Decision support for resource management in the construction industry

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L. Baxevanaki & S. Argyrou
Intracom S. A., Hellenic Telecommunications & Electronic Industry, Greece

K. Menzel & K. Eisenblätter
Dresden University of Technology, Applied Computer Sciences in Civil Engineering, Germany

S. Tretjakov
Helsinki University of Technology, Industrial IT Laboratory, Finland

G. Stalidis
Pouliadis Associates Corp., Research & Development, Thessaloniki, Greece

ABSTRACT: The management of resources is an essential task in every construction company. In order to follow their line of business they need to acquire and exploit resources that may be equipment, materials or services. To determine an appropriate resource, an extensive set of parameters has to be taken into account that can be subjectively selected and weighted. Today, ERP systems and e-Business systems are available to assist construction companies in resource management within the company, but they can not prevent the company from having idle resources. Having idle resources, resulting from e. g. unforeseen occurrences, are serious cost for the company due to the resource's fixed expenses. Companies should have an alternative solution to exploit these expensive resources and compensate their fixed expenses, but also have them available at the time they will need them for their own interest. So, they require a quick and flexible way of leasing any kind of resource for a certain time period to companies of possibly the same line of business. This paper outlines the approach taken by the EU funded project "e-Sharing" (EU-IST-2001-33325) to support resource management decisions within a construction company. It will describe requirements for resource management, as the architecture of the extended B2B platform and its core components, the decision support system and the enterprise integration system.

1 INTRODUCTION

Today's construction industry is characterized by a very tough competition for construction projects resulting in severe price cuts and short construction times. By reducing their costs and improving the quality of their services construction companies attempt to meet the challenges of this competition. Therefore, an efficient resource management plays a significant role because it holds potentials in cutting the cost incurred by the construction companies. There are mainly two objectives that have to be achieved:

1 Efficient resource management decisions to allocate the most suitable company resource to a specific task and
2 Reduction of idle resources within the company vis-à-vis the cost of these idle resources.

The process of allocating companies resources to a specific task that has to be carried out for the construction of a building or any other structure is quite demanding requiring some experience on it in order to be efficient. For the allocation of a resource to a task, he has to consider several aspects such as technical capabilities of the resource, the needed amount, availability, proximity, associated resources, time and costs. But also, he should be aware of alternative ways or resources with which the same task can be carried out. As one can see, many aspects have to be taken into account for an appropriate decision to be reached on which resource to be used.

Today's IT market for the construction industry offers different enterprise resource systems (ERPs) that assist the construction companies in their resource management decisions within the company and accelerate the supply chain. As these systems take into account only the companies' own resource pool they can not prevent the company from having idle resources. But if these idle resources could be offered to other companies or offers of idle resources from other companies can be taken into account, much more economical decision could be arrived at. Therefore, a shared pool of resources with idle resources from several construction companies is needed, as well as decision support on whether it is economically wise to use the companies own resources or to lease or buy resources from another company.

The objective of this paper is to introduce the e-Sharing idea on how idle resources of a construction company can be reduced. In Chapter 2, requirements for resource management will be discussed, before

the idea of e-Sharing will be introduced in Chapter 3. Chapter 4 however tackles the approach taken within the e-Sharing project to support efficient management decisions and reduce idle resources. The resource type model will be described, followed by the architecture of the extended B2B platform, the decision support system and the enterprise integration system. The use of data mining, OLAP and software agents will be outlined.

2 REQUIREMENTS FOR RESOURCE MANAGEMENT

The allocation of resources is a very cost critical process for construction companies that requires some experience on the part of the resource or project manager. The process can become very complex due to multiple possibilities and several parameters that have to be taken into account and can be subjectively selected and weighted. This chapter outlines some of the relevant aspects in resource management and thus, should be considered in e-Sharing.

The demand for a resource can arise on a

- long term notice, mostly from the pre-construction planning stage or
- short term notice due to some unforeseen occurrences.

