Collaborative Virtual Enterprise Environment and Decision Mining

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This paper will present some meaningful insights into the analysis and modeling phases of an Enterprise Virtual Environment (EVE) prototype. The main goal of EVE is to provide an environment for collaborative decisions using a DSS-like approach. In the second part, the proposed architecture of the system will be introduced. This system is developed primarily to simulate decision situations in the academic training of students. The second goal of the system is to provide us with user activity logs that will be the starting point of decision pattern mining process. In the third part of the paper, we will provide evidence regarding the possibility of: mining decision models from user activity logs; comparing different decision making strategies of users; and building decision reference models.
Keywords*: Enterprise Virtual Environment, Decision Simulation, DSS Analysis and Modeling, Decision Mining, Decision Analysis, Decision Models.*

1 Introduction

The need for collaborative decisions becomes increasingly important in today's economic environment. First of all, it is obvious that a manager needs to gain insights into an increasingly various number of decisional situations that require specialized training. Second, a decision can be improved if instead of one vision over the problem several different points of view are provided. Third, it is important to analyze a decision once it is made and it is even more important to compare it with similar decisions in other regional and foreign enterprises. Finally, we believe that decision making abilities and hands-on training should not be achieved only after the students become involved in real-life economy, but they should be developed during college years.

Considering the reasons above, this paper will continue our previous research in two fields: collaborative DSS analysis and modeling; and decision mining and modeling. We will argue our next steps in reaching several overall objectives:

- building an Enterprise Virtual Environment (EVE) focused on decisional simulations that will be used primarily by students for training;
- using activity logs of DSS users to build decision models and patterns.

The simulation must be DSS-like and it must provide the user with all the necessary information and tools that will ensure a documented decision. We will capitalize on our previous experience in building a DSS for enterprise financial decisions [1]. The decision making simulations must be collaborative, so we will also use as a starting point a system architecture we presented previously in [2].

In order to mine activity logs and use the models to compare decision making patterns we will elaborate an approach based on our findings presented in [3].

Therefore, the next section will show some of the research in the collaborative DSS field and the state-of-the-art references in process and decision mining. In the third section we will present some of the artifacts produced in the analysis and modeling stages of the prototype as well as the proposed architecture of EVE. In the fourth section we will discuss the methods we will implement for user activity logging, the format of the logs and the proposed mining methods. In the last section we will state our findings so far, as well as the future flow of the project.

2 Previous and Current Research

The collaborative information systems' life cycle starts with a problem statement; continues with an analysis phase; and ends with the implementation and maintenance of the fully functional system [4]. Therefore, we argue that the system does not require a specialized framework and it can be developed using existent software engineering methodologies. However, some researchers [5], and we [1], argue that a mixed approach using Unified Process and rapid prototyping can be used in order to speed up the process and increase the quality of the final deliverable product. So, we will use for this project rapid prototyping and will follow the four lifecycle phases prescribed by RUP as our approach over the software process. We will also use UML and BPMN for documenting the system and for graphical illustration of some important aspects.

In process mining there is a lot of research that aims to automatically extract workflows based on logged user activity. The domain's most influential writers are W.M.P. van der Aalst [6] and persons in the research group at the Technical University of Eindhoven. Van der Aalst defined a workflow as the depiction of the sequence of operations performed by an individual [7].

Based on existing research in process mining we proposed a new approach over the classical decision making process. A common definition for decision making argued by most influential authors [8] is that it is a process that starts with the need for a decision and ends with the choice of one decision alternative.

Corroborating the definition of decision making with the definition of workflows we argue that "a decision workflow represents the depiction of the sequential activities performed by the decision maker that start with the discovery of the need for a decision and ends with the execution of the chosen alternative" [3]. We further argue that decision workflows can be used in order to compare different decision making strategies. They can also be compared with a properly validated decision reference model in order to establish the quality of the decision process.

