Mask-Co: Multi-Agent System Based Knowledge Management System to Facilitate Knowledge Sharing in Construction Organization Environment

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***Abstract*- Multi-agent system based knowledge Management system construction organization environment (MASK-CO) is a set of agents, software and technology designed to focus and enhance the communication, deliberations, and decision-making of groups. MASK-CO is successful in improving the efficiency, reliability and quality of the group decision-making process. Knowledge management (KM) has received considerable attention in recent years. Some consider knowledge the most strategically important resource, and learning the most strategically important capability for business organizations. Major construction organizations have recognized the benefits that KM can offer and have thus invested in KM. This paper reports on a survey of these companies. The purpose of the survey was: (1) to examine the importance of KM to construction organizations; (2) to investigate the resources used to implement KM strategies. The survey found that the main reasons for implementing a KM strategy was the need to share the tacit knowledge of key employees and to disseminate best practice. In addition, significant resources in terms of staff time and money were being invested in KM. In order to resolve the problems in construction organization and promote the performance of construction organization, a MASK-CO is designed based on Prometheus Design Tool (PDT).**

Keywords- construction organizations, knowledge management, knowledge management system, multi-agent system, and Prometheus Design Tool.

I INTRODUCTION

CO (MAS architecture to facilitate knowledge sharing in construction organization environment) is Architecture aims to provide facilitating knowledge sharing, supporting the system users to successful access to the system resources.

This techniques was inspired by the "there is lack of Architecture of MAS-Based KMS in order to product the sharing of knowledge in construction organization (MASK-COArchitecture)". As well as "lack of decision-making process, users do not know what they need, lack of trust, lack of change management, lack of risk assessment and

failure to learn from successful projects" and also" there is inconsistency of MAS using in test of its functionality", the MASK-CO model has been developed to solve this problem. The main goal of this paper is to design, develop and applying MAS techniques-based KMS in a collaborative environment of lotus notes to facilitate knowledge sharing of CO among the users.

The paper, therefore, investigates the approach adopted by construction organizations in three areas: (1) the importance of KM to the organization; (2) the resources used to implement a KM strategy; and (3) the barriers to managing knowledge within individual organizations. The first area (importance of KM) investigates how widespread proactive KM is within the construction sector. The second area (resources allocated to implementing the KM strategy) provides an insight into the type of infrastructure used to support the KM strategy. The third area (barriers to KM within organizations) identifies problem areas that need to be addressed for KM activities to bring about tangible behavioral and performance improvement.

The construction industry is facing many of the same problems as the software industry. The problems are that projects often run late, cost increases and, in many cases, results in failure. Construction projects are among the most complicated of the human enterprises. There is a high level of skill and knowledge required to translate a client's version or list of requirements into plans and specifications and then into a real building that functions well for the people who will live or work there.

Besides technical skills required in construction projects, it is also important to have people skills in order to coordinate the diverse efforts of the many people involved. There are inevitable problems encountered in the course of a construction project.

The emergence of the knowledge economy means that organizations' know how is becoming more important than traditional sources of economic power (Scarborough and Swan, 1999). Moreover, knowledge is now considered the most strategically important resource, and learning the most strategically important capability for business organizations (Zack, 1999). Thus, knowledge assets must be managed deliberately, systematically and with expertise to ensure corporate survival.

Two types of knowledge are widely accepted: tacit knowledge and explicit knowledge (Nonaka, 1991; Nonaka & Takeuchi, 1995). Tacit knowledge is highly personal, developed from experience, and hard to formalize; therefore, it is difficult to communicate. Explicit knowledge, on the other hand, is formal and systematic. It is, therefore, easy to communicate and share, for example, in product specifications or codes of practice. Drew (1999) described four types of knowledge: 1) what we know, we know; 2) what we know, we don't know; 3) what we don't know, we know; and 4) what we don't know, we don't know. He emphasized that most KM programs were concerned with processes for sharing and distributing existing knowledge that is "what we know, we know." However, he recognized that the increasing use of intelligence gathering based on knowledge networks and intranets contributed towards "what we know, we do not know."

