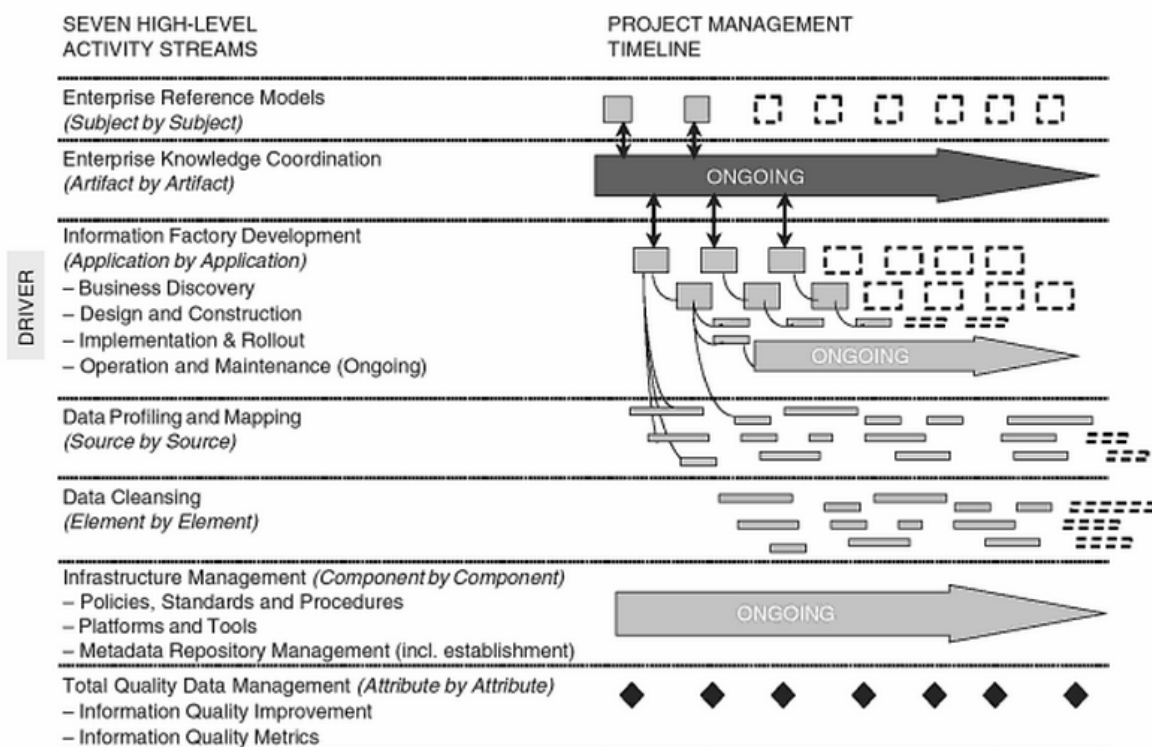


Figure 6: Seven Streams Approach (Inmon et al. 2008)

Phase	Seven streams Approach			Level of detail
<b>Strategy</b>				Not Included
<b>Feasibility</b>				Not Included
<b>Analysis</b>	Enterprise Reference Model.			Detailed
<b>Logical design</b>	Enterprise Coordination	Knowledge		Detailed
<b>Physical design</b>	Data Profiling and Mapping.			Detailed
<b>Programming</b>	Information development. Infrastructure management.	Factory		Detailed
<b>Testing</b>	Data Correction			Detailed
<b>Implementation</b>				Not Included
<b>Evaluation</b>	Total Management.	Information	Quality	Detailed
<b>Maintenance</b>				Not Included

Table 4: Scope analysis for the seven streams approach

The key thing to note about the seven stream approach is the fact that each activity stream marches to the beat of a different drum. “Each stream is simultaneously initiated, is concurrently driven and needs to be coordinated and monitored” (Inmon et al., 2008:129).

Enterprise Reference Model Stream: In this part of the development the traditional database development techniques are used to create the CMD, this activity can be described as creating a large Entity-Relationship Diagram containing the information of all the information systems although it is not created all at once.

Enterprise Knowledge Coordination Stream: this stream takes the results of CDM, Data profiling, and information factory development and provides a critical view that serves business stakeholders and that also works as a feedback loop to make sense of the iterative and incremental development (deals with the reusability of the produced artefacts).

Information Factory Development Stream<sup>1</sup>: this stream is the one that drives the program/project setting priorities for the other streams; it is closer to business needs which are referred to as “business burning questions” (Inmon et al., 2008). The burning questions help the analysts to select which entities are to be included in the next iteration for DIS design.

Data Profiling and Mapping Stream: on this stream analyst need to refer back to the TPS databases to check the quality and completeness of information and map the DSS database to the sources of information that will feed it.

Data Correction Stream: this stream deals whit the cleaning, completion and purging component of the ETL (Extraction, Transformation and Load) component.

Infrastructure Stream: This stream is aimed to the definition and update of “resources, platforms, tools, policies, standards, and procedures”. All these elements need to be watched while the DSS grows in scope and usage in the company

Total Information Quality Stream: this stream comprises the evaluation of quality, poor quality cost estimation, and research and elimination of poor quality sources.

## **Outputs**

Most of the streams that compose the methodology (except enterprise knowledge coordination) have clearly stated artefacts to produce, however the output of the whole methodology handles a big responsibility to the program/project manager. The author states that the steams iterate at different pace, for this reason he or she “will synchronize the work priorities in each of these concurrent streams, and will use this information to define meaningful releases for the organization” (Inmon et al., 2008:137).

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<sup>1</sup> The approach in this stream (Inmon et al., 2008) differs from his original proposal (Inmon, 2002) that was completely supply driven in Giorgini’s et al. (2005) classification. The new proposal takes into account the business needs to prioritize which part of the model should be developed first, taking the proposal to the hybrid area of supply/demand driven classification.



## **Practice**

Background: The origin of this methodology also commercial, according to the official page of the author (Inmon Consulting Services, 2007) he is a very experienced practitioner in data base technology and data warehouse design. Besides according to Inmon and Imhoff (2001) data warehouses and DSS make part of the growth of computers and information technology. The author bases his explanations and back up some components of the methodology in the problems that companies faced when they introduced and evolved IT; Mainly problems of integration and duplication of efforts that came with the increase of storage capacity and after the development of diverse and uneven information systems in the organizations.

User Base: There is not accessible evidence to the number of users of the methodology; there is an online group for the certified users however it was not possible to obtain access to it.

Participants in the methodology: The set of skills necessary to execute the techniques specified in this methodology reduces the possibility of user participation; the main participants in the methodology are IT analysts, they need to know traditional database modelling techniques and also specific techniques. There are two reasons that restrict users, first the scope of the methodology is broader, it is intended to model not only one application but to keep in mind and involve all applications in the company as a whole (The Corporate Information Factory). The second is that the approach does not use business needs as the starting point for the development. On her evaluation of Inmon's methodology, Breslin (2004) points out that this approach takes the users to passive roles where their participation is mainly in reviewing the IT analysts' deliverables.