If the demand for a resource can be predicted some reasonable time before its usage, the decision process can last longer and allow a more carefully carried out check of the available resources. Company's own resources can be booked in advance, required resources can be leased or bought from others after several offers have been considered and evaluated. The participation in submissions or auctions is possible. But often times demands for a resource arise suddenly, in such sudden cases the construction manager has often within a day or two to allocate the needed resources. Since the time constraint is very strict, the participation in submissions or auctions is not practicable, moreover the availability of suitable resources has to be checked right on the spot, on the site, in the office or wherever the need may have arisen.

Due to different time frames for the allocation of resources, different means to allocate resources are possible and thus, should be offered by the e-Sharing system. For example, the e-Sharing system should include functions such as "Search for offered resources", "Place resource offer", "Negotiate resource offer", "Participate at auctions" and "Initiate auction" etc. Furthermore, these functionalities should be accessible easily from different locations and by different means such as mobile clients useable on site or office clients for usage in the office.

Resources belong to a specific category of resource and each category is further comprised of specific types. The main two categories of resources of construction companies can be regarded as equipment and services (as a form of subcontracting) as pointed out in conducted interviews. There are other resources that play a role depending on company size and line of business, such as materials, construction site trailors, warehouse spaces etc. Two categories of equipment should be distinguished:

- Material/substantial resources
- Service related resources.

Interviews, conducted mainly in construction SMEs, pointed out that for example equipment depending on the type, its uniqueness and size remains idle for 50% of the time of the year, whereas human resources remain idle for 5 to 10% of the time of the year depending strongly on the season. The companies mentioned that about 5 to 20% of the demand for construction equipment or human resources or services can not be covered by their own available resources. There are three different means to acquire resources: using own resources that are available or could be removed or withdrawn from another project, leasing resources or buying them.

Equipment can be leased and bought time-oriented, services are mostly hired goal-oriented or time-oriented. Equipment can have associated resources which are imperative to its own functionality, for example an operator that is required to operate a crane, workers that are needed to set-up or maintain crane. For an accomplished service guarantee has to be given for a timeframe.

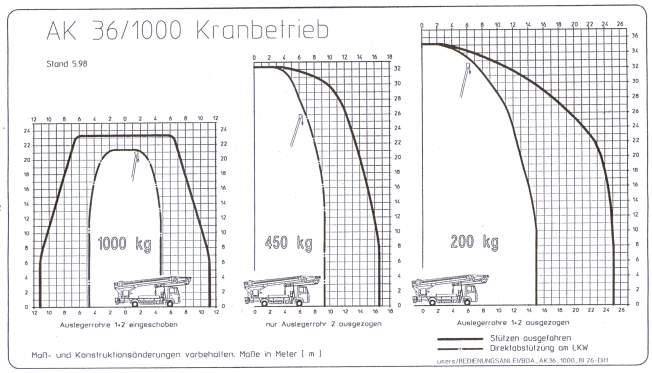

Figure 1. Load/Distance ratio diagrams.

Equipment is described by its technical capabilities, whereby the textual information should be accompanied by some graphical data such as diagrams in the case of cranes as shown in figure 1. Furthermore, the resource manager needs information on costs that will arise from the set-up, the maintenance and the operation of the equipment. Human resources are specified by their skills, experience and quality of work, where as services are often specified by the workload that has be performed.

The existence of different types and categories of resources should be considered within the e-Sharing frame by the development of an appropriate resource type model.

The decisions on which resource to use, is derived from the consideration of several parameters who's importance are ranked depending on the resource type and project constraints. They are mainly:

- technical capabilities, performance and reliability,
- costs for acquisition and usage,
- associated resources,
- availability,
- proximity and
- time.

In summary, the e-Sharing system should take into account the just mentioned requirements for resource management in such a way that it will provide:

- different means for "fast" and "slow" allocation of resources,
- the appropriate support of resource categories and types providing the user and the system with all information needed to make decisions,
- the needed set of parameters,
- some decision support on the best suitable resource available.