Quintas et al. (1997) defined knowledge management as "the process of continually managing knowledge of all kinds to meet existing and emerging needs, to identify and exploit existing and acquired knowledge assets and to develop new opportunity." Webb (1998) defined knowledge management as "the identification, optimisation [sic] and active management of intellectual assets to create value, increase productivity and gain and sustain competitive advantage." It is important to recognize that KM involves the sharing of knowledge, as well as other processes. Several authors have identified these different processes. For example, Ruggles (1997) categorized these processes as generate, codify, and transfer. Siemieniuch & Sinclair (1999) identified five processes: generate, propagate, transfer, locate and access, and maintain and modify. Tiwana (2002) identified five categories as find, create new, package and assemble, apply, and reuse and revalidate knowledge. Laudon and Laudon (2000) recognized that these processes can be cyclical and iterative, and that they all have different process requirements.

Knowledge is increasingly recognised as the most important resource in organisations and a key differentiating factor in business today. It is being increasingly acknowledged that KM can bring about the most needed innovation and improved business performance in the construction industry (Egbu, Sturgesand and Gates, 1999). Knowledge is defined as a dynamic human process of justifying personal belief towards the truth (Nonaka and Takeuchi, 1995). It can also be defined as ‘know-why’, ‘know-how’ and ‘know-who’, or an intangible economic resource from which future resources will be derived (Rennie, 1999). Knowledge is built from data, which is first processed into information (i.e. relevant associations and patterns). Information becomes knowledge when it enters the system and when it is validated (collectively or individually) as a relevant and useful piece of knowledge to implement in the system (Carrillo, Anumba and Kanara, 2000). Besides the meaning of knowledge, it is the identification of the kind of knowledge that has to be managed. There are various kinds of classification of knowledge: formal (explicit) and tacit (expertise) knowledge; foreground and background knowledge; knowledge of business environment or knowledge for control activities (Carrillo, Anumba and Kanara, 2000).

According to (Brelade and Harman, 2001), KM is obtaining and using resources to create an environment in which individuals have an access to information and in which individuals obtain, share and use this information to raise the level of their knowledge. In addition to this, individuals are encouraged and enabled to obtain new information for the organisation. KM is referred to as the process of creating, codifying and disseminating knowledge for a wide range of knowledge intensive tasks. (Harris et al., 1998). These tasks can be decision support, computer-assisted learning, research (e.g. hypothesis testing) or research support.

The construction industry delivers large, expensive, custom-built facilities at the end of a construction process. It is a strong, knowledge-based industiy that relies heavily on the knowledge input by different participants in a project team. Some aspects of KM have been around for awhile, such as the attempt to capture tacit knowledge in Expert Systems and Knowledge-Based Systems during the 1980s. However, these had limited success in much defined areas, such as diagnosing the cause of dampness in buildings (Allwood, 1989). This approach of trying to capture personal experiences in information technology (IT) systems was not very successful. Technology has advanced and there is now a common understanding that IT is simply a facilitator and not the KM system.

The changeable character of the CO requires that the information generated be controlled, stored, and shared. We proposed in order to manage the knowledge generated a MAS formed of three agents are under the client agents implementation. One agent, called the send and receive mail agent, is in charge of organizing the information sent and received from the group. The other two agents are general agent (Interface Agent and Personal Agent).

The rest of the agents are also communicated, thus enabling them to interchange information. The roles of these agents are summarized as follows

i. Comparing new information with that which has already been stored in order to detect inconsistencies between old and new information. If an inconsistency is detected the agent must inform the rest of the agents in order to discover why the inconsistency has occurred.
ii. Informing other agents about changes produced.
iii. Advising certain employee to do a specific job. The system has information about each employee's skills, their performance metrics, and the projects they have worked on. Agents may process this

information to suggest which person is most suitable to carry out a task.

iv. Estimating the cost of future interventions. Information available may be used to make statistical analyses that help predict effort and costs.

II Related Works

Knowledge about agent concept alone is not sufficient to build a good agent system. There are some fundamental issues needed to drive the design of an agent (Bigus, J. P., Bigus, J., 2001). The first is to view the agents as adding value to a single standalone application, or as a freestanding community of agents that interact with each other and other applications. The first type views the agent from the perspective of application-centric, where the agents are helpers to the application, while the second is more agent-centric, where the agents monitor and drive the application.