## **Product**

As the previous discussed methodology, it is not necessary to pay to be able to implement the seven streams methodology. The information necessary to learn the techniques is available in the published books (Inmon and Hackathorn, 1994; Inmon and Imhoff 2001; Inmon, 2002); the company created by the author of the methodology also offers courses and certification courses for IT analyst (Inmon Consulting Services, 2007). Besides there is a series of Web events

and even consulting services with the author is available through the sales representatives of the company.

In this section the most well known methodologies to develop DDSS have been analysed using the framework for comparing methodologies by Avison and Fitzgerald (2006). During the examination of literature in order to complete the analysis, two particular features of the methodologies emerged. What follows now is an explanation of those features in order to include them in the landscape of this research.

## **2.4 Particular features of DDSS development methodologies**

In the revision of literature of DDSS development methodologies some fundamental differences have been identified and they are not enclosed in the framework and are central in the debate of in the topic, in particular Architecture and Approach) will be discussed below added to the framework. The complemented framework will serve as the link between theory and the case to be analysed. This strategy was considered following the recommendation from the authors of the framework, who state that “[t]he framework is not supposed to be fully comprehensive, and one could envisage a number of additional features that might be usefully compared for particular purposes” (Avison and Fitzgerald, 2006:597).

### **2.4.1 Architecture**

Jukic (2006) focuses on the differences of architectures from existing methodologies, Jukic’s analysis is based on ‘data marts’. The term ‘data mart’ popularized within Kimball proposal to refer to “process-centric detailed databases that represented a subset of the enterprise’s overall data architecture” (Kimball et al., 2008:248) but due to wrong interpretation it has been used to describe stand-alone solutions that meet the needs of a single department. Much of the criticism to Kimball methodology points out this misconception. Currently Kimball et al. (2008) states that because this misconception they abandoned the use of the term.

There are three main alternatives for architectures are described based on how the data marts are implemented and logically located according to different methodologies. The first one aligns to Inmon’s (2002) proposal (see Figure 8), where the data marts are fed from an

enterprise model that is completely normalized. The second one aligns to Kimball et al. (2008) proposal where data marts are fed directly from TPS and together make the enterprise data warehouse (see Figure 9). Finally the third one describes the result of implementations where each department build an isolated “data marts” (see Figure 10). In figures below, sources refer to TPS and ETL are the pieces of software that brings data from the TPS to the DSS Database.

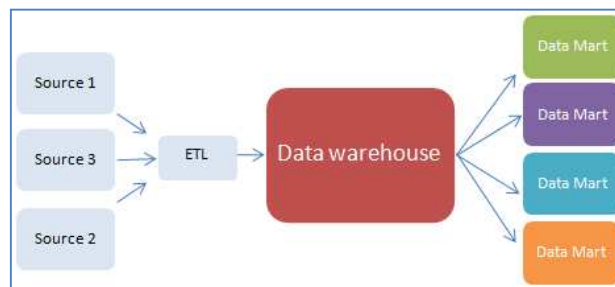


Figure 7: Data mats fed from a data warehouse -adapted from (Jukic, 2006; Inmon, 2002)

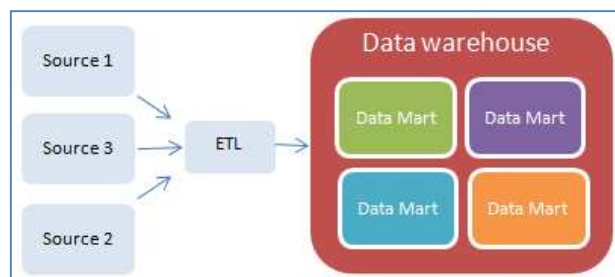


Figure 8: Data marts that constitute the Data Warehouse - adapted from (Jukic, 2006; Kimball et al., 2008)

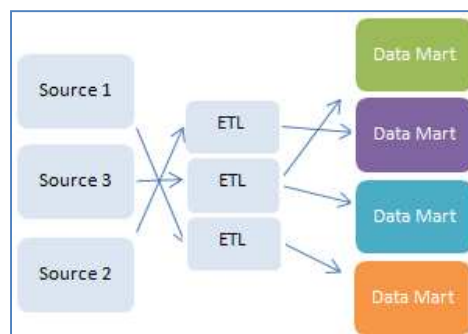


Figure 9: Independent Data marts - adapted from (Jukic, 2006)

### 2.4.2 Approach

Methodologies for the development of DDSS are classified in two main categories (Giorgini et al., 2005). The first one demand-driven refers to approaches that start with business requirements; they are the main input for the logical design. This approach sounds logical for most methodologies but in the case of DDSS there is another approach; it is known as supply-driven and only takes into account user requirements in a later stage of the development process. In supply-driven methodologies the main input for the logical design is the existing information systems that serve as a source for the DDSS. The strategy is to start from the logical and physical designs of the TPS in the company and create a logical design for the system. Although it is stated that it reduces the complexity of the ETL and reduces the gap between user expectations and actual possibilities of the company, it is criticized that it does not take into account user/business needs for the design. There is also a mixed approach where the design is driven by business requirements and it is simplified or regulated with the information available in the sources.

Both methodologies studied in this research are different in architecture and approach. These two features will allow analyse a methodology or method and determine if it aligns to one of those or takes a hybrid approach. Having presented the two features of methodologies to develop DDSS some other proposals for specific phases of the development will be explained.

## 2.5 Extending DDSS development methodologies

### 2.5.1 Requirement Analysis for DDSS

Many problems arise in the development of information systems when there is not an appropriate management of requirements; in addition to the total failure risk or going beyond the limits of budget and time, poor requirement management lead to a failure in meeting business needs (Giorgini et al., 2005). The nature of DDSS is different, Inmon (2002:285) is drastic in this respect and states that users of DDSS operate in a “discovery mode”, according to him “[e]nd users don’t know what their requirements are until they see what the possibilities are” therefore “understanding requirements” is the last phase in his proposed lifecycle. Other proposals approach requirements analysis based on business process (Kimball et al., 2008),

business goals (Giorgini et al., 2005) or using use cases (Bruckner et al., 2001). Besides to the difference in nature of DDSS that leads to the proposal of different models of requirements elicitation and analysis these IS call for a high level of maintenance because any change in processes, policies, goals or the source TPS systems will require changes in the DSS.