Furthermore, the system should assist the user in his decision on which resource to use and on whether to use own resources or resources from other companies.

In the next chapter the objectives of the e-Sharing project will be sketched, as well as its architecture, the resource type model and the components: decisions support system and enterprise integration system.

3 THE E-SHARING PROJECT

3.1 *Objectives*

The main objective of the e-Sharing is to design, develop and evaluate a service provided by a third party for the efficient management and allocation of resources with enabling resource sharing within different companies.

Resources shared through e-Sharing can be of varying types ranging from equipment, human services, buildings to warehouse space etc., described by a resource type model that will be designed in the e-Sharing framework. The e-Sharing target is to provide an intelligent decision support system to companies letting them describe the tasks they need to accomplish and proposing to them the use of a combination of resources for the accomplishment of the described tasks. The suggested resources are selected from a virtual shared resource pool that includes the company-user's own available resources and the idle resources that have been declared in e-Sharing system by other company-users. The selection of the resources is based on several factors such as productivity, leasing costs, functional costs, possession costs, time constraints etc. E-Sharing aims at assisting the company-users in deciding whether to lease resources or use their own and in providing for an alternative channel for the enterprises to exploit expensive and rare resources when they remain idle.

3.2 *Technology*

E-Sharing will introduce an extended model of a B2B marketplace where the interested parties, apart from the owner of the B2B e-marketplace, are the Lessors and the Lessees. This new model introduces the Lessors, enterprises that wish to lease to any interested party any kind of resources for a given time period. The Lessees are the enterprises that wish to lease from another company resources for a given time period. E-Sharing will make use of technologies such as XML, intelligent software agents, mobile agents, data mining and OLAP.

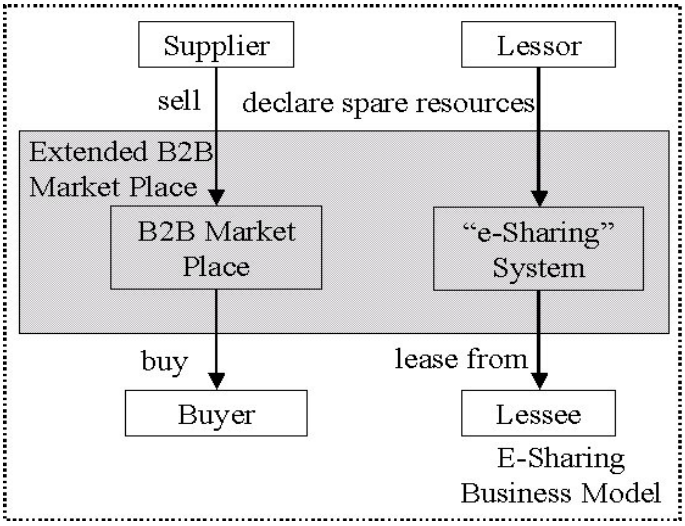

Figure 2. Extended B2B platform.

3.3 *Benefits to the user*

The users that will act as the Lessors will be able to use the e-Sharing as an alternative channel for leasing their idle resources and compensating for the resource fixed expenses.

The users that will act as the Lessees will be able to use an alternative source for leasing resources in a faster and cheaper way, to explore whether the solution of leasing resources is more cost effective than using one's own resources and to raise the availability of rare and expensive resources.

4 METHODOLOGICAL APPROACH

4.1 *Resource Type Model*

The objective of the resource type model is to provide an appropriate means of depicting different re-

source categories and types, together with their attributes and relationships to one another.