In recent years, Multi-Agent System (MAS) has been an active research topic. Due to the difficulties in solving process planning and production scheduling problems using traditional centralized problem solving methodology, MAS approach – a distributed problem-solving paradigm is used as another attempt to solve the planning and scheduling problems. As a distributed problem-solving paradigm, MAS breaks complex problems into small and manageable sub-problems to be solved by individual agents co-operatively (Vermeulen, S. Bohte, D. Somefun & Poutré J. L, 2006).

Agent paradigm lets users think in term of agents rather than objects / functions. The agent exhibits presents high dependencies compared with an object-oriented approach. Such a software application needs an appropriate software development method. An analysis and design methodology is intended to assist first in gaining understanding of a particular system, and secondly in designing it (Wooldridge, M, 2004). There are few choices of agent-oriented methodologies to help software engineers to specify, design and build agents to achieve the system's goals.

(Dignum, V., 2006) proposed Operation per Organizations (OperA), a model for agent's organization, society and interaction model. The Organizational Model implements the desired organizational structure of an agent society, the description of an agent population that will enact the roles described in the structure is detailed in the Social Model, and the specification of agent interactions to achieve the desired society global objectives is described in the Interaction Model. However, this model needs other agent oriented methodology to help designing the system.

(Park, S., Sugumaran, V., (2005) introduced a framework of multi-agent system (MAS) development that considers both functional (services to solve complex problems in distributed environments) and non-functional service (capability to reuse, easy to extend, adapt and process uncertain data) of the system. They also suggested that, in order to develop MAS in a systematic way, system should be analyzed in terms of its ultimate goals and the system should be designed both in the abstract as well as concrete by mapping the goals and the sub-goals to software agents.

(Elst,L. V., Dignum V., & Abecker A., 2004) asserted a three-dimension overview on agent-mediated knowledge management which includes (i) understanding the stage in a system's development process where agents are used (analysis, conceptual design, or implementation) (ii) analyzing the architecture / topology of the agent system, and (iii) identifying KM functionality / application focused on.

MAS developed for job shop scheduling problems in which standard operating procedures are combined with a look-ahead coordination mechanism that should prevent 'decision myopia' on part of the agents. Using their approach, system performance is said to improve in tightly-coupled, real-time job-shop scheduling environments. However, their coordination mechanism is not appropriate for competitive, self-interested agents, which makes it an undesirable choice for coordination in a de-icing setting (Liu & Sycara, K. P, 1996).

According to (Wetherill et al., 2002), knowledge in construction can be classified into three categories: domain knowledge, organizational knowledge and project knowledge.

Domain knowledge forms the overall information content. It includes administrative information, (e.g. zoning regulations, planning permission), standards, technical rules, product databases, etc. This information is available to all companies, and is partly stored in electronic databases.

Organizational knowledge is company-specific, and is the intellectual capital of the firm. It resides both formally in company records and informally through the skilled processes of the firm. It comprises knowledge about the personal skills, project experience of the employees and cross-organizational knowledge. The latter knowledge covers the knowledge involved in business relationships with other partners, including clients, architects, engineering companies and contractors.

Project knowledge is the potential for usable knowledge and is at the source of much of the knowledge identified earlier. It is both the knowledge that each company has about the project and the knowledge that is created by the interaction between firms. It is not held in a form that promotes reuse. Companies and partnerships are often unable to capitalize on this potential for creating knowledge. It includes both project records and the recorded and unrecorded memory of the processes, problems and solutions. This paper is mainly concerned with project knowledge.

Our KM system consists of four main components comprising:

i. Interface for input and updating of captured knowledge into the knowledge web-based portal
ii. The web-based portal that stores the knowledge base which allows the users of the KM system to access the hosted knowledge
iii. A search engine that provides some searching mechanism to allow the users to search
iv. For the desired knowledge and provide a set of alternative solutions if the user is
v. Looking for solutions to a particular problem

vi. An open forum to allow all users to contribute and show their solutions on a particular problem, share their knowledge and information and get the updates of specific projects.