Schiefer et al. (2002) propose a requirements specification model and a set of requirement management activities aimed to DDSS development. Their proposal is based on the process centric requirement elicitation by Kimball et al. (2008), they extend the existing proposal introducing three levels of detail or perspectives for DDSS requirements (business, users and implementation perspectives), and they provide templates to facilitate and guide the process. Requirements from business perspective are more general and state business opportunities and objectives. In the user perspective what they need to do with the system is expressed using scenarios or uses cases. Finally the implementation perspective is the most detailed one, in this level an important differentiation among functional and information requirements is made. Going from a high level of abstraction to specific details helps to reduce the complexity of the process and leads to a more complete deliverable also templates confer a useful starting point.

Giorgini et al. (2005) propose an approach to requirement analysis for DDSS systems that is oriented by business goals. Two different perspectives are adopted in this proposal for the analysis of requirements. The first one business modelling is centred on stakeholders and models the organizational setting in which the IS will operate; stakeholders dependencies, tasks, resources and goals are included. The second one decisional modelling relates to the information needs of decision makers, it aims to model how the DSS can support the decision making process in the organization, here goals of each stakeholder are analyzed and related to the source systems. The two perspectives seek to relate the enterprise goals to facts and dimensions; elements of the dimensional model proposed by Kimball and Ross (2002).

### **2.5.2 Extraction, transformation and load processes design**

The development of ETL processes is one of the tasks that take more effort in the development of DDSS. The ETL process is the piece of the information system that makes all the backstage processing. The processes extract the data from different the TPS in the company, they perform

all transformation of that information (Cleaning, calculations, derivation of new data), and finally loads the data in the data warehouse of the DDSS. In Fact to 80% of the development effort in the DDSS is used to complete ETL procedures (Inmon, 2005; Kimball et al., 2004). The importance of ETL has motivated the development of several proposals for the completion of this task.

Trujillo and Lujan-Mora (2003) propose an approach for the development of ETL based on UML (Unified Modelling Language). Their proposal uses the notation included in UML to model the different components of the system, also they developed specific notation in the UML language domain that allow to model the different task that are commonly performed in ELT processes. These elements support analysts in the creation of a conceptual model of the whole process using one notation. It its positive of this proposal that is based on a well known notation and analyst that are not experienced in the field can also understand it.

Another proposal to model ETL Processes is offered by Vassiliadis et al. (2002); they recommend to perform the modelling using ETL scenarios. The definition of ETL scenarios is defined using the combination of Data sources and ETL activities. In their proposal, the authors show how to transform the scenario into a graph. The components of the process are modelled as nodes and relationships of for kinds. Using those components an initial graph that represents the flow of data from data sources to the DDSS database is built. After that, the complexity of initially generated graph is then reduced using a procedure indicated in the proposal.

This proposal results in a relatively complex model, and its readability is affected by the fact that the transformation of every attribute is drawn. Besides the use of the graph is performed under a mathematical formalism that limits its reach as communication tool.

A very important phase in the development of DDSS is designing the flow of data between sources and destination (Giorgini et al., 2005; Skoutas and Simitsis, 2006). Skoutas and Simitsis (2006) propose the use of semantic to go deeper during the exploration of data sources and to automate the mapping between sources and destination in the DDSS database. They argue that the ETL design is a process driven by data source semantics that is sometimes available in data

source documentation and some other times it has to be elicited from TPS stakeholders. Then web semantic technologies are presented as a way to assist the selection of relevant information of the sources and the transformation to take it to destination.

## 2.6 Summary

Until now we have highlighted the importance of having specific methodological proposals intended to the development of DDSS due to their special characteristics. Then we introduce a framework for comparing methodologies to analyse the existing proposals. After that, the analysis of the two most important proposals that comply with the initially proposed definition of methodology was carried out. From that analysis two particular features of DDSS development methodologies emerged and were presented. Finally several particular proposals for single activities of DDSS development process were explained with the aim of use them later in the proposal for improvement in the study case organization.

Using the results of the use of the framework in the analysis of DDSS development methodologies and the specific features that emerged in the process, an adaptation of the framework has been performed and will be presented along with the research questions, aims and research design in next chapter.

## 3. Methodology

The aim of this chapter is to present the research questions that are addressed and the overall purpose of the study. Also the research design is explained. Besides here the results of the adaptation of the framework used to analyse the methodologies for DDSS is clarified.

### 3.1 Research questions

When one takes into account the importance of using software development methodologies and then thinks about the special features of DDSS, the first question of this research arises. This is further supported when the situation is contrasted with the fact that there is no consensus to say that any of the existing proposals are considered a standard model. Different approaches have been presented in recent years concerning DDSS design. These approaches

include conceptual and logical data models using proprietary or renowned graphical notation, namely ERM (Entity Relationship model) or UML. However none of the accepted methodologies include modelling techniques encompassing the different tasks necessary to complete the development (Luján-Mora and Trujillo, 2004).

Therefore the first question to be addressed in this study is:

What are the proposed Methodologies for the development of DDSS?

Once the first question is answered, the information gathered will serve as background to start searching for evidence of how the proposals from the literature provide a solid base and influence the way that practitioners are developing DDSS. To be able to understand it at least on a small scale it is considered appropriate to have access to that information from a primary source, for this study a company with experience in the data- driven DSS has been selected.

The second question aims to bring together the theoretical and practical perspectives and contains three components:

What is the method used in the selected case study organization to develop DDSS; where does it originate and what drives the choices?

Once the method has been understood it might be possible to identify any chances of improvement, for this purpose the information of complete methodologies is useful and also other proposals available in literature. While some authors aim to cover a complete methodology other focus their efforts in specific techniques, in specialized studies is possible to find practices that are relevant to the selected case study organization and that could be generalized to other cases.

Therefore the third question of the study is:

How can the method used in the case study organization be improved with the existing proposals?



### **3.2 Aims of the study**

This research is aimed to understand the methodological proposals for the development of DDSS. Important features that differentiate methodologies will be studied and presented, and a framework for comparing development methodologies will be used to back up the analysis and to link theory and practice. Particular proposals to improve the most used methodologies will be investigated and presented.

Once the information necessary about development methodologies has been understood, it will be used as a base to present and analyse the method used in a specific case study, the process will be done based on the framework and other findings of the literature review. Finally using the theoretical background a proposal to improve the method will be presented; the reasons for the choices made by the company (and that shape the method) will be explained and be used to moderate the proposals for improvement.

### **3.3 Framework adaptation**

In chapter 2, the framework proposed by Avison and Fitzgerald (2006) is used to study the methodological proposals for the development of DDSS. At this point of the research the use of the framework will be continued, indeed it is the link between the two parts; the literature review and the case study analysis. However there is a difference in this part of the research because the analysis is about a specific case study. This implies that we will be talking about the method used in the case study organization, the concept of methodology is more extensive than method, a method implies the application of a methodology for a specific case study that implies some kind of simplification (Avison and fitzgerald 2006; Checkland 1981). Therefore not all the elements of the framework will be included; this is the case of the Practice and Product.

