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Author(s): Chandarasupsang, T., Chakpitak, N. and Dahal, K. P.

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Organisational Learning Model for Utility Asset Management Using Knowledge Engineering Approach

Tirapot Chandarasupsang[1], Nopasit Chakpitak[1], and Keshav Dahal[2]

[1] College of Art, Media and Technology, Chiang Mai University, Chiang Mai, 50200, Thailand

[2] School of Informatics, University of Bradford, Bradford, BD7 1DP, United Kingdom

***Abstract* — Under the evolving environment, a utility company is required to improve the operation and maintenance of its physical assets usually in the forms of an asset management program. This paper proposes an organisational learning model for the utility companies with respect to the asset management activities. CommonKADS is utilised as a tool to capture the knowledge associated with managing the assets from the learning processes of the utility company. A case study of Bangpakong power plant in Thailand is presented. The results show that by applying the proposed methodologies, the learning processes within the utility companies can be categorised and explained by five major learning steps of breakdown, corrective, preventive, predictive, and proactive maintenances.**

***Index Terms* — Asset Management, Knowledge Engineering, Learning Organisation, Maintenance.**

I. Introduction

Under the evolving environment, utility companies are required, by business nature, to eliminate low value, high cost practices, and develop ones which can lower future costs in order to survive in this new environment. Typically, these main costs of the utility companies are associated with the installation, the operation and maintenance, and the decommissioning [1]. However, the costs associated with the installation and the decommissioning are fixed and primarily included in the planning stage. Hence, to meet the new challenge the utility companies need to improve the operation and maintenance of its assets by reducing these variable costs while continually maintaining the similar quality of services.

This usually comes in the forms of an asset management program. The key features of this asset management program are to control costs, reduce risks and improve the utility operation within a constrained operational budget. This is in contrary to the traditional view and method of the utility companies where it is believed that spending and system performance are directly linked [2]. Basically, the asset management program can range from the replacement and the refurbishment of the assets to the management of the business and operational risks [3]. This is because under changing environment, both reliability and financial aspects are equally important. Since the utility companies concern with the short and long-term hypothetical replacement costs, these costs need to be declared and included in the asset management plan, as well as explained to the shareholders. Moreover, with some business constraints placed on the utility companies, new replacement may not be a practical solution [4]. As a consequence, life extension beyond the designed asset life is also necessary, and plays an important role in the asset management program.

In asset life extension, the main business risks depend on the engineering design of the assets, the operational and maintenance practices, and the business requirements [5]. Regarding the life extension of the major equipments, the life-cycle assessment and replacement of the auxiliary parts of the major equipments must also be conducted. This method is usually known as 'Reliability Centred Maintenance' (RCM) which ensures the correct maintenance activities on where and when as well as indicating the design deficiencies [6]. Moreover, the marginal cost is also another important consideration in the asset management's perspective. This is especially in the case where any major equipment has no operational margin. In this case, the utility companies typically have to decide whether the replacement or the refurbishment is an appropriate solution. Hence, it shows that asset management involves highly intensive knowledge and a lot of data and information. To efficiently manage the assets, the knowledge workers' collective experience in the operation and maintenance is required and plays a key role in the process.

This paper is organised as follow; Section II briefly reviews Knowledge Engineering, and discusses the usefulness of it and Learning Organisation theory in the development of an effective asset management program. Section III presents a typical learning model of the utility companies within an asset management context. Section IV shows that Knowledge Engineering approach discussed in section II can assist the utility companies to capture, analyse and model this organisational learning process systematically. Case study and conclusion are then given in sections V and VI respectively.

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II. Knowledge Engineering and Learning Organisaton

This section discusses a methodology proposed in this paper to assist in the development of the utility asset management program. The Knowledge Engineering methodology is applied to capture, analyse and model the knowledge from the learning processes within the utility asset management context. In short, Knowledge Engineering is a newly emerging discipline influenced by an advance in the development of the information technology. Knowledge Engineering provides the scientific methodology to analyse and engineer knowledge. The widely used methodology is CommonKADS which is a Knowledge Analysis and Data Structuring program [7].

Generally, learning processes of the utility company starts from the beginning of the initial operation of its first plant. After that, this 'how-to-do' knowledge occurs and be learned on the daily basis at all levels (i.e. individual, team, system and organisation). From the asset management's perspective, this includes the knowledge on 'how-to' assemble and de-assemble equipments, schedule resources, diagnose faults and events, monitor incidents, and assess risks during operation and maintenance as well as adapting to business changes [4]. Normally, these learning processes are collectively gained over a period of time, and the knowledge can be lost with the workers when they leave an organisation.