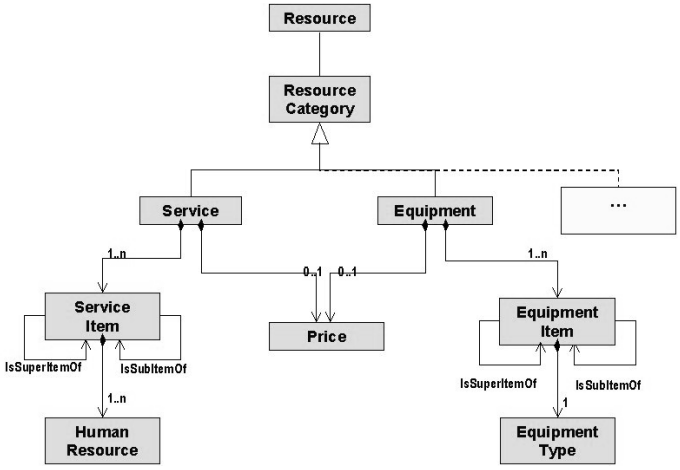

Figure 3. Resource type model.

As stated, there are for example, equipment and human resources, these would be two categories of resources. Each category can be composed of several types, for example cranes, diggers and grinders, all belong to the category equipment, but stand as different types. Therefore, the resource type model should allow the classification of resources. The hierarchy should be flexible and take all possible resources into account, we propose therefore that the standardized, domain-specific classification in the BGL2001/Eurolist should be relied upon.

The objective of the Eurolist is to provide the basis for national lists of construction equipment in order to harmonize standards for construction equipment in Europe. The Eurolist is a joint initiative of the German and French construction industry. The BGL 2001 is the German national list of construction equipment, containing technical and financial information about construction equipment. The construction equipment are classified into 24 main groups (Deutsche Bauindustrie).

Each resource should be described horizontally and vertically. In which vertically means to classify the specific resource item to a defined resource type and horizontally means to give the specific attribute values of the resource. The attributes for each resource type, at least for equipment, should be derived from the ones used Eurolist and extended if needed.

4.2 *The e-Sharing extended B2B platform*

4.2.1 *Functional architecture*

The functional architecture of the e-Sharing is based on the 4-tiers architecture that is proposed by the Java 2 Platform Enterprise Edition (J2EE). The four tiers that are being described in this architecture are:

- the Client tier from the client side,
- the Interface tier from the server side,
- the Business Logic tier and

the Persistence Storage tier.

The client tier is responsible for prompting for user input, for validating the user input, for interpreting the user actions, for communicating with the server (to send requests or to receive responses) and finally for presenting the results to the client. The interface tier manages the interaction between web clients and the application's business logic and the business logic tier implements all the business logic that is required by the e-Sharing system. Finally the persistence storage tier stores all permanent data.

4.2.2 *Physical architecture*

Concerning the physical architecture, there will be a so-called e-Sharing server that stores all necessary data. Users will be able to use the e-Sharing services through PC clients connected to a corporate network and access to the e-Sharing server through the Internet. The e-Sharing server will also be accessible through mobile clients, such as mobile phones or PDAs, connected through GPRS, UMTS or through a wireless network.

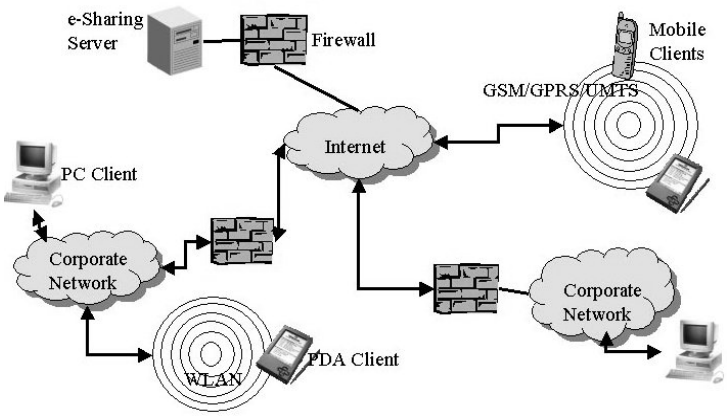

Figure 3. Physical architecture.