III METHODOLOGY

Our methodology composed of three main phases as followed:

Phase 1 – MASK-CO design by Prometheus Design Tool (PDT)

The Prometheus methodology consists of three phases (Padgham. L, & Winikoff. M, 2002):

i. System Specification: where the system is specified using goals and scenarios; the system's interface to its environment is described in terms of actions, percepts and external data; and functionalities are defined.
ii. Architectural Design: where agent types are identified; the system's overall structure is captured in a system overview diagram; and scenarios are developed into interaction protocols.
iii. Detailed Design: where the details of each agent's internals are developed and defined in terms of capabilities, data, events and plans; process diagrams are used as a stepping stone between interaction protocols and plans.

Each of these phases includes models that focus on the dynamics of the system, (graphical) models that focus on the structure of the system or its components, and textual descriptor forms that provide the details for individual entities.

Phase 1.1 Systems Specifications

Phase 1.1.1 Goals

As shown in Figure 1 below, there is one main goal for the agents, and how they are achieved, are described as follows:

A. Send and Receive Mail

i. Send mail to the destination user.
ii. Receives mail from the source user.

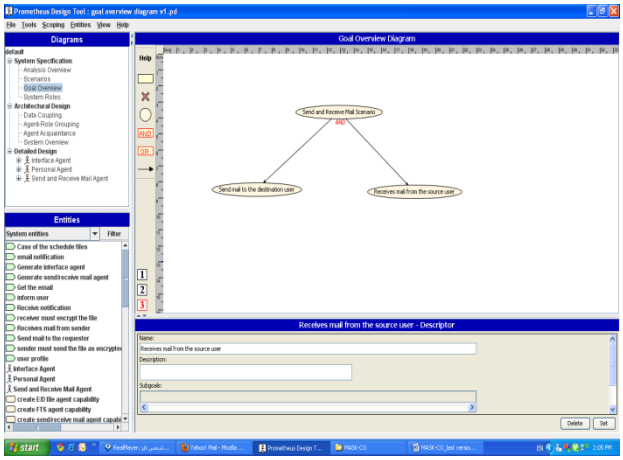

Figure 1: Goal Overview Diagram

Phase 1.1.2 System Roles

Based on the different functionality/scenarios, different roles may be extrapolated as above as shown in Figure 2 below.

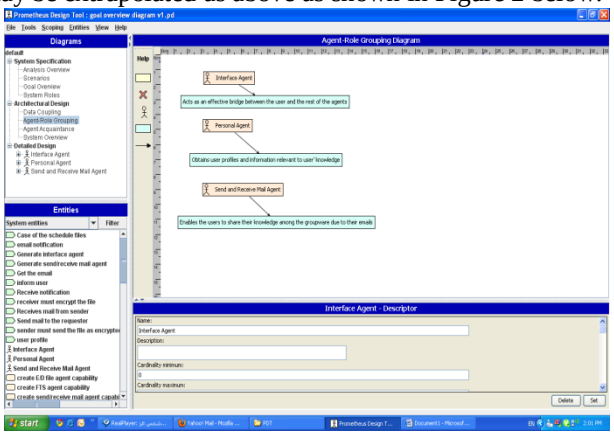

Figure 2: System Role Diagram

Phase 1.2 Architectural Design

Phase 1.2.1 System Overview Diagram

To explain in detail the functionality of each agent, the System Overview Diagram shall be used as shown in Figure 3.The identifies the Scenarios, the Agents, the Data, the Actions and the messages that are used by all Agents.

