From Early Requirements to Late Requirements Modeling for a Data Warehouse

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Abstract-**In recent years, a number of requirements engineering (RE) proposals for a data warehouse (DW) systems have been made. In the traditional/operational systems, requirements engineering has been divided into two phases: early & late requirements engineering phase. Most of the data warehouse requirements engineering (DWRE) approaches have not distinguished early requirements engineering phase from late requirements engineering phase. A very few approaches are seen in the literature that explicitly model early & late requirements for a DW. In this paper, we propose an agent-oriented approach having support from early requirements to late requirements modeling for a data warehouse. Here, the early requirements have been modeled through two models: organization model and goal model whereas late requirements are modeled through decision model. The proposed approach is illustrated through an example of the university for which DW is to be built to support decisional goals.**

Keywords-*agent; early requirements engineering; late requirements engineering; data warehouse*

I. INTRODUCTION

In the last decade, great interest has been shown in the development of Data Warehouses (DW). The initial thrust of DW was in decision making that principally involved numeric facts and textual dimensions. In recent years, however, Data Warehouses have been proposed for domains of image data [Won02], voice data [Mil97]. For DW in the decision-making domain, two different approaches, data-driven [Inm96] and requirements-driven [Bal98] have been used. In the former, data is gathered from operational systems into DWs whereas in the latter the attempt is to identify the information needs to be met by the DW. In these approaches, the real issue is that of DW design: given data needs what is the logical structure of the DW. Proposals to add a conceptual layer on top of the basic data layer have been made, for example, by Jarke et al. [Jar98]. Here, it is assumed that the conceptual objects can be determined but the question of what are useful conceptual objects for a DW and how these are to be determined is not addressed. To answer this, we need an explicit Requirements Engineering (RE) phase in DW development. The requirements engineering task has been divided into two phases: early requirements engineering phase and late requirements engineering phase [Dou93, Yu95, Yu97]. The "early-phase" of requirements engineering activities include those that consider how the intended system would meet organizational goals, why the system is needed, what alternatives might exist, what the implications of the alternatives are for various stakeholders, and how the stakeholders' interests and concerns might be addressed. The emphasis here is on understanding the "whys" that underlies system requirements [Yu94], rather than on the precise and detailed specification of "what" the system should do. The notion of agent and related mentalisic notions are used in all software development phases from early requirements analysis down to the actual implementation [Bre04, Yu97a, Yu97b]. The mentalistic notions can be founded on BDI (Belief, Desire, and Intention) agent architecture [Rao91].

The various data warehouse requirements engineering (DWRE) approaches have not distinguished early requirements engineering phase from late requirements engineering phase. However, in [Gio08] the early phase of Tropos [Bre04] has been extended to the requirements engineering of data warehouses. This approach [Gio08] uses stakeholder dependencies, which are represented in an actor diagram. Thereafter, two perspectives are proposed, organizational and decisional. In the former, facts are identified and associated to goals of different actors. In the later, each fact is related to their dimensions and a set of measures is found out and associated with facts. This goal driven approach [Gio08] is mainly focused on DW conceptual design, which can be employed within both supply driven and a mixed supply/demand driven design frameworks for DWs. However, this approach does not look at the decisional goals [Pra07] of the organization for which DW is to be built. In [Pra07], GDI (Goal-Decision-Information) model [Pra03], has been viewed in two ways, one from the organizational and the other from the technical perspective. The former look upon the warehouse as embedded in an organization and considers the manner in which it supports organizational tasks. The latter deals with issues of data warehouse contents, their broad properties etc. This approach [Pra07] is modeling the late phase requirements but not the early phase requirements in the context of DWs.

In this paper, we propose an agent oriented approach to model early & late requirements for a DW by extending the GDI model proposed in [Pra03]. Here, we introduce the notion of agent, which represent stakeholders of the

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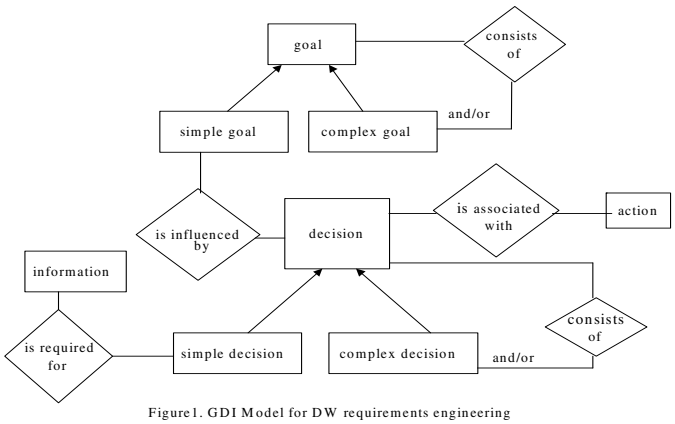

Figure1. GDI Model for DW requirements engineering

organization for which DW is to be built. The proposed approach as discussed in section IV supports three interrelated modeling activities as organization modeling, goal modeling and decision modeling. The organization and goal modeling activities capture early requirements whereas decision modeling activities looks at late requirements for a DW.

Organization of the paper is as follows: related literature is presented in section II. Section III gives an overview of GDI model. The section IV discusses the proposed agent oriented approach, which extends GDI model to support early and late requirements engineering issues for DW. The proposed approach is illustrated through an example in section V, followed by conclusion in section VI.

II. RELATED LITERATURE

In recent years, a number of proposals for Requirements engineering of DW systems have been made. Efforts have also been made to define the Systems Development Life Cycle, SDLC, for DW development [Gol99, Hus00]. Both these assume the ER diagram as the input to their DW Requirements engineering phase. Kimball [Kim98] proposes a four-step approach where, from an initial choice of a business process, dimensions and facts are determined. According to Frendi et al. [Fre03], DW requirements can be elicited using business process requirements and strategic decision processes. They propose that DW models are produced using a combination of DW requirements and as–is data models. Once produced, DW data models can also be used to elicit new requirements. Winter [Win03] points out that a detailed analysis of business processes is not a good starting point for DW development. They propose a methodology to develop a DW system that supports exclusively decision processes. A different approach is adopted in [Bon01] where the problem is to extract data marts [Inm96] from the enterprise wide information system. It adopts the top-down approach for determining goals using the Goal-Question-Metric approach. It can be seen that the information content of a DW is found in the larger context of the goals and objectives of an organization. These goals and objectives identify the decision-making capability to be supported. Therefore, it is proposed in [Pra03] that the identification of goals suggests the decisions that influence the satisfaction of these goals. Implementation of decisions is done by actions associated with them. Finally, from knowledge of the decisions, it is possible to identify the information that is needed to take the decision. Here, the product of requirements engineering is represented as a schema of GDI model [Pra03]. The easy requirements modeling technique for DW system [Shi02] represents good practices for requirements management. This approach [Shi02] focuses on the communication between the stakeholder and users of a new data DW system and those who are building it. Furthermore, it helps to apply an effective requirements engineering method by the use of different perspectives for capturing of DW requirements. Our proposed agent oriented approach mainly focuses on stakeholders and their dependency modeling for a DW. Our approach shares some similarities with the goal driven approach [Gio08] and also with the easy requirements modeling techniques for a DW system [Shie02]. The GDI model [Pra03] is discussed in the next section that will form the basis for the proposed approach.