4.2.3 *Functionality*

The e-Sharing system will provide quite a number of functionalities in order for the users to have a more efficient management of their resources. The functional components are:

- Auctioning Manager: enables the user to organize an auction for leasing their idle resources.
- Bidder Agent: places bids on behalf of the lessee, with the intention to win the auction according to the rules set by the potential lessee.
- Negotiation Requests Manager: allow the lessor to accept/deny negotiation requests and the lessee to create a negotiation request, to accept/deny an offer or to create a new quotation.

– Matching Agent: acts on behalf of the user that have created a request for resources and generate lists of offered resources that match with the specific request. The system helps the user to decide which resource is more effective and appropriate for him according to his criteria.
– Requests Manager: enables the lessee to create requests by defining either the resource he needs or the task he wants to accomplish. The system will propose to the user a combination of resources for the accomplishment of the described tasks through an intelligent decision support engine that will be developed.
– Offered Resources Manager: lets the lessee to search for offered resources and to create offers for resources manually or via the company's internal system. It also lets the lessor to search for own idle resources and helps the lessor to decide if it is more effective to keep the idle resource or to lease it.
– OLAP Reports: provide information about a resource after analyzing the resource's specific characteristics through multidimensional calculations.

The functional components mentioned above denote that the user of the e-Sharing system will be able to take easily some decisions regarding his resources.

4.3 *Decision Support System*

Leasing of company's resources to another company when these remain idle or leasing from another company instead of owning a resource, are both business decisions that can become very complex. The benefits in cost reductions are not always easy to determine and multiple choices in matching offers with requests may exist that are not easily comparable. Moreover, an extensive set of parameters may be taken into account (e.g. quality of equipment, uniqueness) that can be subjectively selected and weighted.

It is thus evident that the "operational" e-Sharing platform, which manages and delivers resource information, offers and requests, actor information and matching suggestions, is only one aspect of the solution. An additional "analytical" part is envisaged, which is capable of intelligent processing of multidimensional data, in order to optimize the benefit of the users. More specifically, e-Sharing comprises Decision Support System (DSS) components

– for suggestion to use a specific combination of resources for the accomplishment of a described task. The suggested resources are selected from a shared virtual resource pool that includes the company-user's idle resources;
– for analyzing resource behavior and
– for driving conclusions on their productivity, functional costs and other parameters that affect their selection.

The DSS capabilities are intended to enhance the effectiveness of the system and to assist its users maximizing the benefit therein two ways. Firstly, by processing complex data and providing intelligent suggestions for leasing decisions, based on quantitative estimations that are not easily done by the user. In this way, ranking of options according to complex criteria are readily available. Secondly, by accessing ERP and historical data and discovering hidden patterns and relationships. Future decisions can then be taken with the aid of additional information.

The e-Sharing DSS is planned to be implemented as a set of intelligent agents, each acting on behalf of a lessee, searching for the most effective resource sharing solution. Furthermore, data mining and OLAP technologies will be explored for the processing of complex data and driving conclusions.

4.3.1 *Data Mining and OLAP*

Two different techniques will be explored within e-Sharing pilots for decision support purposes, namely data mining and on-line analytical processing (OLAP).

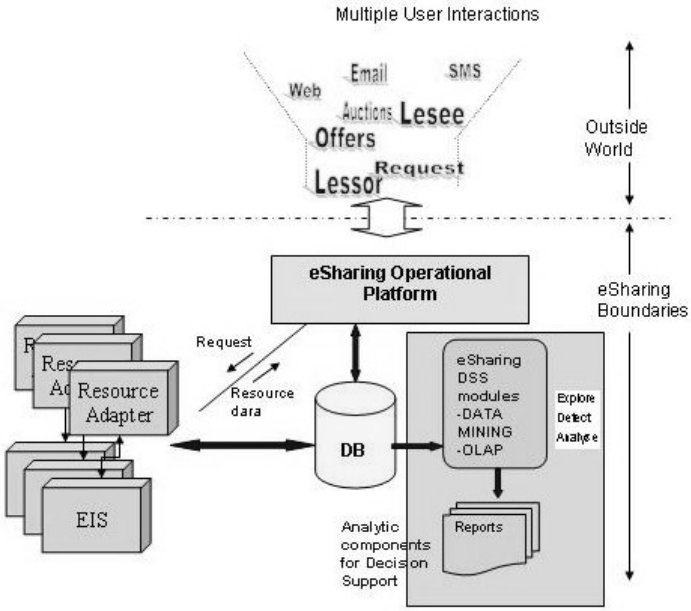

Figure 5. OLAP within the e-Sharing platform.

Data mining is the analysis of data for relationships that have not previously been discovered. The data mining process involves processing of immense amount of data in order to

– automate prediction of trends and behaviors and
– automate discovery of previously unknown patterns.

The results of data mining include

– associations, when one event can be correlated to another event,
– sequences, when one event leading to another later event,

– recognition and classification of patterns into meaningful categories,
– clustering, that is finding and visualizing groups of facts not previously known and
– forecasting, or simply discovering patterns in the data that can lead to predictions about the future.

Currently, data mining is used by companies in many areas including retailers, telecommunication companies, car manufacturers etc.

OLAP enables a user to easily and selectively extract and view data from different points-of-view. To facilitate this kind of analysis, OLAP data is stored in a "multidimensional" database. Whereas a relational database can be thought of as two-dimensional, a multidimensional database considers each data attribute (such as product, geographic sales region, and time period) as a separate "dimension." OLAP software can locate the intersection of dimensions and display them. OLAP can be used for the discovery of previously undiscovered relationships between data items.

The Data Mining and OLAP techniques will be employed in e-Sharing on trial basis. The exact target goals, the parameters to be used, the dimensions of search spaces and the configuration of reports will be defined according to the available data in the pilot applications. The initial definitions will result from joint work by users and DSS experts and will be available for implementation for the final prototype. For the designing purposes, the data schemes and example data from the initial prototype will be used. The focus of the scenarios will be to assist a lessee in choosing whether to lease or use its own resources, as well as which is the most appropriate combination of resources for the accomplishment of the described task. For this purpose, previous use patterns, resource profiles and estimations of cost will be used as input. Useful data will be imported by companies ERP systems, historical data on e-Sharing usage will be kept and special fields on the transactions will be used. It is clear that a critical issue for the success of the approach is the size and quality of the input data. An initial phase of system operation, during which usage data will be collected, is thus necessary before data mining techniques will be able to produce meaningful results. Data processing schemes will be continuously adapted to the actual data during pilot trials and the success of the Decision Support services will be used as feedback for fine-tuning of the methods. It is expected that valuable conclusions on the potential of decision support techniques for resource management will be derived and usable system components will result from prototype implementation.

4.3.2 *Software agents*

E-Sharing will use the software agents technology in two ways, for resource-offer match making in the kind of intelligent decision support system and for the implementation of the interface with the companies ERPs.

The Decision Support System (DSS) is supposed to be used in e-Sharing application to enable companies efficiently describe the tasks they need to accomplish and provide suggestions to them in using a combination of resources for the accomplishment of the described task. The suggested resources are selected from a shared virtual resource pool that includes the company-user's idle resources. The e-Sharing DSS is planned to be implemented as a set of intelligent agents, each acting on behalf of a lessee, searching for the most effective resource sharing solution.

The intelligent agent can be defined as a software entity that carries out some set of operations on behalf of a user, with a degree of independence or autonomy, and in so doing, employ some knowledge or representation of the user's goals or desires.

Artificial intelligence (AI) that is possessed by intelligent agent is the imitation of human intelligence by mechanical means. Clients, then, can reduce human workload by delegating to intelligent agent tasks that normally would require human-like intelligence. Many researchers that formerly referred to their work as AI are now actively engaged in "agent technology". Thus the word "agent" itself generally connotes intelligent agent in the terms of the present-day research community.

Basically, the intelligent agent can perform the following set of standard tasks (Farhoodi 1997):

– send and receive information to and from other agents using appropriate protocols (sensing and communication) - this requires communication services that support message queue management, asynchronous messaging and content-based routing of messages.
– generate multiple objectives, goals and plans for itself and other agents, process information received and perform reasoning (e.g. inferencing, synthesis and analysis) - these require services that support rich knowledge representation schemes (e.g. for Rules and Objects), alternative logics (e.g. fuzzy logic, temporal logic, Bayesian logic), alternative inferencing strategies (forward, backward, opportunistic), planning (plan generation, plan execution, and plan repair), and concurrent operations.
– maintain explicit belief models of itself and other agents and can reason with incomplete, inconsistent and uncertain information. This requires support for belief revision (e.g. Truth Maintenance).
– have a set of capabilities (which can change dynamically) - i.e. the tasks it can perform - and can reason about its own and other agents capabilities and skills (e.g. planning, inferencing, communication and negotiation). This requires a task specification language, and mechanisms that sup-

port 'learning' (e.g. Explanation-based learning, Induction).
- assume roles and perform tasks and execute physical and non-physical actions - actions can result in events which in turn may trigger other actions and processes (in this context a process is analogous to a plan and consists of a pre-defined, temporally ordered, set of activities which are designed to achieve a given goal). This requires task selection and task execution mechanisms.
- engage in complex interactions with each other, such as negotiation and task delegation. This requires support for interaction protocols (e.g. Contracting, Conflict Resolution, Resource Allocation). Knowledge Query Manipulation Language (KQML) is the de facto standard for designing inter-agent interaction protocols.
- dynamically join or leave groupings or organizations - organization may be functional or social. This requires support for specification of organizational structure, organizational procedures/rules, and roles/responsibilities.
- have its own internal architecture (e.g. Blackboard, Actor or Stimulus/Response). This requires different architectural specifications and alternative control algorithms.
- explain its reasoning in terms of 'how' and 'why'. This requires explanation mechanisms.

Because in DSS the intelligent agent must work in cooperation with the human-user of e-Sharing system we can define it as a user agent which performs the following tasks: assists user; knows his/her interests, preferences, habits; may act on user's behalf.
The "intelligence" for this user agent can be provided in three different ways (Maes):

1 User programmed. Person must provide the rules and criteria for agent's behavior directly. This way is simplest, not very "smart", relies on user's programming skills and commercially available.
2 AI engineered. Created by traditional, knowledge-based AI techniques. This way is very complex, "smart", requires knowledge engineer to program an agent and not commercially available yet.
3 Learning agent – "program itself". Agent detects patterns in user's actions and among users and exploits them. This way is of medium complexity, "smart" in key areas where user concentrates and its beginning to become commercially available.

Of course, each way has both strong and weak sides and to achieve the best result it is possible to use combined way for providing the "intelligence" to agent taking into account only strong sides of each basic approach.

The "combined" way will give agent the access to *background knowledge*, which is available and general; allow *user to program* the agent, especially when the agent is new or drastic changes occur in user's behavior; *agent learns* to adapt and suggest changes. This "combined" way is seems to be the most suitable for intelligent agents in DSS of e-Sharing system as the peak of each basic "intelligence"-providing technique.

4.4 *Auctioning and Negotiations Support*

The e-Sharing system will provide auctions and negotiations services. A lessor will be able to organize an auction and select the type of the auction that he prefers or to authorize an auctioneer agent to start or close an auction, to accept bids and to decide whether there is a winner in auction and who this winner is. A lessee will be able to participate to an auction, to place bids to resources that is interested in, or to authorize a bidder agent which gets informed about the bids of other bidders and the status of an auction, places bids with the intention the lessee to win the auction according to the rules set by the potential lessee.

The e-Sharing system will enable the lessees to create a negotiation request, to accept or deny an offer, to create a new quotation. The system also enables the lessors to accept or deny negotiation requests made by potential lessees and to make new quotations. The e-Sharing will provide a negotiation agent that will be responsible for setting the rules for negotiating over offered resources and this component will be get informed about the counter-offers, the acceptance or denial of quotations.

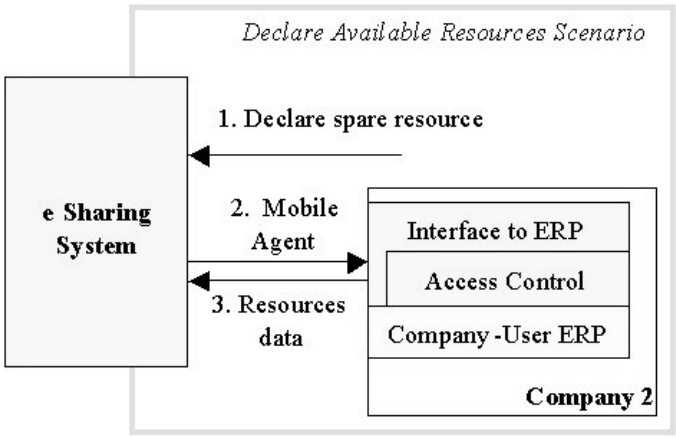

Figure 6. e-Sharing system interaction with companies ERP systems.

4.5 *Enterprise Information Systems Interfaces*

The integration of e-Sharing system with the companies ERPs is needed in order to extract information from the companies ERPs and support decisions having to do with whether to lease resources or use their own. Figure below depicts the interaction be-

tween the e-Sharing system and the companies ERP systems.

All the set of interfaces that exists in modern ERPs can be divided onto six main groups according to the type of system to be served:

1 Legacy systems. Purpose is the exchange of archived financial data stored in the old formats.
2 Client-server systems. Purpose is the automation of sales data processing and report preparation.
3 Other ERP systems. Purpose is the transaction of data exchange with the specialized systems.
4 Data storages. Purpose is the exchange of huge data volumes from archived reports and of information for decision-making.
5 External interfaces for connection with business partners. Purpose is the transaction data exchange including the buy-sell operations with EDI and EFT protocols support.
6 External interfaces for Internet access. Purpose is to get access to the customer information and Internet accessed databases.

But as usual the certain ERP has the subset of all possible interfaces only and sometimes these interfaces don't fit for our needs. For example, Baan ERP system has 2 interfaces: DDC (Distributed Data Collection) for online integration of different systems and data exchange between them, which is based on DCOM technology from Microsoft; and BOI (Business Object Interface) that provides an API to specific pieces of functionality of Baan ERP, which is based on COM technology.

SAP ArchiveLink interface is a component of the R/3 System used to link optical archives and document management systems with SAP's R/3 System. The interface is based technically on standard HTTP and on SAP's RFC (Remote Function Call) technology. SAP DCOM Connector unites the SAP Business Framework with the Windows platform by allowing developers to access R/3 data as DCOM objects.

It is visible that existing interfaces of leading ERPs are targeted nowadays basically to Windows platform and since the J2EE platform is chosen for e-Sharing development to work in any operating system, we are unable to use them directly. But at the same time, there are interfaces to the existing ERPs from the side of application servers. Since we are focused on J2EE platform we consider the usage of both Web-centric approach (web tier components communicate directly to the ERP resources) and EJB-centric approach (EJB tier components encapsulate EIS resources and provide connection to them by means of connectors (Sun Inc.)) in e-Sharing application.

5 SUMMARY

Today's construction companies can optimize on their resource management in order to reduce costs. The paper presents the idea of the e-Sharing project in which the above mentioned intention can be achieved by better made decisions and by reducing the presence of idle resources.

E-Sharing will provide the required functionality for resource management in the office and on site by an extended B2B platform for lessee and lessor functionalities. The architecture is a four-tier-architecture with components such as decision support system and enterprise integration system. E-Sharing will make use of technologies such as XML, intelligent software agents, mobile agents, data mining and OLAP. The e-Sharing approach will be validated by trials conducted within three construction companies in Greece and in Germany.

6 ACKNOWLEDGEMENTS

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