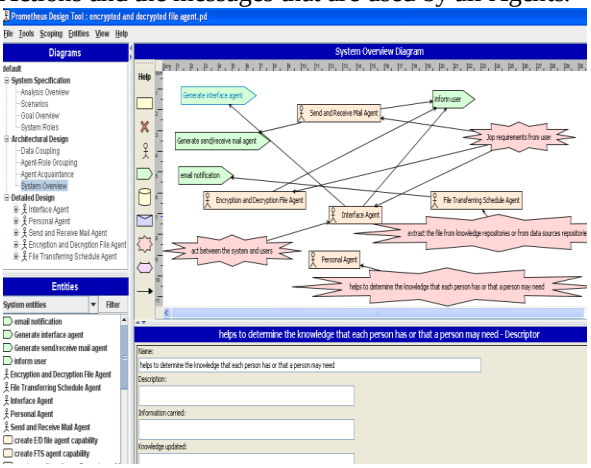

Figure 3: System Overview Diagram

Phase 1.3 Detailed Agent Design

Phase 1.3.1 Interface Agent

Interface Agent acts as an effective bridge between the user and the rest of the agents. Such agents actively assist a user in operating an interactive interface as shown in Figure 4.

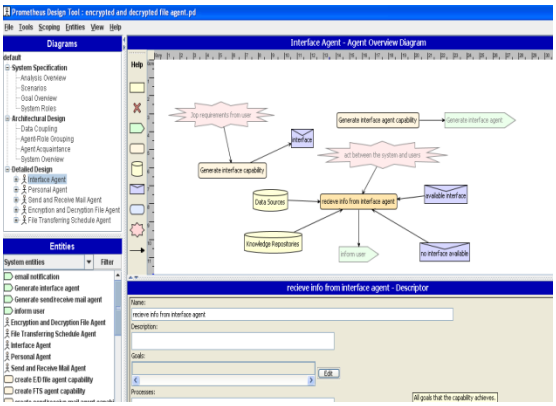

Figure 4: Interface Agent

Phase 1.3.2 Personal Agent: which obtains user profiles and information relevant to user' knowledge that helps to determine the knowledge that each person has or that a person may need as shown in Figure 5.

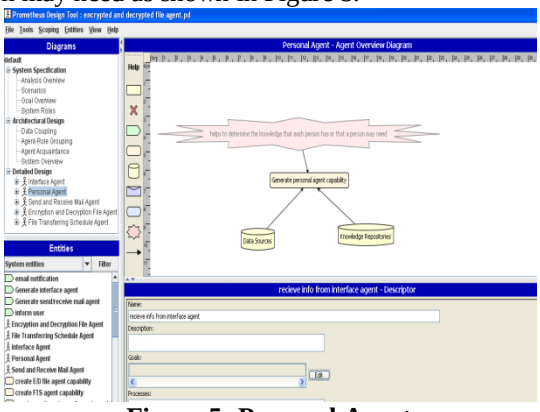

Figure 5: Personal Agent

Phase 1.3.3 Send and Receive Mail Agent: is enables the users to share their knowledge among the groupware due to their emails. This process is provided by this agent. It's also learns about interactions of a user and E-mail application to perform the tasks on E-mail according to the user preferences as shown in Figure 6.

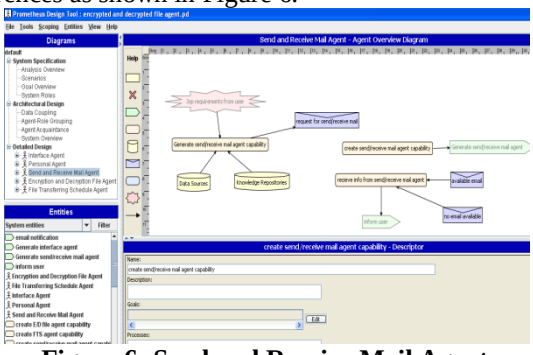

Figure 6: Send and Receive Mail Agent

Phase 2 – MASK-CO development

By using the groupware of Lotus Notes (Lotus company, 2007), the best agent technology capability that could be developed is used Java Script programming that comes along with this package.

Figure 7(a), 7(b) and 7(c) describes the communication between the agent and the whole system among the users' mails and also demonstrates the agents into the system.