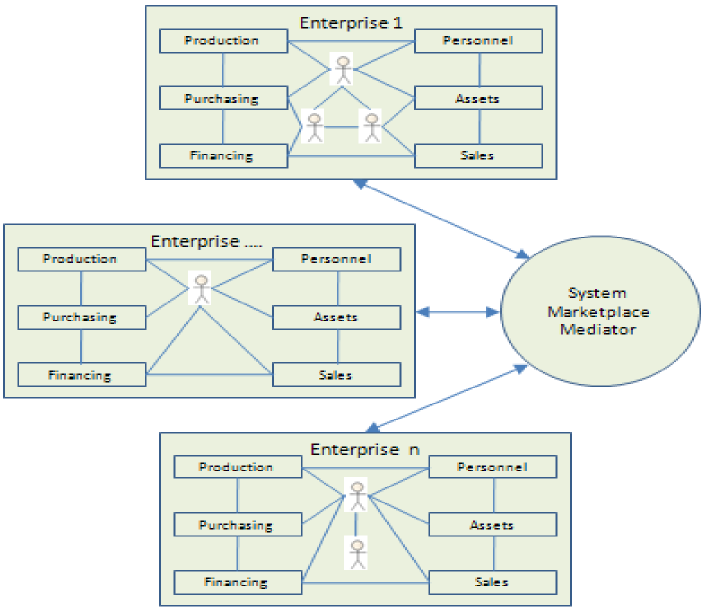

Fig. 1. Collaborative Virtual Environment

3 Analysis and Modeling of an Enterprise Virtual Environment

Since, as shown in the previous section, there are no real challenges in using one software engineering approach over the development of the system we will further introduce some of the artifacts produced in the analysis and modeling phases.

We will begin with the system's general statement: "the system aims to support collaborative decision making applied in a virtual environment. It needs to log the behavior of the decision makers so that decision patterns can be automatically created."

The virtual environment needs to be composed of virtual enterprises. The collaboration will be required at two levels: among virtual enterprises and among decision makers inside each enterprise. The environment and the collaborative decisions can be depicted as in figure 1.

It can be seen in figure 1 that each enterprise can be run by a different number of decision makers, with different abilities. For example, in the first enterprise there are three decision makers that need to collaborate since each of them is in charge of different aspects of the enterprise's activity. In another enterprise there can be only one decision maker that is deciding in all aspects of the enterprise. In another enterprise set-up there can be one decision assistant (that reviews data and presents alternatives) and a decision maker who makes the final choice based on the recommendations of the assistant.

There is also the need for cooperation among the enterprises involved in EVE. We expect the collaboration to take place as exchanges of enter-

prise's internal knowledge, information and processes but also in regard to each enterprise's view over the marketplace. The collaborative process will be enabled by the possibility of communication between the actors in the environment. All communications will go through the system and will be logged. This way we intend to capture the collaborative processes that take place between the decision makers. Mining this kind of logs will represent one of the major concerns in our future work.
The activities performed by the actors of the system are depicted using an UML use-case system level diagram. Each use-case is expanded by subdiagrams for subsequent levels of detail. The general use-case diagram can be depicted as:

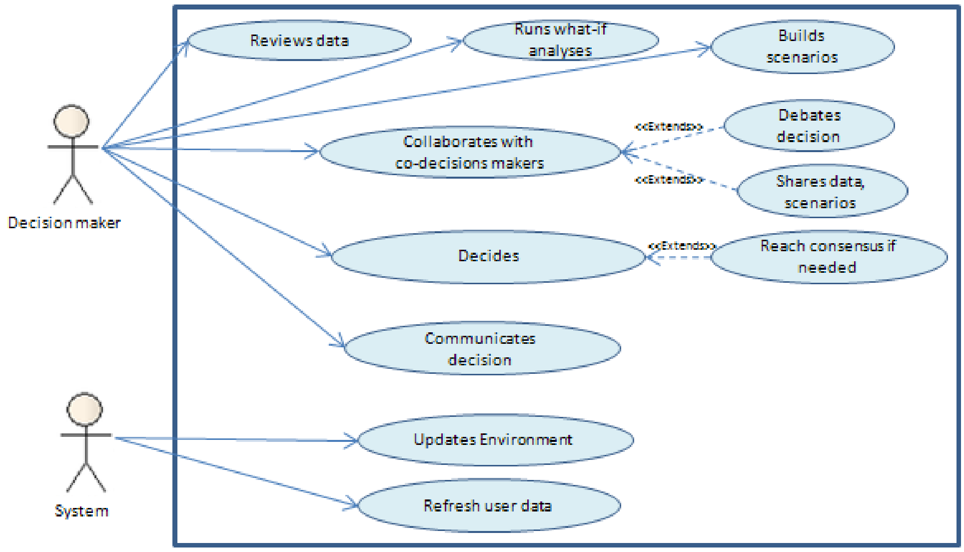

Fig. 2. General Use-Case Diagram

As depicted in figure 2, in order to document decisions the decision maker will engage in three kinds of activities review available data, run what-if analyses and build scenarios.
The available data consists of internal data belonging to the enterprise and of some view over the environment available from the marketplace. Internal data will be available from each department in the virtual enterprise. It will be presented in the system as reports originating from each department. External data will be presented as a partial view over the marketplace. It will be presented in the system either as a news bulletin originating from the marketplace or as messages and files originating from other enterprises. The user needs to review internal data, in conjunction with the view over the marketplace, in order to make informed decisions. Based on the original data, the user will be able to create new information and to extend its knowledge using what-if analyses and scenarios. Some of those tools will be embedded in the system but there also needs to be an option of creating customized queries on available data. If the enterprise has two or more decision makers, they need to collaborate in order to reach a decision. The collaboration will be aided by tools as instant messaging, file sharing or blackboards.

Our approach over the virtual environment is similar up to a certain point with Business Architecture domain as presented by OMG [9], also present in the Zachman framework [10] and subsequent derivations. The architecture aims to develop an integrated view over an existing organization quite as we are trying to develop a virtual enterprise environment. The key views of this approach are:
- business strategies;
- business capabilities;
- business processes;
- business knowledge;
- organizational overview.

What is different in our approach is that we aim to provide an overview of the: organization and the marketplace; business capabilities; business processes and, at a certain extent, over the business knowledge. Then, considering the actions of the actors involved in the virtual environment we will automatically mine mainly for the business strategy view but also, if possible, for the business knowledge. In the next section, we will provide an overview of the environment and the way we plan to use the actions of the actors to extract decision making strategies and patterns.
We also believe that our approach can benefit from multi-agent environments research domain.

The characteristics of the multi-agent systems as autonomy, local views and decentralization will be present in EVE. We aim to provide each actor with a place in one enterprise in EVE, corresponding to one decision maker in a real enterprise. Each enterprise will have its own set of resources and internal processes, therefore being autonomous. Each actor will evaluate available data for his position (all internal data of the enterprise and some view over the market), without a global view over other enterprises. There will be no super-enterprise in EVE. The market-place will be influenced by the actions of each individual enterprise and will only update available information in return. Each agent needs to develop some sort of a strategy, can collaborate with other agents and will react freely to the market developments. Each actor will communicate only through EVE, following constrains in the communication protocol imposed by the environment.

The system will be developed using a classical three tier architecture: the business logic and models tier, the presentation tier and the data/implementation tier.

In the business logic and models tier we propose the classification of the enterprise's activities in six departments, linked to one another. Those are: purchasing, production, personnel, company assets, financing, and sales. There is also the market, which is external to the enterprise but influences some of the enterprise's departments. The logical connections between the composing elements of the model are described as business rules. A business rule can be stated in regard to a process that takes place inside the organization regarding internal workflows or in regard to the enterprise's interaction with the exterior. The connections between the elements of the departments are depicted in the following figure:

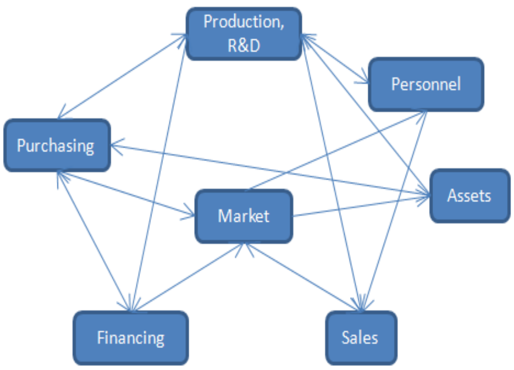

Fig. 3. Departments of an EVE Enterprise

Each element's interaction with the other elements will be described using BPMN. The BPMN diagrams will be in the end automatically converted to BPEL using available tools such as BPMN2BPEL in order to validate and execute the model.

For example, the market is the main element of EVE. It has a major role in allowing the interaction between enterprises. It can be influenced by other elements such as financing, purchasing and sales actions of the enterprises. In turn, it will influence the financing, purchasing, personnel, assets and sales indicators of the enterprise.

In order to show a partial model of interaction between the market and the enterprise's cash-flows we created the diagram from the figure 4.

EVE will be set up so that enterprises will have to compete for resources. For example, the available space for advertising will be limited. So, if the advertising requirements from the enterprises in EVE are high, the advertising price will raise and will be reflected in the advertising price/unit indicator updated by the marketplace. If the decision maker chooses to keep the same advertise budget, the result will be a decreased number of advertising units awarded to the enterprise, therefore generating a decreased well-known number of points on the market, thus leading to decreased sales. The decision maker will have to decide on how much budget to allocate to advertising, because increasing the advertising spending will upset the cash-flow balance, which in turn will lead to the need for financing and so on.

In the presentation tier we will focus on developing a user-friendly interface. However, the most challenging part of this tier will be mapping and logging each activity of the decision maker to enable automatic decision mining. This is due to the fact that most of the decision making activities take place inside the head of the decision maker. This is why we argue that, in order to enable automatic decision pattern extraction and modeling, the DSS-like interface that helps the decision maker must be build so that each mental action can be mapped to one object and therefore logged. ProM Framework is a tool that enables the mining of process models and workflows from logs. We previously used it to extract decision patterns from logs generated by modifying a DSS prototype we created [3]. There is also a tool (ProM Import Tool) that enables different types of logs to be converted to the MXML format required for input by ProM Framework. In order to enable automatic decision pattern extraction and modeling, creating a log that can be imported using ProM Import Tool is a must for the DSS simulation we are planning.

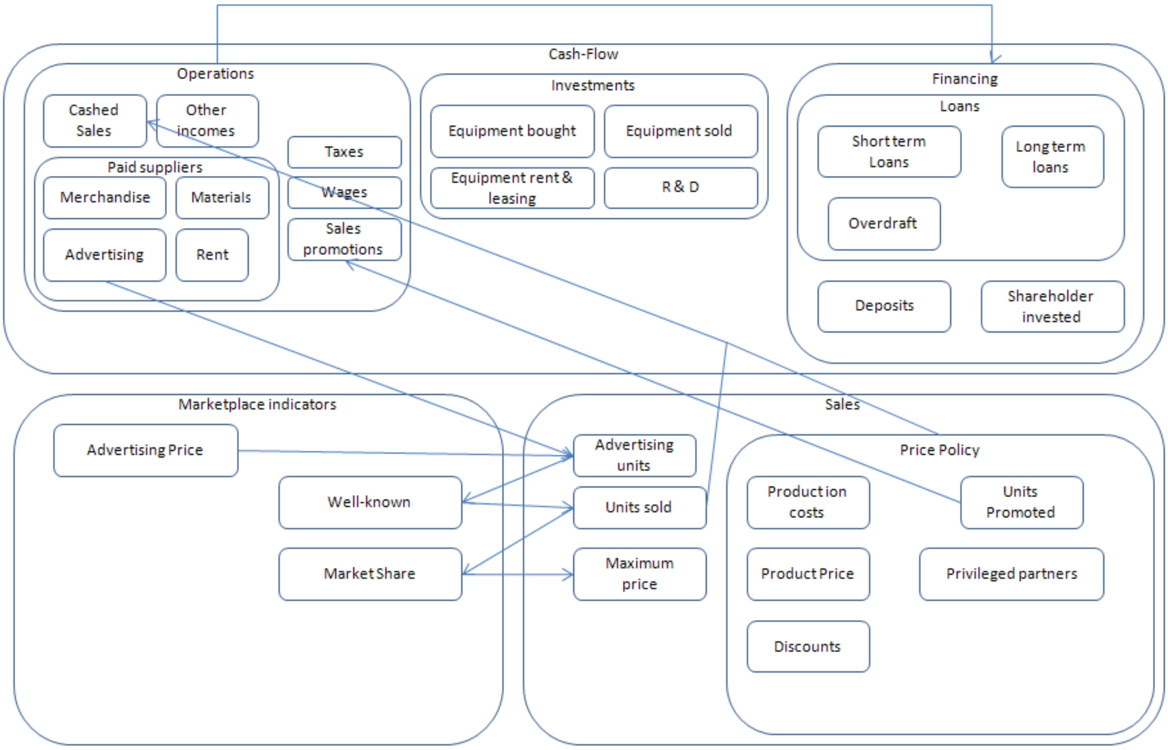

Fig. 4. Partial model of interaction between EVE elements

The data/implementation tier is yet to be established, based on the needs determined in the modeling phase. We will need an environment that will allow a client-server architecture, where a client is one of the decision makers and the server stores all enterprises' data and also acts as the marketplace, updating the decision makers' views.

4 Logging User Activity and Decision Mining

The decision makers need to reach a decision. This means indicating which option is chosen from the decision alternatives revealed after the collaborative process. If there are several decision makers, then a consensus needs to be reached. The process that leads to the decision is very important for us, therefore we modeled it in the following diagram [2].

As shown in the second section of this paper we argue that each decisional process starts with the recognition of the need for a decision. In the model shown in Fig. 5 this is considered the start point. We further modeled the Collaborative Discussion component of the diagram. The result is shown in the following diagram [2].

We believe that the model presented in Fig. 5 and Fig. 6 is a theoretical model that requires validation. Therefore, we used the DSS we previously created [1] in order to check whether the prescribed model is actually followed. This requires checking if the real-life collaborative decisions are actually following the steps presented in the model. Our findings in this regard were presented in [3]. We used three real enterprises in order to log the actions of the decision makers. We enforced on the decision makers nine different decisional situations based on the real data in each enterprise. Each decision maker was asked to use the DSS in order to research the problem at hand and to choose one decision alternative.

The actions of the decision makers were logged. This is possible only if each action of the decision maker is performed only through EVE. The logs are stored in a dedicated section of the database. Those logs will be transformed in an MXML file that can be imported into ProM Framework in order to be mined. The Entity Relationship Diagram that is recommended to be used by ProM Import tool is presented in the next section.

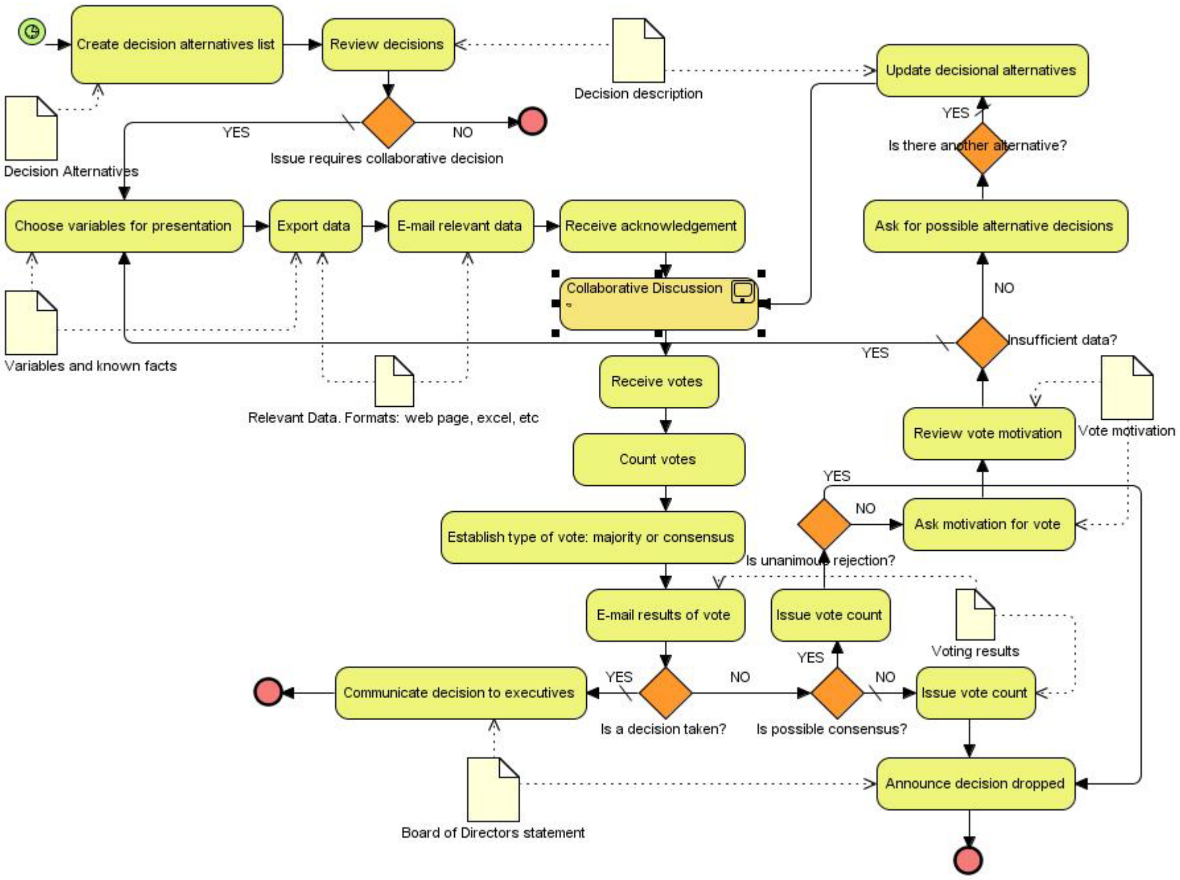

Fig. 5. Collaborative decision process

A major threat to the quality of the logs is the possibility that the users will collaborate using means that cannot be logged. The only way to prevent this is to make sure EVE offers all the necessary communication and documentation means needed all through the process of collaborative decision making.

Another threat to the quality of the logs is the occurrence of incomplete decision processes. Those will show in the logs as processes that start with the prescribed action (the identification of the need for a decision) and do not end with the "communicate decision for implementation" action. So far, those incomplete actions were avoided because we imposed structured, well defined and easy to understand decisions on the decision makers. In real life, we actually expect that a lot of decision workflows will begin but will not be finalized. This is due to the fact that the problem statement is not always clearly defined, or due to the fact that the decision maker can conclude that not all the necessary data is available. This is a major concern that will be addressed in future research by building specialized decision mining algorithms.

Once imported in ProM Framework, the logs can de manually cleaned up. As we stated before, there was no need for such an action because of the controlled test environment. However, until the creation of our specialized algorithm, we can manually clean any log generated by EVE.

The logs were then mined using three different algorithms (alpha++, fuzzy miner and heuristic miner) present in ProM Framework. Those are all algorithms designed to be used in process mining. Each algorithm employs a different method in order to identify the user's actions inside the logs and to create a sequence of the identified actions. Based on the definition we provided in section two (the decision making process is a sequence of actions of the decision maker), we argue that, so far, process mining algorithms can be employed in decision mining.

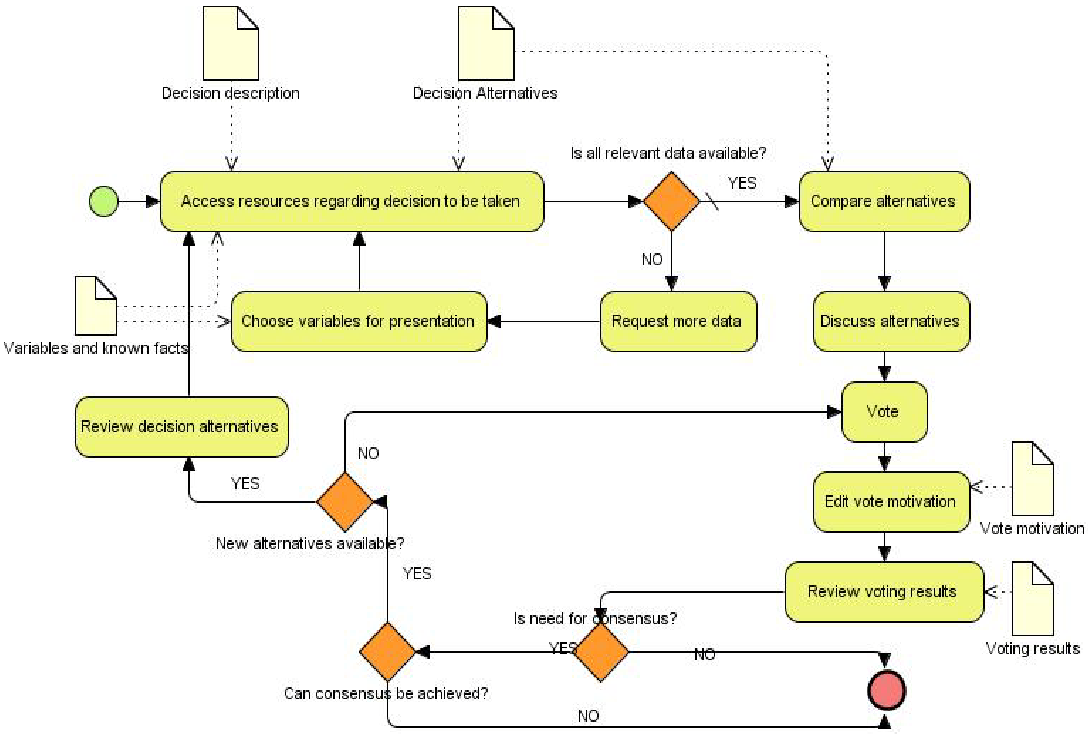

Fig. 6. Model of Collaboration

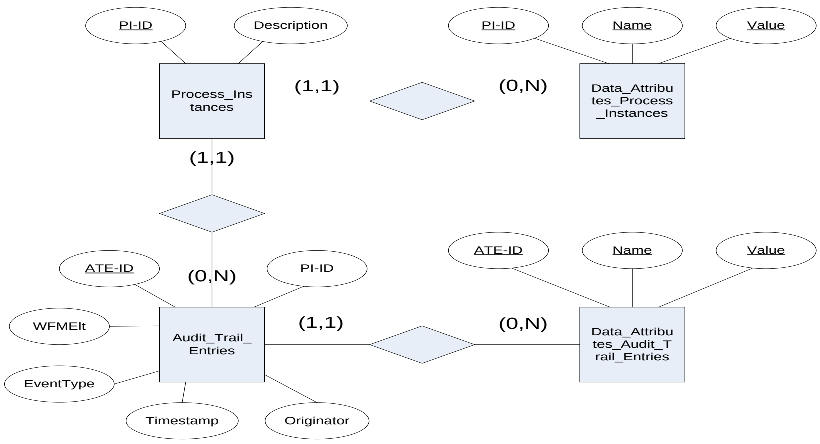

Fig. 7. ERD of Process Mining Tables

The third enterprise had two decision makers and choosing one alternative required consensus. Parts of the mined models for each decision maker are presented in the following two diagrams:

The models presented in Fig. 8 and Fig. 9 show the decision workflows (sequence of actions) performed by the two decision makers. We argue that the mined models give us an insight into the decision process. Using those models we can determine the control-flow perspective over the decisional process and also the social networks in case of collaborative decisional process.

For example, D1 used the historic cash-flow data as a starting point of his problem research. Then, he ran a cash-flow simulation, changed the initial data of the simulation and re-ran the cash-flow simulation. He then reviewed the past revenues and expenses of the company and the indicators calculated based on the P&L (Profit and Loss). On the other hand, D2 ran a cash-flow simulation, then reviewed revenues and expenses data and then ran again a cash-flow simulation without changing initial data. By comparing the two decision processes we can state that D1 was more thorough in researching and evaluating the decision context.

The social networks view over the decision process aims to show the interactions between the decision makers. We can create a model of interaction based on the lower part of the decision workflows in Fig. 8 and Fig. 9.

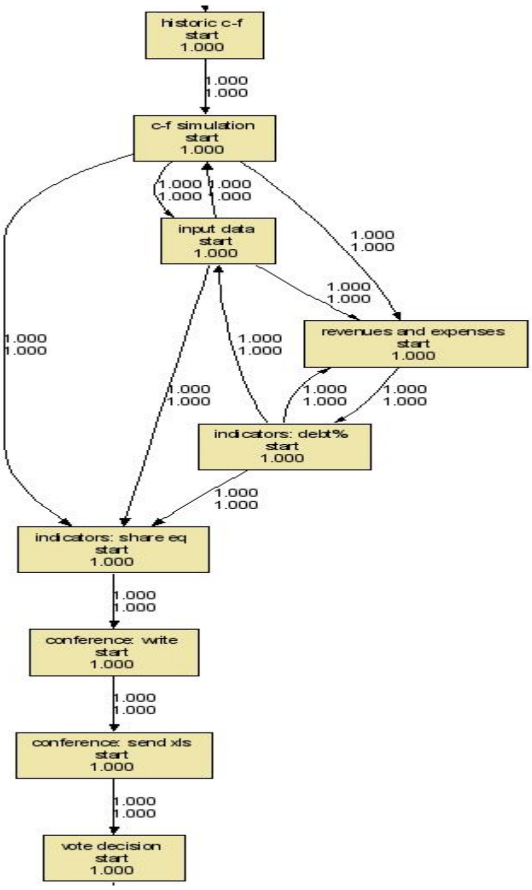

Fig. 8. Partial Decision Model for D1

We can state that there was a conference that was initiated by D1 and that then, also D1 initiated a file transfer (.xls). There was no further need for discussion because the next action was to vote the decision. We can conclude that, overall, D1 is the most influential decision maker and he is the "de facto" leader of the company.

In order to validate the theoretical model proposed in Fig. 5 and Fig. 6 we need to match it with enough mined models. The four models mined so far are relevant only in a small percentage due to the fact that they were obtained using a modified DSS that was not created primarily for logging decisional behavior. It is obvious that the decision makers are confined within the tools provided by the DSS and cannot exhibit their full decision making strategies. Even further, the DSS we used was initially developed for a single decision maker use [1], so the collaboration between the decision makers in the third enterprise is limited to an add-on of the original system. However, even with the aforementioned limitations, we can observe some similarities with the theoretical model both in the documentation stage and in the collaboration part of the diagram. We must use EVE in order to log more actions from an increased number of users before we can proceed to the next step of creating decision reference models.

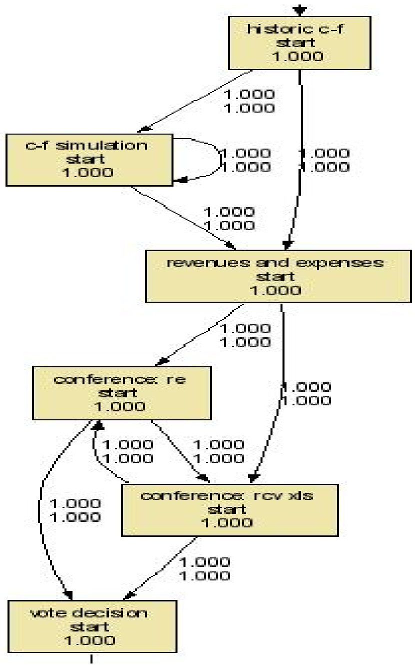

Fig. 9. Partial Decision Model for D2

5 Conclusions

Our research is focused on two main directions. The first one is creating a DSS-like enterprise virtual environment that will be used to simulate decision situations. The second one is automatic mining of decision models and patterns based on user activity logs. This paper addresses both directions by arguing some aspects of the analysis and modeling stages of an Enterprise Virtual Environment that will allow the logging of decisional behavior of the participants.

In the first part of the paper we argue that the software process that needs to be employed for the project must be a mixed approach based on prototyping and RUP. Then, we argue the general approach over the virtual environment. We believe it must contain virtual enterprises that interact with each other within the system's boundaries. There needs to be different types of internal decision set-ups inside the enterprises (e.g. enterprises with: one decision maker; several decision makers with different weights; several decision makers that require consensus; decision makers and decision advisors). We follow up with the general use-case diagram of the system that depicts the decision maker's major interactions with the system. We also introduce the internal structure of the environment. We intend to use six de-

partments in every enterprise, linked to one another (purchasing, production, personnel, company assets, financing, and sales). One example of how several elements in the enterprise departments will influence each other and will also influence and receive influences from the environment is provided.
The next section is dedicated to the decision mining. Basically, we argue that the decision process is a workflow (a sequence of activities) and that, based on the logged user interactions with the system, a decision model can be mined using various algorithms. We show the entities that need to be implemented in order to log the user activity. We also show a prescriptive collaborative decision process. We follow up with an overview of the first experiments in decision modeling in order to validate our approach.
In this paper, we intended to give arguments regarding the choices we made so far in the modeling of the proposed virtual environment. The creation of such software and the software process is not an innovative research direction. The new elements are: the actual model we developed; and the integration of the DSS tools with the approach on the enterprise's environment simulation.
We also want to argue our new approach over decision mining. This is a new research direction that aims to explain the decision process based on what the decision maker is actually doing when using the software. What we want to achieve is a large number of logged decision behaviors in the simulated environment that can be exploited by mining decision patterns and models. If enough models are mined and if the patterns are similar, then we can create reference models for that decisional situation. The models can later be used in conjunction with an evaluation of decision effectiveness.
One other higher purpose of this research is to promote our beliefs that using decision mining and a carefully designed system we can turn cision maker's implicit knowledge into explicit knowledge that can be captured, reviewed, plained and compared.

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