As mention previously, data and information collected in all processes play an important role in the operation and maintenance of the assets [3]. By translating this information and data into useful knowledge, the asset management program can then be effectively developed. Knowledge Engineering can assist the utility company in maintaining and making use of this otherwise lost knowledge systematically. It provides methodologies to design and construct knowledge systems. In other words, it provides heuristic approach to capture, analyse, model and utilise expert's knowledge within the organisation. Hence, together with Knowledge Engineering methodology (CommonKADS), the Learning Organisation theory is also utilised and applied in this paper. The organisational learning is defined as a continuous process of creating, acquiring and transferring knowledge accompanied by a modification of behaviour to reflect new knowledge and insights and to produce a higher level asset [8].

Eventually, IT-based knowledge management system can be designed, constructed and implemented. To implement this structured knowledge-based system, it requires some effective design techniques and tools provided by the Knowledge Engineering methodologies. These are for example, CommonKADS which is the EU de facto standard methodology for supporting design and implementation of knowledge system [9]. CommonKADS or KADS has widely been applied in power business such as Knowledge Management for planning, operation and maintenance, pricing negotiation, asset management and regulatory issues.

III. Organisational Learning Model for Opeation and Maintenance

From the asset management's perspective, the organisational learning processes of a utility company on the operation and maintenance can be categorised and modelled as shown in Fig. 1.

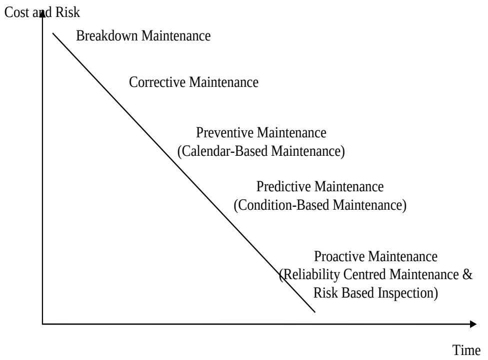

Fig 1 Organisational Learning Model of the Utility Company in Operation and Maintenance

Fig. 1 shows the organisational learning model (learning curve) of the utility company in the operation and maintenance activities. This learning model is based on experience collectively gained over a period of time. Hence, it requires a step-by-step development from breakdown to proactive maintenance. In the breakdown maintenance scheme, equipments are de-assemble and assemble to get the basic knowledge. Corrective maintenance scheme represents knowledge on 'how-to' repair equipment when failures occur. In preventive maintenance scheme, most activities involve resource scheduling to avoid unplanned outages. Predictive maintenance scheme indicates the abilities of the knowledge workers to foresee the future faults and events based on present condition of the equipments. Finally, with more knowledge gained over an operating period, the proactive maintenance indicates abilities of the knowledge workers to assess the asset life time as well as its' parts which consequently assists the utilities in the decision making on the replacement or the refurbishment.

As shown in Fig. 1, associated costs and risks reduce over time indicating better maintenance strategy. This is partly because more knowledge has been gained over a period of time. More detailed explanation of this proposed learning curve of the utility company will be given in the following section where an application of Knowledge Engineering will also be given.

IV. Knowledge Engineering for Asset Management

The organisational learning model or the learning curve of the utility asset management collectively comprises of maintenance schemes, and represents an organisation knowledge gained and developed through experience over a period of time. To capture, utilise and model this knowledge systematically, a Knowledge Engineering methodology is proposed in five steps of the asset operation and maintenance.

CommonKADS, which is one of widely used methodologies, is utilised as a tool to capture the knowledge associated with managing the assets from the learning processes of the utility company. CommonKADS offers some inference or useful templates to create knowledge framework [7]. These include for example, templates for planning, diagnose, scheduling, monitoring and assessment. These templates provide useful guideline for interview, analyse, model and utilise knowledge of the plant operation and maintenance from the experts.

The following sub-sections demonstrate an appropriate template to capture the relevant knowledge.

A. Breakdown Maintenance

During the commissioning, operators learn to operate new equipments and plant processes. Their basic work practices include for example, isolation and test, start-up, shut-down, normal and abnormal operation, and correct calculation of plant efficiency. On the other hand, maintenance workers learn to assemble and de-assemble plant equipment/processes by inspecting the contractor's works. In other words, the knowledge from manufacturers and instruction manual books are thoroughly studied. Then, new knowledge on 'how-to operate' and 'how-to maintain' assets in real workplace situation is developed. In this step technical supervisors are always required on hand to assist in some critical tasks. The working procedures in operation and maintenance are explicitly developed for knowledge sharing and dissemination among plant knowledge workers. This can also be called 'routine planning knowledge'.

Hence, to capture this type of knowledge the planning inference template is selected. The planning inference template is illustrated schematically in Fig. 2.

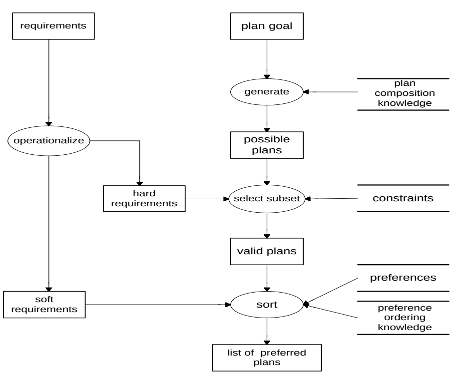

Fig 2 Planning Inference Template [7]

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Fig. 2 shows the planning inference template selected to capture the knowledge in the breakdown maintenance scheme. The planning template in Fig. 2 shows that both hard and soft requirements from the plant operation and management's perspective should also be included in the knowledge elicitation. Moreover, working constraints and preference ordering of the knowledge workers from their real experience need to be taken into account. Then, the working instructions can be developed for knowledge sharing and dissemination.

B. Corrective Maintenance

In the early few years of the unit's commercial operation, the operators and maintenance workers collaboratively learn to diagnose some equipments, processes and failures. Experience and knowledge in failures and events are collectively gained by the workers. This allows the workers to develop the knowledge on 'how-to repair' the assets in each particular failure and/or event. This can also be called 'diagnosis knowledge'. Hence, to capture this 'how-to-repair' knowledge the diagnosis inference template is selected and can be schematically illustrated in Fig. 3.

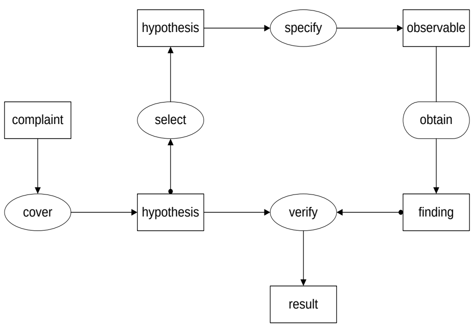

Fig 3 Diagnosis Inference Template [7]

Fig. 3 shows the diagnosis inference template which is selected to capture the knowledge in the corrective maintenance. During the diagnosis, essential information is identified and extracted by the experts from the Data Acquisition System or reports of the problems encountered. Then, faults and events are analysed using hypothesis and test methods. Note here that, the expert's hypothesis and verification rationale are the main knowledge and reasoning issues in this expert interview.

C. Preventive Maintenance

With the knowledge gained in the previous step, the operators and maintenance workers can then attempt to schedule the plant activities and resources as well as to minimise costs in order to prevent unplanned outage from faults and unpleasant events. This is also called 'Preventive Maintenance' or 'Calendar-Based Maintenance' scheme. Note that the opportunity costs and/or the plant availability are also taken into account in the scheduling. Heuristic-based techniques can be implemented to optimise the maintenance scheduling problems [12]. Hence, the scheduling inference template is selected to capture this type of knowledge and is illustrated in Fig. 4.

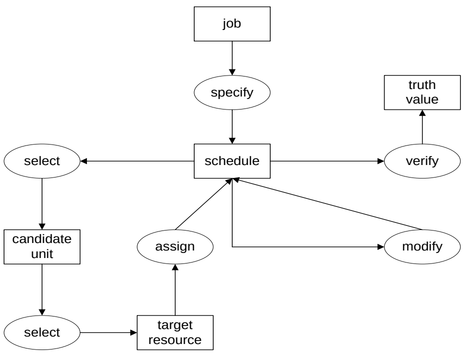

Fig 4 Scheduling Inference Template [7]

Fig. 4 shows the scheduling inference template selected to capture the knowledge in the preventive maintenance scheme. As shown in Fig. 4, it starts by identifying the preventive maintenance job. Then, the initial schedule is developed using the practical rules of the organisation in the selection and assignment of its units and resources. The important issue in this scheme is that the knowledge acquisition should address on the organisation experience/knowledge in modification and verification of the preventive maintenance. Moreover, it also covers some operational routines such as equipment test, exercise, visual inspection and adjustment.

D. Predictive Maintenance

With more knowledge gained over a period of time, this helps the workers to be able to detect some incidents or some conditions as well as to predict the likelihood of faults and events. This ability is called 'Preventive Maintenance' or 'Condition-Based Maintenance'. As a consequence, the monitoring inference template is selected for this maintenance scheme and can be illustrated in Fig. 5.

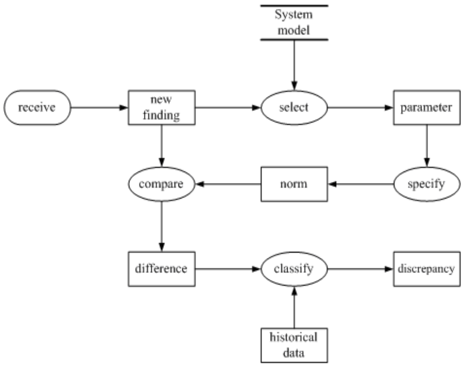

Fig 5 Monitoring Inference Template [7]

Fig. 5 shows the monitoring inference template selected to capture the knowledge in the predictive maintenance scheme. With the ability to predict the potential future failure, this allows the appropriate operation and maintenance actions to be conducted immediately when a discrepancy conditions are found. As shown in Fig. 5, field knowledge, especially new findings (information, parameters, process system models, normal condition of each parameter, comparison method between new findings and norm values, trends), must also be acquired. Note that the plant parameters monitored can be either operating or inspecting parameters from the plant information.

E. Proactive Maintenance

This maintenance scheme is based on historical records of equipment failures and its design information. This knowledge assists in the assessment of the equipment life time and its part's life-cycle, and also in the decision making process of the utility companies to refurbish or replace some equipments proactively before its expected life time. This maintenance scheme is called 'Proactive Maintenance'. To reduce the risks by refurbishment and replacement the methods such as 'Risk Based Inspection' or 'Reliability Centred Maintenance' can be utilised within this maintenance scheme. Hence, to capture this type of knowledge the assessment inference template is selected and can be illustrated in Fig. 6.

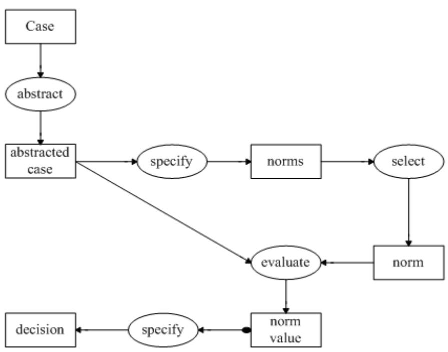

Fig 6 Assessment Inference Template [7]

Fig. 6 shows the assessment inference template selected to capture the knowledge in the proactive maintenance scheme. Based on the guideline provided by the assessment template (Fig. 6), the scope of the asset management or case inference role can be initially classified by operation and maintenance experience. Moreover, risk factors are also abstracted by the experts for each asset category. To categorise the types of the asset risks, knowledge on equipment design, failure history records, operation and maintenance practices, environment, disaster, health, and/or safety is necessary [6]. All possible norms and other specific norms for each risk factor must be specified. It is important that the experts are elicited on their heuristic techniques or practical assessment methods to evaluate the asset risks, life-cycle and marginal costs.

According to the results of the asset evaluation, the asset management decisions could be to maintain or modify the current practices, refurbish or replace some equipment in order to minimize business risks or eventually develop asset management plan. Note here that it is more convenient to conduct the asset risk assessment and management activities during the turnaround period. If some risks are found but not urgent, the condition monitoring system should be implemented on the asset for the normal operation.

Eventually, to utilise the knowledge captured by these templates an IT-based Knowledge Management System is realised in order to share and disseminate the asset management best practice. This is conducted by using a commercial software tool, called iKue. More detailed explanation of this software tool can be found in [10].

V. CASE STUDY

Here Bangpakong power plant in Thailand is used as a case study to confirm the applicability and benefits of using the CommonKADS and Learning Organisation theory to capture and model the organisational learning processes systematically.

A. General Description of Bangpakong Power Plant

Bangpakong power plat is one of the power plants owned by the Electricity Generating Authority of Thailand (EGAT). This plant comprises of 4 thermal generating units utilising gas as a fuel in the production process [11]. Each gas-fired generating unit has a capacity of 600 MW, and the total investment in this plant is nearly 2,400 million US dollars. The boiler tube of the Bangpakong power plant is considered as one of the most critical equipments because the value of the boiler tube is approximately half of the total value.

According to the financial plan of this plant, the plant's life was initially designed for 25 operational years, but now the average asset age is approximately 20 years. Recently however, the life assessment has been conducted and the plan to extend the plant's operational life to 40 years has been investigated. For operation and maintenance, the fiscal operational budget is approximately 8 % of the total asset value per year. For the plant availability, the requirement is set such that the number of unplanned outage from the boiler tube failure should be less than 2 times per year. Lastly, the major inspection or turnaround for each power units should be done every 3 years or more frequently to better suit the condition of the assets.

B. Research Methodology

A knowledge engineering exercise was conducted on the boiler tube monitoring issue. The Community of Practice (CoP) in boiler operation and maintenance was recruited for the interview purpose. This CoP comprises of engineers and chemists from different sections including shift operation, efficiency, chemical, planning and boiler maintenance sections. The knowledge elicitation was completed by using structured interview on CommonKADS's planning, diagnosis, monitor and assessment templates.

C. Results

With the Knowledge Engineering approach proposed in this paper, the asset management program of the Bangpakong power plant has successfully been developed. The tacit knowledge, typically embedded within each domain expert, could be gathered and made more explicit in the organisational wide context. This results in the knowledge being well structured and more manageable. To make use of the knowledge framework by constructing the IT-based knowledge system, the captured knowledge models were put into Knowledge Management software called iKUE [10]. This software is selected because it provides decision support and e-learning environment.

The results of the research presented in this paper shows that the Knowledge Engineering methodology provides a structure to observe, capture, analyse and utilise the knowledge in the operation and maintenance activities systematically. This assists the utility companies in overcoming the most encountered problem of data/information overload but not effectively usable when it is needed. Moreover, the results demonstrate that Knowledge Engineering is another useful heuristic approach for modelling the asset management knowledge. This knowledge model can be useful for the development of a qualitative decision support system as well as the asset management best practices in the future.

VI. Conclusion

Knowledge Engineering is another effective approach in the development of an asset management plan. It is essential to capture heuristics from the plant's Community of Practices. By using structured interview, CommonKADS inference templates can be applied to capture domain knowledge, especially operation and maintenance, and consequently construct a knowledge framework. From the utility's perspective, the asset management program requires the knowledge gained over a period of time through organisational learning experience with respect to breakdown, corrective, preventive, predictive, and proactive maintenances.

This paper shows that by applying the Knowledge Engineering and Management methodologies, the learning processes within the utility companies can be categorised and explained by five major learning steps with respects to operation and maintenance experiences.

Acknowledgement

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References

[1] C. Vetter, T. Werner, T. Kostic, "Building an Asset Management System for Electric Utilities on a Component Based Environment", *IEEE Trans.*, vol., no., pp. 241-245, 2000
[2] C. Glover, "Asset Management: Reliability Centred Maintenance and Overhead Lines", *IEEE Trans.,* vol., no., pp.,
[3] C. Galusha, "Getting Started with IT Asset Management", *IT Professional,* pp. 37-40, May/June 2001
[4] L. Lai, "Power System Restructuring and Deregulation: Trading, Performance and Information Technology", *John Wiley & Sons, LTD,* 2001
[5] J. Ostergaard, A. Norsk Jensen, "Can We Delay the Replacement of This Component? – An Asset Management Approach to This Question", *CIRED2001 Conference Publication,* CIRED, 18-21 June 2001
[6] M.E. Beehler, "Reliability Centred Maintenance for Transmission System", *IEEE Trans. on Power Delivery,* vol. 12, no. 12, pp. 1023-1028, April 1997
[7] G. Schreiber, H. Akkermans, A. Anjewierden, R. de Hoog, N. Shadbolt, W. Van de Velde, B. Wielinga, "Knowledge Engineering and Management: the CommonKADS Methodology", *MIT Press,* 2000
[8] D. Garvin, "Learning in Action: A Guide to Putting the Learning Organisation to Work", *Harvard Business School Press,* 2000
[9] European KM Forum, "KM Terminology and Approach", *IST Project No. 2000-26393,* Published 5 August 2001
[10] Dynamic Knowledge Coporation, "iKue", available at http://www.dynamic-knowledge-corp.com/index.html, last accessed Jan 2006.
[11] Elecricity Generating Authority of Thailand, Information available at www.egat.co.th, last accessed Jan 2006.
[12] K. Dahal, J. McDonald and G. Burt "Modern heuristic techniques for scheduling generator maintenance in power systems" *Trans. of the Institute of Measurement and Control*, **22** 179-194.

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