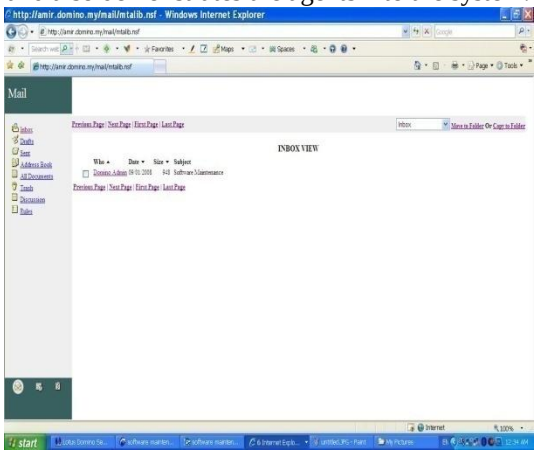

Figure 7(a): Mhd talib mail in lotus notes COE

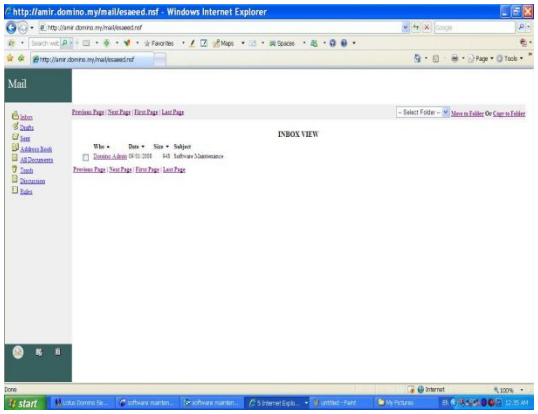

Figure 7(b): egbal saeed mail in lotus notes COE

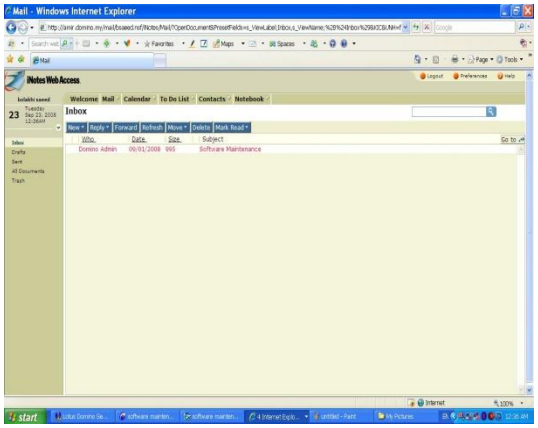

Figure 7(c): bolakhi saeed mail in lotus notes COE

Phase 3– MASK-CO evaluation

Phase 3.1 Participants

The respondents including System Analyst, System Developer, Software Engineer, and User and will be chosen to fill the questionnaire of this study. The respondents should be applying the system before solving the questionnaire to be situated.

Phase 3.2 Procedures

In the beginning, the respondents will receive a short, scripted verbal orientation. Then they will be asked to complete a short background questionnaire to collect their demographic characteristics. The respondents will be asked to perform a set of information about how to share knowledge as a kind of multi-agent technology for COE. The tasks were written on a sheet of paper that included a space where respondents will be asked to indicate their answers. Once the tasks are completed, respondents will be asked to complete a short participant satisfaction questionnaire to collect and test their own perceptions towards CO.

Phase 3.3 Tasks

Respondents will complete three tasks:

i. They will complete a background/experience questionnaire that including name, gender, age, education level, Major/Department, and years of experience.
ii. They will perform tasks using the questionnaire's sheet.
iii. There is also a post-survey questionnaire that specifically examines MAS techniques. After completing a task, the respondents will ask to rank satisfaction and to write down comments.

Phase 3.4 Data collection

This evaluation model considers both quantifying elements of performance (experience and experiment) as well as subjective empirical. If the answer is wrong, or he/she not familiar with this question then skip to the second question until all the question will be solved. We will, however, record whether respondents are able to complete tasks successfully. The criteria for successful task completion are:

i. Participant is able to give a correct answer based on his own information about the system. Any guessed or assumed answers, whether correct or not, are not record as successfully completed tasks.
ii. Participant is able to give a definite answer to the question. Where respondents indicated they are unsure about the answer or would seek clarification, the task will record as not successfully completed.