The analysis carried out in the literature review pointed out important elements that are central to current debate in the field. They are to be included in the framework to understand from which methodology were drawn the different elements of the method (i.e. Architecture, Approach). The same rationale applies to the Philosophy that will be included although a method does not include philosophy (Avison and fitzgerald, 2006; Checkland, 1981).

In summary the case study analysis will be driven by the framework proposed by Avison and Fitzgerald (2006) adapted to the analysis of a specific situation and complemented with element especially relevant to the development of DDSS. The elements to be included are Philosophy, Model, Techniques and Tools, Scope, Outputs, Architecture, and Approach.

### **3.4 Research design**

#### **3.4.1 Rationale for Case Study Organization Approach**

The details that can be analysed about the development of DDSS when one investigates in an organization with experience are considered useful for this research, because this research is more about the development process and reasons of certain choices of the way things are done. This is further supported when the researcher is an insider of the organization and has been in touch with people responsible for the development, as is the case. In fact the researcher makes part of a group created around the topic in the organization and has participated in training and projects with other members. These features of the organization, the role of the researcher and the relationship with participants make possible to maintain an open dialog with participants. All this features of the case study organization promises to provide better data for the research than secondary sources.

#### **3.4.2 Case study organization presentation**

The context of the research is an integrated state owned Utilities Company called EPM. It is responsible for the provision of electric power, natural gas, drinking water, sanitation, and telecommunication services in a metropolitan area with three and a half million of inhabitants in Colombia, South America. It has provided services to this market during the last fifty five years and in the last years it has adopted a strategy to expand its achievements as a local company; thanks to this strategy the company has presence in different regions of the country (EPM, 2009).

The company has been developing DDSS during the last ten years, the development of this kind of information systems started with the need to provide information to decision makers from legacy information systems and other information systems starting with commercial

information. Once this information was published other areas of the company were motivated to initiate projects to provide information about infrastructure maintenance, supply and demand of electric power among others. Currently the different divisions of the company work in the development of a program for the inclusion of more business areas and business processes in the information system and there is a group of analysts committed to the topic in each the three different technology areas existing in the company. The number of full time IT analyst working of the system maintenance and development is about ten and they use the outsourcing resources to be able to cope with the business demands, the number of final user of the system is close to two hundred fifty.

### **3.4.3 Sources of information**

The case study organization was selected on the basis of the experience that the company has in the development of DDSS. Two main sources of information have been identified to study and understand the case study. First the experience is explicitly recorded in the projects documentation, including the project plans, and other main deliverables used in the projects like requirement documentation and system design. The second source of information is the experience that IT analysts have accumulated during their participation of the projects. This information is not explicitly recoded anywhere and to be able to included in the research a series of interviews with the analysts will be carried out. The interviews are considered a very important source of information because they allow to establish an interactive dialog to deepen the analysis performed on written documentation. They will provide useful information to analyse the method and also to try to identify the forces that directed choices.

The data collection process is framed by the modified framework; the framework allows concentrating attention in specific elements when the source material is accessed. Each of the elements in the framework suggests a set of data to be collected and then it is possible to identify which of the sources could be appropriated. The result of the process is summarized in the data collection framework on Table 5.

Framework Element	Data	Source	Method
Philosophy	Possible reach of the project	IT Analysts	Interview
	Principles	IT Analysts	Interview
Models	Models included	System design documents	Interview, Documentary analysis
	Problems, advantages	IT Analysts	Interview
Techniques	Techniques usage	IT Analysts	Interview
	Problems, advantages	IT Analysts	Interview
Scope	Coverage of lifecycle	Project Plan	Interview, Documentary analysis
	Lifecycle rationale	IT Analysts	Interview
Outputs	Outputs for each phase in the project	Project Plan, System design documents	Interview, Documentary analysis
	Project evaluation criteria	IT Analysts	Interview
Architecture	System architecture	System design documents, System architecture documents	Documentary analysis
Approach	Source of business needs	System requirements document	Documentary analysis
	User participation	IT Analysts	Interview
	TPS data models usage	System design document	Documentary analysis

Table 5: Data Collection Framework

### 3.4.4 Collection methods

#### **Semi structured Interviews**

The interviewees were selected on the basis of their role; three of them are currently responsible for the development of DDSS in their business areas and one more had the same role but has changed now to work in other topics. The interviews are held in Spanish and the selected transcription translated to be included in the results and evaluation chapter. Spanish is the first language of the researcher and therefore the translation is done by him.

The base questionnaire was developed based on the adapted framework, they are aimed to identify the different elements of the framework in the method that the company is using in a dialog with the IT analyst that is guided by the questions but that is also open to other topics that could emerge in the process.

A semi structured interview has been designed around the different elements of the adapted framework and are aimed to find evidence to analyse the method used by the company in the development of DDSS and establish the position that the company has taken in the existing debate on the field. The topics to be discussed with the interviewees are presented and classified according to the elements in Table 6. Fore TI analyst of the company were interviewed by telephone, this strategy is adopted to deal with the restrictions of time of the research (Bryman and Bell, 2007), and the interviews were recorder to facilitate the transcription and later review.

Element	Topic
Philosophy	Reach and purpose of the projects
	User participation
Models	Requirements recording, analysis and design
	Appropriateness of Models
Techniques	Requirements elicitation
	Analysis and Design
Scope	Project plans
	Lifecycle coverage
Outputs	Extent of definition in each stage
	Project deliverables
	Final output
Architecture	Architecture preferences
	Data mart arrangements
	Knowledge and position on the debate
Approach	Timing of requirements in the project
	Use of TPS data models
	Knowledge and position on the debate

Table 6: Framework elements and Interview topics

## Documentary Analysis

The use of documentary analysis was adopted in the research as a strategy to supplement the information acquire by other methods (Bell, 2005). In this case the revision of existing documentation of the project was adopted to supplement the interview data.

### 3.4.5 Data analysis

From the means to perform the analysis of qualitative data identified by Denzin and Lincoln, (1998 cited in Morgan, 2009) the narrative analysis of the data is considered the most appropriate for the research. In order to perform a narrative analysis of the interviews using the framework each interview is reviewed one time for each of the elements of the adapted

framework to interpret the content and search for evidence that backs up the analysis of the method. Selective transcription is used where relevant to present the results.

The documentary analysis is performed using the 'Problem-oriented' approach (Bell, 2005). Each document is reviewed to search for evidence in the analysis of each element of the framework and having in mind other evidence drawn from the interviews. The procedure will allow confirming any findings from interviews or finding contradictions. Some of the elements will be mainly analysed from the documentation as can be seen in Table 5. The analysis can be performed based on the data of interest identified in the data collection framework.

After this explanation of the research questions, aims and research methods; the results of the process will be presented.

#### **4. Results and evaluation**

With the existing methodologies for the development of DDSS as background, the findings of the analysis of the development process in a company with experience in the field will be discussed. The data has been gathered via interviews and complemented with documentary analysis; all the analysis is driven by a framework for comparing methodologies that was adapted for this purpose, the adaptation consist in adding elements that are the axis of the current debate in the field and discarding others that does not apply when a method is analysed instead of a methodology. Both the interviews and the documentary analysis is performed and structured around the elements of the framework, on their basis the topics for semi structured interviews were selected and the documentary analysis was carried out. The chapter ends with a proposal for improvement that is also structured around the elements of the framework, the proposal is fed by the methodologies studied and good practices for specific activities studied in literature review.

## 4.1 Analysis of the Information Systems Development method in the case study organization

Each of the elements of the adapted framework will now be analysed for the case study organization in a similar way to the one carried out for methodologies. The analysis based on the interviews and the documentary analysis.

### 4.1.1 Philosophy

The analysis of philosophy element is carried out around the objectives sub-element, on this sub-element some evidence emerged during interviews that help to analyse what the objectives of the method are. When the methodologies are analysed it can be appreciated that on Kimball's methodology the objective is narrower than the one in Inmon's. Kimball Lifecycle leads to the development of an information system while Inmon proposal sees the DSS system as part of a bigger system and the projects can lead to further changes in organization.

In this respect, the analysts interviewed consider that the objectives of the method are narrow and that is difficult to obtain outputs different to the working software. Typical further outcomes of a project may be manual, procedural, managerial, organizational, educational, or political (Avison and Fitzgerald, 2006). When asked about those potential outcomes of the project, the analysts considered:

*"We have not reached the tactical and strategic levels of the [decision making] pyramid... once we reach them we will be able to support higher level decisions related to processes and structure" (Interviewee1)*

*"We are just starting but we have made efforts (In his business area) and I have seen other areas doing the same thing, we try to deliver the technical solution accompanied with organizational chart suggestions... those should be another output of the projects. In fact in the implementation strategy document we are discussing the importance to include a working face in the projects to deal with people and processes issues" (Interviewee2)*



#### 4.1.2 Model

**Dimensional model** is the most important view of the system. Once the business needs have been understood and recorded (even during this process) analysts start working on the model. Once the dimensional model has been created the source mapping, ETL design and the analytical application design can be started. All interviewees mentioned the use of dimensional models as a useful mechanism to render the important details of the solution.

*“The most important part of the design is the development of the dimensional model”*  
(Interviewee1)

*“Once requirements have been collected we start working on the start model”*  
(Interviewee3)

*“The dimensional model should be tested to see if all the stated business questions can be answered with it”* (Interviewee6)

The use of the data another model proposed by Kimball, the **Warehouse bus matrix** appeared during interviews. Interviewee3 shows concerns about the use made of the model. The model should be used to integrate the different components of the system as a whole and avoid the isolation of application that leads to problems of architecture.

*“We have been including one Bus Matrix Model but we really need to consolidate its use, I mean we need to keep one matrix that all projects can use instead of starting a new one for each project”* (Interviewee 3)

However the topic of consistency and integration was mentioned by interviewee4 without explicit reference to the warehouse bus matrix model:

*“We create our star models keeping what we have built in previous projects; the existing dimensions should be reused to keep information integrity”*

The extent to which this model is used leaves some space to problems in the architecture and one opportunity to improve the method is to spread and standardize its use though the different IT areas.

This type of information system has several components that should be developed during the project. This situation creates space and need to include different models. For example the lack of a proper model to record business **Requirements** is one of the sources of incompatibility between the method used for DDSS and the standardized method that is in use in the company for other types of IS. It was mentioned several times that the use of Use Case from RUP methodology is widely adopted and recommended in the company but is not appropriate for DSS:

*“Definitely use cases are for systems orientated to CRUD [create, read, update and delete] transactions on business transactions, they do not match well when we try to analyse a requirement associated to decision support systems, then people working in the topic is improvising a bit with the use of template documents” (interviewee4)*

DSS analysts see problems with their use for DDSS. Some analysts use verbal models or have implemented the use of templates; others have tried to adequate the requirements of the DSS system to Use Cases with not much success.

*“We face difficulties when we use the RUP methodology, the use cases are not always useful in DSS, I’ve attempted to develop use cases in DSS but they do not contribute much” (Interviewee2)*

Besides this situation with requirements and the importance of dimensional model affects the “Outputs” element of the method because while analysts are performing the requirements phase they feel tempted to start the dimensional model to be able to detail more the business needs. This situation leads to skip important activities from the requirement phase and cause confusion about deliverables (Outputs) of the stage.

*“It is not clear how to detail the requirement because when I try to do it I find myself designing, in that point I see the limit is blurred” (Interviewee 1)*

In this respect there is a good opportunity for improvement in the method if a standardised model could be introduced for requirements recording.

Lastly, in one of the interviews the need for a graphical model for the design of ETL processes surfaced. Currently templates are in use for this purpose but it leads to a duplication of efforts from the outsourced resources.

*“We fill out several templates to submit the specification of the ETL process to our provider, but they don’t start from the template they go back to the definition of the needs, I think that we lack a more effective mean to submit the ETL details in order to avoid duplication of efforts” (Interviewee 3)*

#### **4.1.3 Techniques and tools**

Techniques and tools are closely related to the models presented above; focusing in the specific techniques for DDSS, dimensional Modelling technique (referred to as ‘star schema’ by analysts) appears as a very important technique during the interviews followed by the ability to understand the requirements and separate them from those belonging to the TPS domain. In this respect they commented:

*“It is desirable to have experience in designing star schemas and how to manage it at the physical level, Indexes, partitioning, and history handling” (Interviewee2)*

*“The analyst should be skilled to do the warehouse design in a denormalized way, the fact tables in the middle and dimensions around” (Interviewee4)*

About the requirement process interviewee4 points out issues:

*“Those who are attendant to hear business need to request the projects lack training about how to do the elicitation for DSS, because in this case the requirements are documented based on the business questions while when you develop transactional*

*information systems you ask the users to describe their business process, therefore is very different ” (interviewee4)*

#### 4.1.4 Scope

It can be said that the method used by this company has a wide coverage of the systems development life cycle; this can be attributed to the fact that this method is not only influenced by the methodologies for DDSS but also for the methodologies used for transactional information systems.

Besides the company is aiming to standardize the whole process of information systems development, the situation has lead to analyst to perform the development of DDSS into the phases for the development of transactional systems for the sake of standardization. Possibly for this reason some IT analysts in the company consider that the life cycle for transactional information systems is adequate to develop DDSS. This is clearly stated by interviewee2:

*“I’ve always said that traditional software development is applicable to DSS solutions, I’ve always said that both discipline project management and software engineering apply generally speaking. Then to avoid analyst to get stuck they can follow the flow of activities, use the same roles and artefacts”*

However the discussion is open, other analysts in the company have an opposite view:

*“The development methodology for DSS is very different to the one for transaction processing systems...the company has gone forward with the methodological implantation for transaction processing systems, regarding DSS we are only starting”*  
(interviewee4)

The point made by interviewee2 come into view when the scope analysis of the method using the project plan (Reference: Project plan1) documents is carried out with the highest level activities (phases), the analysis is presented in Table 7.