III. OVERVIEW OF GOAL-DECISION- INFORMATION MODEL FOR DW REQUIREMENTS ENGINEERING

The goal-decision-information (GDI) model is shown in Figure1. In accordance with goal-orientation [Ant96, Bub80], we view a goal as an aim or objective that is to be met. A goal is a passive concept and unlike an activity/process/event it cannot perform or cause any action to be performed. A goal is set, and once so defined it needs an active component to realize it. The active component is decision. Further to fulfill the decisions appropriate information is required. As shown in Figure1, a goal can be either simple or complex. A simple goal cannot be decomposed into simpler ones. A complex goal is built out of other goals which may themselves be simple or complex. This makes a goal hierarchy. The component goals of a complex one may be mandatory or optional. A decision is a specification of an active component that causes goal fulfillment. It is not the active component itself: when decision is selected for implementation then one or more actions may be performed to give effect to it. In other words, a decision is the intention to perform the actions that cause its implementation. Decision-making is an activity that results in the selection of the decision to be implemented It is while performing this activity that information to select the right decision is needed. As shown in Figure1, a decision can be either simple or complex. A simple decision cannot be decomposed into simpler ones whereas a complex decision is built out of other simple or complex decisions. Figure1 shows that there is an association '*is influenced by'* between goals and decisions. This association identifies the decisions which when taken can lead to goal satisfaction. Knowledge necessary to take decisions is captured in the notion of decisional information shown in Figure1. This information is

a specification of the data that will eventually be stored in the Data Warehouse. Figure1 shows that there is an association 'is required for' between decisions and decisional information. This association identifies the decisional information required to take a decision.

IV. AGENT ORIENTED APPROACH FOR DW EARLY & LATE REQUIREENTS MODELING

The GDI model [Pra03] starts with the determination of goal of the organization with the help of decision makers by assuming that only decision maker are the stakeholders responsible for decision making activities in the organization. The other stakeholders and their dependencies for achieving the goals of the organization are also important to be modeled. For this GDI model does not have any notion to model stakeholder explicitly. In this paper, it is proposed to introduce the notion of agent with the existing GDI model [Pra03] to represent the stakeholders of the organization. We may call the extended GDI model as an AGDI model as shown in figure 2. We also model stakeholders' dependencies through agent dependencies in proposed AGDI Model. The concepts of AGDI model have been presented in the next sub sections to follow. The Agent may depend on another agent for goals to be achieved, decisions to be suggested & information to be provided. These dependencies among agents are called goal, decision & information dependencies respectively. Our agent oriented approach uses proposed AGDI model to support three interrelated modeling activities as organization modeling, goal modeling and decision modeling. During these modeling activities, agent, goal, decision and information concepts of AGDI model have been represented as bubble, rounded rectangle, rectangle and hexagon graphic symbols respectively. The organization and goal modeling activities model early requirements whereas decision modeling activities model late requirements for a DW. The organization modeling as in [Bre04, Gio08] looks at the organizational context and identifies the agents and their associated goals. An agent may generate its own goals or may operate to achieve goals on the behalf of some other agents. It may collaborate with or delegate to other agents for a specific goal. The output of the organization modeling is represented as an organization model showing agents and their goal dependencies. This organization model is further refined till all the complex goals of an agent are converted into the simple goals, which may be delegated to other agent. This refined organizaton model will be given as input to the goal modeling. During goal modeling, the agent will be asked by the requirements engineer to suggest relevant decisions for achievement of simple goals of all agents. The relevant decisions may be a simple or complex decision. The complex decision will further be refined into simple decisions through agent interaction. The output of goal modeling is represented as a goal model showing agents and their decisional dependencies. The goal model is fed to the decision modeling activity where set of information to support all the decisions is identified through agents' interaction. The output of the decision modeling is represented as decision model showing agents and their information dependencies to support a particular decision. The set of information identified during decision modeling may be kept in the DW. The following subsections discuss the various concepts used in the AGDI model of the proposed approach.

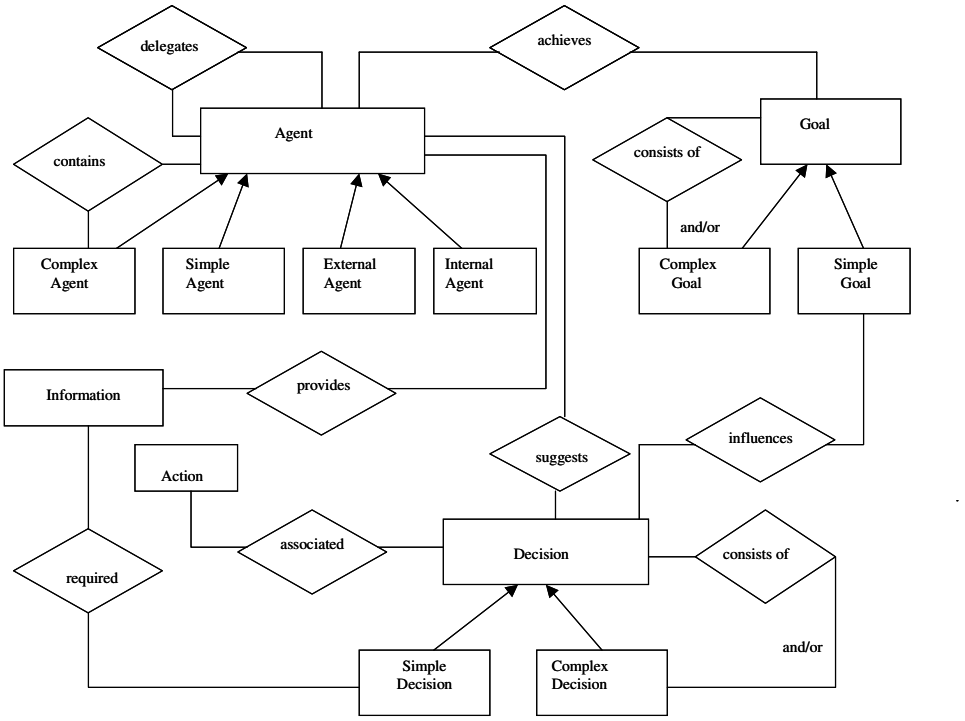

Figure 2: AGDI Model for DW early & late requirements modeling

A. *Agent*

The concept of an agent can be traced back to the early days of research into Distributed Artificial Intelligence. Hewitt [Hew00] proposed the concept of a self-contained, interactive and concurrently executing object, which he termed 'actor'. Here, an actor is a computational agent, which has a mail address and a behavior. Agents can be identified of seven types as: collaborative agents, interface agents, mobile agents, information/internet agents, reactive agents, hybrid agents and smart Agents [Hya96]. Another issue of note is that agents need not be benevolent to one another. It is quite possible that agents may be in competition with one another, or perhaps quite antagonistic towards each other. However, it has been viewed in [Hya96] that it is possible to have competitive collaborative-type agents, competitive interface agents, and competitive information agents.

Here, the notion of agent models various stakeholders playing different roles for the organization: decision makers, resource (information) provider, action implementer, etc. The agent may be an internal agent or an external agent as shown in figure 2. The internal agent models the internal stakeholders of the organization whereas external agent models the external stakeholders of the organization as shown in figure 2. For example, in the case of University System, the student and the staff of the university may be internal agents whereas funding agencies and regulatory agencies may be the external agents. The external agents may provide various financial/informational resources to the organizational agents in order to control/regulate the decisional activities in the organization. The agent (internal/external) can either be a simple agent or a complex agent as shown in figure 2. The complex agent may contain simple agent or complex agent, as shown through contains relationship in figure2. For example, the decision maker is a simple agent whereas the organization, for which DW is to be built, is a complex agent. The organization as a complex agent contains departments and faculties. Here, department is again a complex agent whereas faculties are simple agents. We may keep on decomposing the complex agent till we get simple agents who can actually contribute for achieving the goals of the organization.

B. *Agent & Goal*

Agent may have goals to be achieved. Goals are valuable in identifying, organizing and justifying system requirements [Van01, Ant96]. In accordance with goal-orientation [Ant96, Boe91], we view a goal as an aim or objective that is to be met. The goals have been classified in different ways [Dou93, Myl92, Pra07, Rol98, Sut93, Van01]. According to Van [Van01], goals are functional or non functional and the differentiation is made on the basis of purpose behind the goal. According to Prakash [Pra07], a facet-attribute–value approach is adopted to develop a framework for goal classification. Prakash [Pra07] pointed out that the purpose behind the goal may be decisional and termed the goal as decisional goal. Here, we are focusing on decisional goals. An agent may achieve the goal on its own or an agent may dependent upon other agent for achievement of the goal. The former case is shown through achieves relationship and the later case is shown through delegate relationship in figure 2. In the later case, one agent is delegating its goal to another agent and the receiver agent should be committed to achieve the goal. For example, University as a complex agent may

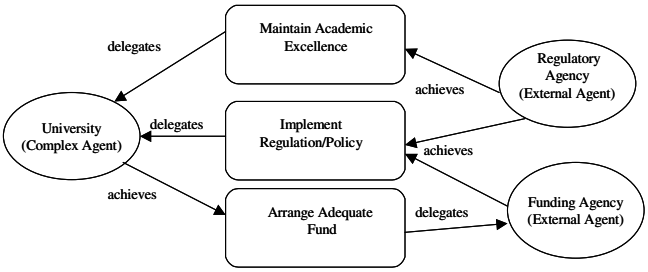

Figure 3. Organization Model: showing agents and their goal dependencies

depend upon the internal agent 'Head of University' to achieve the goal' Maintain Academic Excellence'.

C. *Agent, Decision & Information*

A goal is set, and once so defined it needs an active component to realize it. The active component is decision. The agent will be asked to suggest the relevant decisions for achievement of goal, which is shown through suggest relationship in figure2. For example, 'Dean Academic' as an agent may have a goal 'Improve Lab facilities' and to achieve this goal, the agent may suggest various decisions as: 'select lab for improvement 'and 'survey latest facilities'. Agent may provide the information required to support the decision, which is shown as provides relationship in figure2. Agent may also be dependent upon other agents for the required information to support the decision. For example, the agent HODs may require the information ' course wise students academic feedback' and 'course wise students performance feedback' for last three years in order to support the decision ' select course for improvement'. An agent 'DW' may maintain this kind of information. The DW as an agent will provide quality information to support the decisions whenever required by any agent. The decision once taken as suggested by the agent should influence the goals towards achievement of the goal as shown through influence relationship in figure2. The decision once taken will be implemented through the set of actions to be carried out by an agent, which is shown as associated relationship in figure2.

V. ILLUSTRATION WITH EXAMPLE

To illustrate the proposed agent oriented approach, we are taking an example of Guru Gobind Singh Indraprastha University (GGSIPU) for which DW is to be built to support its decisional goals. The GGSIP University has been setup by the Delhi Govt. in consultation with the Regulatory Agency like UGC to fulfill their goals in order to build knowledgeable nation. The UGC may expect from the university to maintain academic excellence for the benefit of students and the nation as well. The university needs adequate funds from the Govt. to discharge its academic

activities. Here, to model initially the early requirements, we will perform an organization modeling activity in order to analyze the organization context, where DW system is to work, which is discussed in the next sub section to follow.

A. *Organization Modeling*

In the organization modeling, we identify the various stakeholders as internal/external agents and their expectation/ intention as goals of the agent, which can be shown in figure 3. We may identify University as a complex agent, which contain faculty, staff and the students as internal agents whereas UGC and Delhi Govt. are external to the university and may be termed as external agents. The UGC wants to achieve the goal maintain academic excellence and this goal needs to be achieved by the university. Now UGC has delegated the goal to the University, which university has to achieve. Now UGC is dependent upon university to achieve the goal maintain academic excellence, which is shown in figure 3. Similarly, university is dependent upon Delhi Govt. to achieve a goal arrange adequate fund'. When the agent/goal is complex then further refinement is required so that agents and their goals are converted into its simple agent/goal, which is shown in figure 4. The university being a complex agent contains Head of University as a simple agent, who can achieve the goal on behalf of the university. The agent 'head of university' view the goal 'maintain academic excellence' as a complex goal. The agent breaks down this complex goal into sub goals: improve academic infrastructure, attract good faculty & staff & attract good students as shown in figure 4.The agent 'head of university' perceives that all these sub goals are mandatory to achieve a complex goal, as shown through 'and' link in figure 4. This breaking activity will continue till the entire complex goals/sub goals are converted into simple goals or the goal/subgoal may have been delegated to other agents for their fulfillment. The goal 'improve T&P of students' and 'offer good quality entrance exam' may be delegated to the agent 'Head T&P' and 'Controller Examination' respectively for their achievement as shown through 'delegate' arrow links in figure 4. The refined organization model as shown in figure 4 will be given as input to the goal-modeling activity, which is discussed in the next section to follow.

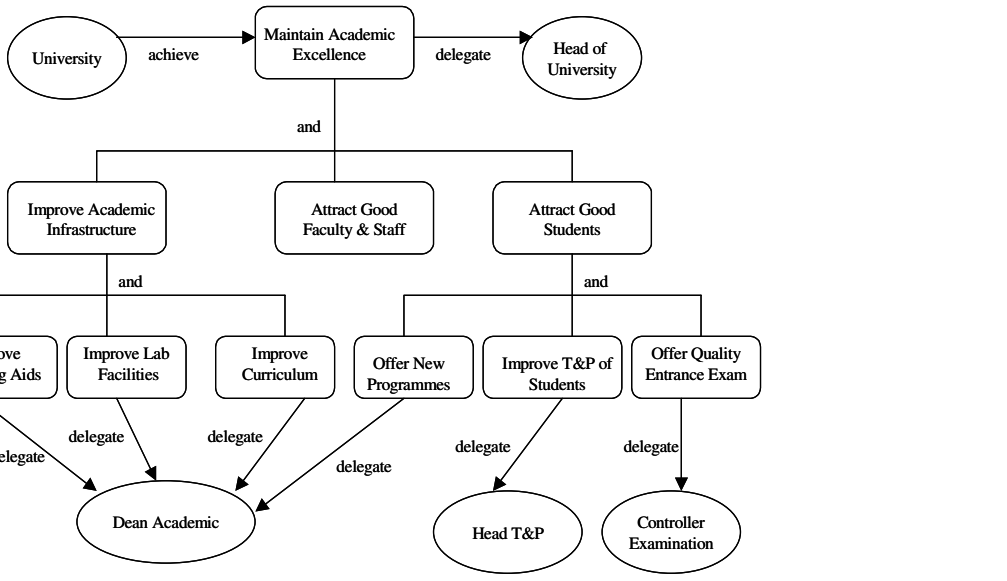

Figure 4. Refined Organization Model: showing new agents and their goal dependencies

B. *Goal Modeling*

During goal modeling, agent will suggest the various decisions that may be taken to achieve the goal of the agent. Keeping in view the figure 4, we can take 'Improve Curriculum' as a goal of an agent 'Dean Academic'. In order to achieve this goal, the agent 'Dean Academic' as shown in figure 5 may suggest the following decisions:

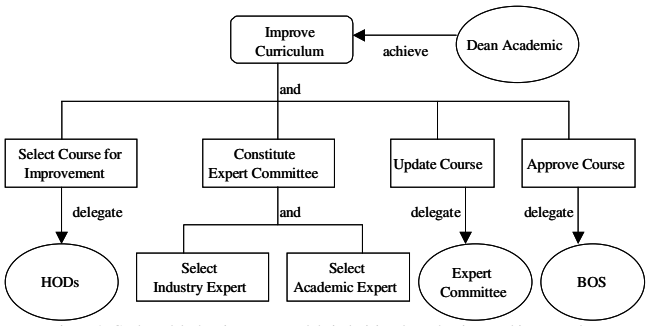

Figure 5. Goal Model: showing agents and their decision dependencies to achieve a goal

(a) Select the course for improvement
(b) Constitute an expert committee
(c) Update course
(d) Approve course

The above-mentioned decisions (a), (c) and (d) are simple decisions and may be delegated to heads of various departments (HODs), Expert Committee and Board of Studies (BOS) respectively. The decision (b) is a complex decision, which is broken down to two simple decisions as

'select industry expert' and 'select academic expert'. These two simple decisions are mandatory for achieving the complex decision as shown through 'and' link in figure 6.

Similarly, for achieving a goal 'Improve Lab Facilities', Dean Academic as an agent may be suggesting the following decisions:

(a) Select lab
(b) Survey latest facilities.
(c) Get Experts Opinion
(d) Set up lab facilities

The decision (b) is a complex decision, which is built out of two simple decisions as 'Survey Industrial Labs and Survey Academic Labs and may be delegated to the agent 'Survey Team'. Similarly decision (d) is also a complex decision, which is built out of two simple decisions, as 'Purchase required Items' and 'Install & Test facilities'. These decisions may be delegated to the agent 'Purchase committee' and the agent 'Vendors' respectively. Similarly, for achieving a goal improve T&P of students, following decisions may be suggested by T&P Officer as an agent:

(a) Establish Industry-Institute Relationship
(b) Update Faculty & Staff with latest technologies.
(c) Set up latest technical infrastructure
(d) Update Students as per industry requirements

Similarly, for achieving a goal offer good quality entrance exam, following decisions may be suggested by the Controller of Exam as an agent:

(a) Adopt latest technology for conducting the exam
(b) Select experts for paper setting with the advise of Head of University
(c) Get question papers set from experts
(d) Review the standard of the question papers by the review committee
(e) Adopt foolproof checking procedure

This goal modeling activity will be continued till all the goals of all the agents are taken into consideration. The output of goal modeling activity is represented through goal model showing agents and their dependencies as shown in figure 5 considering one goal of an agent only. The output of goal modeling is fed to decision modeling activity.

C. *Decision Modeling*

During decision modeling, Agents are consulted by the requirements engineer to get needed information to support the identified simple decisions during goal modeling. For example, to support the decision 'select course for improvement' following set of information may be required by the agent HODs as shown in figure 6:

(a) Students Academic Performance feed back
(b) Students Placements feedback
(c) Experts comments regarding relevance , employability etc.

The information as required in (a) may compose of the information as 'course wise feed back for last three years' and 'semester wise feed back for last three years'. This set of information may be available with the agent Dean Academic. There is need of an agent, which can manage this kind of historical information in an effective manner, in our case that may be a Data Warehouse, which will work as decisional system for the organization. Similarly to support all suggested decisions, the required information may be identified through interaction among agents. This set of identified information may be kept in DW. The set of decision models produced during decision modeling activities capture the late requirements for a DW.

VI. CONCLUSIONS & FUTURE WORK

The proposed agent oriented approach modeled early and late requirements by taking an example of a University for

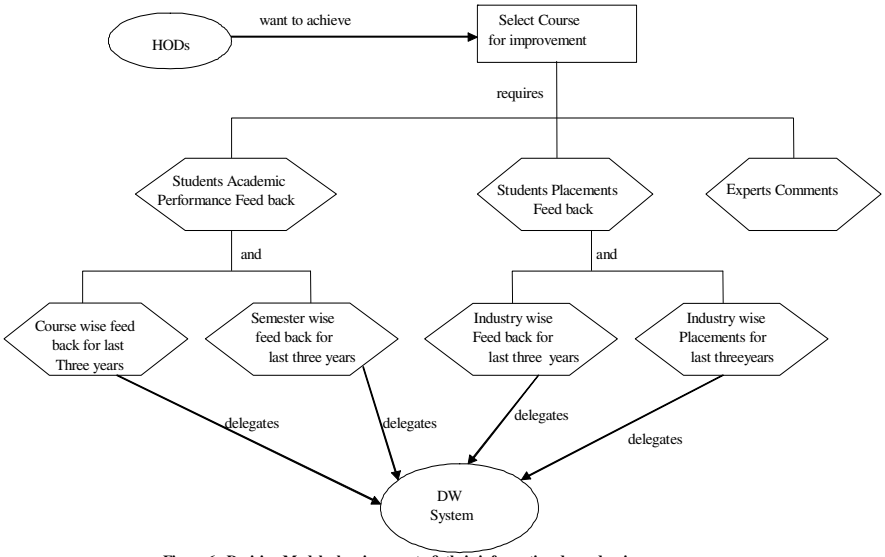

Figure 6. Decision Model: showing agents & their information dependencies

which DW is to be built. The early requirements have been modeled by producing organization model and goal model whereas late requirements are modeled by producing decision model. As a part of our future work, we will extend our proposed approach to address conceptual modeling issues for a DW and will also develop a CASE tool to support the modeling activities.

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