Phase 3.5 Survey

The purpose of the survey is to prove:

i. Handle the interpretation of the term KM and the company's key objective in CO.
ii. Handle the aspects that come into play in KM, such as the existence of a strategy, the processes of quality control of data, the content that is being managed, and the functioning of communities of practice.
iii. Identify the Multi-Agent technique of willingness of cooperation for research work.
iv. Identify the Multi-Agent technique for helping the user according to his needs.

IV Conclusion

Knowledge Management is of increasing interest to the construction sector. Many of the individuals tasked with implementing KM strategies have an engineering background and no previous experience in managing knowledge on a corporate or business-unit scale. They are, therefore, eager to learn from others who may be further advanced than themselves.

KM is being given a high profile throughout the construction industry. It is seen as a mechanism to support the continuous improvement being sought and complements a number of other business-improvement measures. The findings documented herein should help to provide organizations with insight into the KM activities currently being undertaken by other organizations.

This process takes a lot of time and effort. Besides, it generates a huge amount of different kinds of knowledge that must be suitably managed. MAS in charge of managing this knowledge might improve the construction organization since agents would help developers find information and solutions to problems and to make decisions, thus increasing organization's competitiveness. KMS is a good place where people could share their knowledge between the CoP. In this case, agent's technology is a tool that could be used in order to act on behalf of CoP of CO to do something repetitively and time based system. The agent techniques describe send and receive agent use to enable the user to share their knowledge among their emails. We have briefly presented the Prometheus methodology for designing our MAS. The methodology provides detailed guidance in terms of processes as well as notations. It is not intended to be prescriptive, but is rather an approach which has evolved out of experience, and which the authors expect to be further adapted, refined and developed to suit the needs of agent software developers.

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Appendix A
QUESTIONNAIRE

Appendix A.1 Pre-Survey Questionnaire

Thank you very much for agreeing to participate in this experiment. All of your personal data that we collect will be entirely confidential. I would like to gather a bit of background information about u.

Participant
Name_____
Gender: _____Male _____Female
Date_____
How old are you? 20-29 30-39 40-49 50-59 60 or above
Level of education:
_____Certification Bachelor _____ Certification Diploma
_____Degree Postgraduate
Race: _____Malaysian (Local)
_____International
Years of Experience
_____

Appendix A.2 Testing Questions

The goal of this Survey to evaluate the KMS and prove the KMS is a useful support system.

I will ask you a series of questions and would like you to think out loud while you look for the answer. Please remember that we are testing the effectiveness of the KM and this is not a test of you. The whole test should take less than one hour. Thank you

Description for How to Answer the Question:

Evaluation of the matrix: Assign yourself the following points for each

NA = 0, where 0 is doing nothing at all = NONE and

1 = Don't Know, Not Sure or Can't Say = NO

2 = Not Important or as Not been Addressed = MINIMALLY

3 = Partially Beneficial or somewhat Effective or Less Scope for Overall Improvement = PARTIALLY

4 = Important or May not be effective but other associated necessary actions being taken =SUBSTANTIALLY

5 = Critical or already in place and effective = FULLY

Also, the scale can generally be summarized as follows for majority situations

'NA 1 2 3 4 5' is calibrated as in

'5 (Always) 4 (Often) 3 (Sometimes) 2 (Occasionally) 1 (Never)'

NA (Not Applicable), (Note: "NA" and "1" scale values are equivalent.)

QUESTIONNAIRE - Part One (Quantitative Analysis)

1.Is recording and sharing knowledge a routine and like any other daily habits for the employees?

NA 1 2 3 4 5

2. Are the employees co-operative and helpful when asked for some information or advice?

NA 1 2 3 4 5

3. Is Knowledge sharing seen as strength and knowledge hoarding as a weakness?

NA 1 2 3 4 5

4. Is good knowledge management behavior like sharing, reusing knowledge actively promoted on a day-to-day basis?

NA 1 2 3 4 5
5. Are people in the organization aware of the need to proactively manage knowledge assets?
NA 1 2 3 4 5
6. Do people at all levels in the organization participate in some kind of a community or communities of practice?
NA 1 2 3 4 5
7. Is there top management representation for KM?
NA 1 2 3 4 5
8. Is knowledge management a formal function area in the organization?
NA 1 2 3 4 5
9. Are the teams in the organization effective? Are self managed teams composed of individuals capable of learning from each other?
NA 1 2 3 4 5