Phase	Case Study Method	Level of detail
<b>Strategy</b>		Not included
<b>Feasibility</b>	Initiative Understanding	Detailed
<b>Analysis</b>	Analysis and Design	Detailed
<b>Logical design</b>	Analysis and Design	Detailed
<b>Physical design</b>	Analysis and Design	Detailed
<b>Programming</b>	Implementation	Detailed
<b>Testing</b>	Test and Adjustments	Detailed
<b>Implementation</b>	Deployment	Detailed
<b>Evaluation</b>		Not included
<b>Maintenance</b>	Stabilization	Detailed

Table 7: Scope analysis for the case study method

However an important finding appears when an analysis of the next level of detail in the project plan (the activities of each phase) is compared with the life cycle of proposed methodologies. It shows that analysts are carrying out the activities proposed by Kimball but they have distributed them in the traditional life cycle phases .A matching between the life cycle used in the company and the activities is presented in Figure 10. In the figure it can be seen that most of the activities are carried out. It shows how during the ‘Initiative understanding’ the activities of Project planning (Program planning is not included) and business requirement definition are carried out, the same can be seen in the figure for the rest of the phases. There is an exception for the ‘technical architecture design’ and ‘product selection and installation’ mainly because these were carried out for the first DDSS projects and now a reference architecture (project document) is followed and decisions about technology to use are mostly taken. ‘Growth’ is also not covered because it refers to the addition of new contents (Kimball et al., 2008); in the case study this means another project.

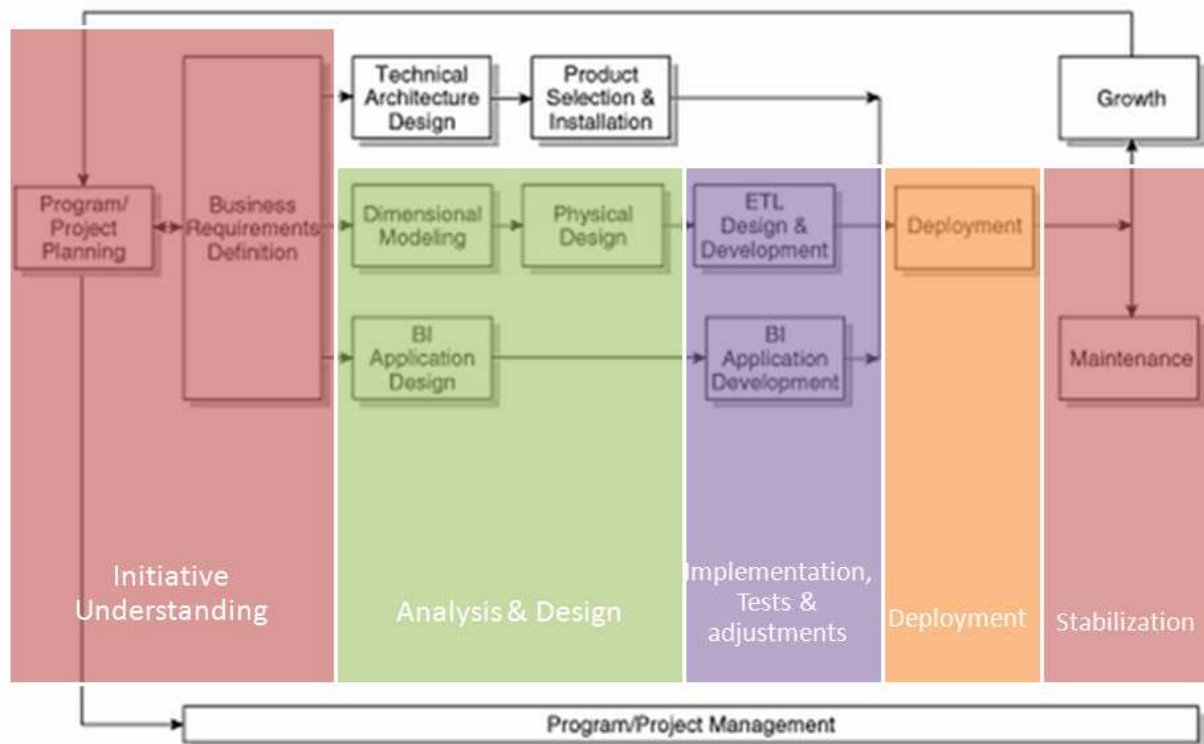


Figure 10: Case study and Kimball life cycle match analysis (Adapted from Kimball et al. 2008)

#### 4.1.5 Outputs

For most phases of the method outputs are well defined. This can be attributed not only to the influence of development methodologies for DDSS but also to the level of standardization that company has achieved for the development of TPS. When asked about the extent to which the output are defined in the development interviewees said:

*"We have the same artefacts, the same documents and the same phases established for the rest of projects... I follow the proposed format without problems using the appropriate terminology for the domain"* (Interviewee2)

*"We produce different documents during the process and we know when they should be completed"* (Interviewee3)

However, as pointed out in the models section, the lack of a model for requirements recording creates confusion on the deliverables of requirement phase.

*“When you want to detail a requirement in the development of transactional systems, you go to the next level when you detail the flow of activities and alternative flows but when you want to do the same in DSS I don’t know what’s the procedure and deliverable” (Interviewee1)*

The evidence shows that outputs are mostly well defined. There is only some lack of definition in the requirement phase that can be avoided with a mechanism to define in greater detail requirements without doing activities that are to be done in the design phase.

#### **4.1.6 Architecture**

The revision of the documents, specifically the ‘alternatives evaluation document’ shows that the proposed architecture is to have a data warehouse that is made of different groups of information (still called data marts), and the system is fed from transactional information systems. These features can be seen in the architecture of level zero of one financial project to provide DSS capabilities in the company. The architecture is presented in Figure 11 that is conceptually equivalent to the one presented in chapter2 in Figure 9: Data Marts that constitute the data warehouse. This architecture implemented in the company is aligned to the one proposed by Kimball and is one more element of the framework influenced by his proposal.

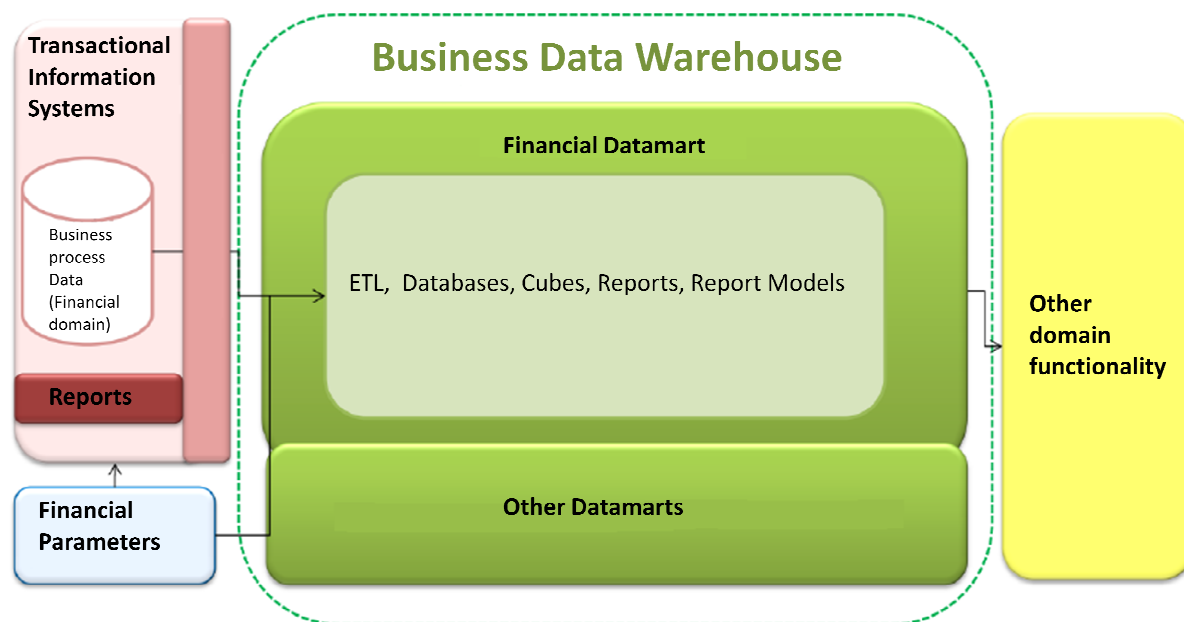


Figure 11: Zero level architecture of the system

#### 4.1.7 Approach

There are two features of the method used in this case study organization that takes it into the category of demand-driven approach; first the requirements phase is always at the beginning of the life cycle (According to the project plans reviewed). Second, the data models of existing information systems do not influence the requirements elicitation or design process (as proposed supply-driven approaches). Interviewee1 stated this second point clearly:

*“We only use the data model from the sources when we start to design the ETL processes, although I think that we should use it at least when we start modelling”*

However some evidence emerged to say that the method is demand/supply driven. For instance Interviewee 4 remarks the importance to know the information sources in order to moderate user expectations and build a system that shows data supported on real business operations:



*“DSS systems should depart from actual data and that data lies in transaction processing systems... if one is going to develop such a system one should have the appropriate data sources”*

This is only enough to say that the method is starting to change in some areas of the company; it is now tending to be a hybrid demand/supply approach.

Despite analysts mentioning key features of Kimball recommendations to carry out requirement analysis there are some important elements missing and improvement can be made in this respect. Besides analysts pointed out problems like the inclusion of reports or indicators in the system because they already exists but there is no decision and action associated to it. Interviewee3 questions the approach, especially to what is related to requirements:

*“Sometimes when we approach business users to ask about their needs they present a series of indicators or reports and we use them as a starting point or simple we implement the solution around them. But do they consult this information, sometimes they just look at the indicators but when it changes nothing happens”*

One last point related to the approach is user participation, analysts give much importance to the participation of users in the different phases of the project; interviewee4 comment reflects clearly this believe:

*“Users should be able to understand the design and contribute to it”*

Now that the analysis of the elements of the modified framework have been presented. The methodologies proposed and the method for the case study organization are brought together and summarized in Table 8

	<b>Kimball Life Cycle</b>	<b>Seven Streams approach</b>	<b>EPM</b>
<b>Philosophy</b>	Science Paradigm Analytical application domain Targeted to DDSS Objectives narrowed to IS	Science Paradigm Analytical application domain Targeted to DDSS Objectives reach organization	Science Paradigm Analytical application domain Targeted to DDSS Objectives narrowed to IS
<b>Model</b>	Dimensional Model Data warehouse bus Matrix	Departmental/Corporate Entity-Relationship Diagram Departmental/Corporate Data Item Set	Dimensional model
<b>Techniques and tools</b>	Dimensional Modelling	Stability analysis	Dimensional Modelling
<b>Scope</b>	9/10 included	6/10 Included	9/10 included
<b>Outputs</b>	Tightly defined	Defined with the exception of the final outcome	Tightly defined
<b>Architecture</b>	Data marts constitute the data warehouse	Data marts are fed from normalize data warehouse	Data marts constitute the data warehouse
<b>Approach</b>	Demand-driven	Supply-driven	Mostly demand-driven whit some initiative to be hybrid/Mixed

Table 8: Methodologies and Case Study method summarized with the adapted framework

## 4.2 Factors shaping this method

### 4.2.1 Standardization initiatives

The efforts made by the company are evident in the documents and statements of interviewees; in this case the company is trying to develop all information systems in a similar way to achieve benefits of standardization. This strategy influences the way that DDSS are developed; in terms of the selected framework it affects mainly two elements; scope and models. About scope as presented in the previous section this influence mainly affect the

broader level of the project lifecycle however some activities need to be done to shape the DSS system; those activities are performed anyway in a convenient phase of the standardized life cycle. About models it was shown also in the analysis of the method that analysts tried to introduce models (Use Cases) that are designed for TPS in the development of DSS, they were also motivated for the standardization of practices however they found it ineffective and are willing to have models more appropriate for the special features of the system.

#### **4.2.2 Methodological proposals**

It is clear in this case that the company studies the methodological proposals existing for DDSS and have included author recommendations in their process. The influence of methodologies can be identified clearly in this case for most element of the adapted framework. In this company the need for specific technique to develop DDSS is recognized and analyst study and apply what authors propose although it appears that the influence comes from only from Kimball's proposal.

Although the reasons for the choice were not investigated during the research, it can be said that in the environment of the company and providers the methodology proposed by Kimball is more known. This can be attributed to the fact that specific tools for the development of DDSS are built around the concepts of the dimensional modelling technique, which was proposed by Kimball (1996). And for that reason analysts consider that Kimball's methodology is more appropriate for the company than Inmon's.

#### **4.3 Proposal for Improvement**

The different elements of the proposed framework provided a view of the method in use in EPM for the development of DDSS. From the analysis of the elements of the method in the light of existing proposals and from the concerns of analyst some opportunities for improvement have emerged.

The first proposal is structured around the techniques and models. To deal with the issues about the specific features of the requirement phase for DSS it could be beneficial to adopt one proposal for requirement analysis oriented to DDSS that includes specific techniques and an

adequate model to overcome the lack of model in the method and provide personality to the first phase of DSS projects. Three features of the method indicate the more appropriate proposal, first it is mainly influenced by Kimball life cycle, second it is centred around processes (although it needs to be refined and communicated) , third is influenced also by RUP (Rational Unified Process). From the methods presented in section 2.5.1 the one from Schiefer (2002) shares the three features. Because of that its use is recommended and its introduction in the company should be less problematic.

The second proposal comes from the model element of framework but has an important effect in the architecture. Both proposals are iterative and both emphasize in the importance of building the system piece by piece but keeping the view in the whole system, otherwise the disordered addition of more applications, topics or data marts to the system will lead to problems of isolated sources of information. For that reason the use of the data ware house bus matrix that has already started should be consolidated and agreed in all IT areas.

## **5. Conclusions**

### **5.1 Summary**

Using a framework to compare software development methodologies that includes seven elements (i.e. Philosophy, Model, Techniques and tools, scope, output, practice, product) we have analysed consistently the most relevant methodologies proposed for the development of DDSS (Kimball life cycle, Inmon's seven streams). Also some important proposals for single phases of the development process were also discussed (Requirements, Dimensional modelling, and ETL design). After this first part of the research the attention is turned to the practice area with the analysis of the DDSS development process in a company with experience on it. To do so the framework initially used was adapted building upon theory to include features that are the base of the debate in the field and also to discard elements that are not helpful for a case study. The method used in the company was analysed with the adapted framework and several opportunities to improve it appeared. Additionally some factors were identified as the most

influential in the method. Finally the opportunities for improvement were addressed with proposals to help the company of the case study to enhance the method.

In this chapter an answer to the research questions is proposed. Also the limitations of the study are stated. Next a reflection of the use of the framework in the research is presented and final conclusions offered.

## **5.2 Research questions revisited**

An answer to the research questions of this be summarized

RQ1: What are the proposed Methodologies for the development of DDSS?

Two methodologies that are comply with the definition of methodologies presented in chapter x were found in this research.

First Kimball life cycle that is well-known for the dimensional modelling technique and an approach that encourages user participation during all the process, it is a demand driven approach that departs from business processes to discover the analysis needs of the company and proposes a system architecture where the system is that is composed by several subsystems that are all designed using dimensional modelling.

Second Inmon's seven stream approach is a more complex proposal for the development of DDSS. Its techniques are more suitable for IT analysts and more passive user participation in a role that approves the deliverables produced by IT analyst. This approach is also broader in reach because it covers the DDSS as part of a bigger system denominated Corporate Information Factory. The methodology approaches the development with a supply driven approach that departs from the data models of existing TPS of the company and proposes a system architecture where a central normalized repository feed other repositories that might be designed using dimensional modelling.

RQ2: What is the method used in the selected case study organization to develop DDSS; where does it originate and what drives the choices?

The method analysed during this research is highly influenced by methodologies used for the development of TPS in the company. It can be explained by the aim of standardization of the system development process in the company, the standard process is tailored to the efficient development of the most developed systems, i.e. TPS and therefore it lacks some special features especially necessary for DDSS.

The need to fill this gap of the standardized method brings to the scene the second shaping factor: the methodological proposals, in this case it is more evident the influence of one of the proposed methodologies (i.e. Kimball life cycle).

RQ3: How can the method used in the case study organization be improved with the existing proposals?

The process of building a DDSS that meets all analysis requirements in a company needs several projects to be completed, whether the company decide to do it process by process or topic by topic there should be a mechanism to control how the new parts of the system fit to the existing ones and ensure that they are conformed with the architecture that its selected at the start of the whole initiative. It has been recommended for this company to emphasise in the mechanism available from the methodology that is most influential for their method. Therefore complete this opportunity of improvement the Data bus matrix model should be built, shared and maintained by the different business areas that cooperate to build the information system.

The second mechanism to improve the method is the introduction of one of those proposals that are aimed for specific tasks in the development of DDSS, specifically for requirements analysis because this phase has been found to be the source of issues in the method during the analysis. For this case which method is shaped not only by specific methodologies but also more TPS focused methodologies the introduction of one of those proposals for requirement analysis that have the same background has been recommended. Despite it does not provide a graphical model it suggest different

levels of detail for the specification based on templates, its process-centric elicitation based also on Kimball's methodology will support analyst in defining a requirement analysis that process that is specific enough for DDSS and that complies with the standardization conditions.

Here we can see that an answer to every question initially proposed in the research have been addressed using de proposed research method and the information sources provided by the case study organization.

### **5.3 Limitations of the study**

This study contributes to understand how development methodologies influence the practice of developing DDSS. Primary sources of information were used from a study organization in Colombia and direct contact with IT analyst with experience in the topic was illustrative. However the results from the study cannot be generalized using a single case study, the possibility to include other cases was restricted by the time available and the availability of secondary sources. On the other hand the results and the information generated in the study can serve for further research.

### **5.4 Reflection on the framework**

This framework has been proposed by Avison and Fitzgerald (2006) to analyse software development methodologies, this starting point help us to put in the same level the development methodologies for DDSS. While helping to focus the review of those methodologies it also led to the identification of topics of special interest in the area.

The framework is also useful to study a case where the development methodologies might be applied. It was necessary to discard some elements as they do not provide much information for a case study beside it was complemented with the findings mentioned above. The use of the framework supported the identification of the sources of information and the application of selected methods.

The use of the framework in the research contributed to understand the case study organization and to relate it to the theoretical proposals in most senses. However it lacks detail

on how the activities of the lifecycle are organized, if they are linear or iterative. There could have been a deeper discussion in this area but out of the framework landscape, some part of the discussion has been presented under the scope element of the framework.

## 5.5 Conclusions

This research has shown:

That dimensional modelling is one of the most appreciated techniques in the development of DDSS. The dimensional modelling represents a different mindset of IT analyst that work for simplicity and accessibility of data instead of the aims of transactional data modelling. The change of mindset is the first and sometimes the hardest step to be able to develop DDSS.

The construction of a complete DDSS is made in several projects and by several teams, it is very important to have a mechanism to take care of the architecture of the whole system to avoid isolation and problems among sub systems. For example DW bus Matrix or Corporate Information Factory.

Another important feature of DDSS is that is built on top of other information systems, mainly TPS. In order to give the system credibility and manage user expectations it is necessary to adopt a demand/supply driven approach. Sources should be reviewed from the start of the project for all stages of the project, especially during requirements elicitation, design, and ETL construction.

IT analysts consider that the stages of the software development life cycle are applicable to the development of DDSS. However they include activities proposed in the life cycle of specifically designed methodologies in each of the development phases.

Further research can attempt to apply this framework and methodology to different cases to verify how the results of this study can be applied in different context. Other researchers can prove if factor shaping a method are the same as in this case, refute or complement them, they can interview people and review project documentation to identify what is the actual method use to develop DDSS.



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