QUESTIONNAIRE- Part Two (Qualitative Analysis)

Do the employees share their knowledge?
Yes No
2. Is the intranet used to share knowledge in an informal manner (non-routine, personal and unstructured way)?
Yes No
3. Do workplace settings and format of meetings encourage informal knowledge exchange?
Yes No
4. Are there incentives given for knowledge contribution, exchange or on knowledge sharing in your firm?
Yes No
5. Is the support from executive management to KM (Knowledge Management)\ knowledge sharing VISIBLE?
Yes No
6. Are there specific knowledge roles identified and assigned?
Yes No
7. Are all senior managers and professionals trained in knowledge management techniques?
Yes No
8. Is knowledge validated through peer or superior review or, is there some kinds of librarians or information management staff that coordinate knowledge repositories.
Yes No
9. Is knowledge sharing across departmental boundaries actively encouraged? (Not similar to ‘’incentives’’)
Yes No

Appendix A.3 Post-Survey Questionnaire

Thanks again for participating in this experiment. This questionnaire gives you an opportunity to tell us your reactions to the system you used. Please circle a number on the scale to indicate your reactions. Thank you
The goal of this part to evaluate the MAS that applying into the Lotus Notes Domino and to prove the MAS will help the users according to their needs.

QUESTIONNAIRE - Part One (Quantitative Analysis)
1.Is it possible to change the send and receive agent schedule.
NA 1 2 3 4 5
2. We can run the send and receive agent "After new mail arrives" and "Before new mail arrives".
NA 1 2 3 4 5
3. Send and receive agent option will appear in the current mail file.
NA 1 2 3 4 5
4. One of our users left the office without enabling the send and receive agent. We can enable it for him or her.
NA 1 2 3 4 5
5. I sent to someone multiple e-mails while that person is out of the office. So I will receive only one e-mail notification.
NA 1 2 3 4 5
6. To customize the "Welcome Back" message, the "Disable Reminder" message, or the default wording of the e-mail notifications sent to all senders of e-mail.
NA 1 2 3 4 5
7. In order to notice the Domino Designer 5 client has new agent properties, such as "Allow user activation" and "Run on behalf of." The both of these we need to set in the mail template (on the server) or in the individuals' mail files for the send and receive agent to work properly.
NA 1 2 3 4 5
8. The send and receive agent work in a clustered environment.
NA 1 2 3 4 5
9. We can enable the scheduler agent for leaving "Today" instead of the recommended "Tomorrow" or another date in the future.
NA 1 2 3 4 5

QUESTIONNAIRE- Part Two (Qualitative Analysis)

1. We can set the scheduler agent for an absence period of a half day or a few hours.
Yes No
2. Whenever we receive a warning in Designer while attempting to save an agent
"You do not have execution access privileges for this agent on server ". This indicates one of two things: either the agent signer does not have the rights on the scheduled server, or that server is not reachable to check the signer rights. Running agent "test" in the Designer will give you a better indication.
Yes No
3. "Do you know why I get 'Object variable not set'?" This is a result of a logic error in the code. The problem should become clear if you single step through the code in debugger (File - Tools –Lotus Script debugging). Server might be configured to delay execution of your agents.
Yes No
4. If these tips don't help you figure it out on your own, when you post in the forum please include in your post screen shot of server log output with agent manager debug flags set to '*' (best) and/or diagnostic output of "agent test"

(a good second choice when you don't have access to the server log).
Yes No
5. It is possible to pass parameters between agents.
Yes No
6. It is easy to sign an agent with a server.id For Lotus Notes 5.
Yes No
7. It is easy to console commands from send and receive and scheduler agent.
Yes No
8. Agents runs but mail is not being sent. If our agent runs to completion (i.e. no run time errors that stop the agent before it gets to the send logic) this symptom usually means that it is configuration issue, not an agent problem.
Yes No
9. Does the agents that applied will help the users of the system?
Yes No
Comments about the system: