CHAPTER 6
Conclusion and Future Work

6.1 Chapter overview

In order to perform the maintenance tasks effectively, relevant knowledge and skills are required. Visual inspection skill is very important in the maintenance process since it allows the maintenance operators to be able to observe and make appropriate decisions according to the asset's conditions. This type of skill is classified as episodic where being in the real environment is needed in order to acquire this knowledge. However, the traditional HRD methods are less effective to enhance these skills of the maintenance operator. This research proposes game based knowledge management as an alternative HRD method for the development of the visual inspection skills of the maintenance staff. The 22 kV switchgear maintenance game is developed as pen-and-pencil prototype game. This prototype is used to evaluate the effectiveness of framework. The evaluation is done by 3 case studies as present in Chapter 4. During the evaluation process, the novelties of the research were found. This chapter presents those novelties. This chapter divides into 3 parts. First part is the overview of the chapter. The second part defines the originalities of the research. The final part proposes the future study to improve the current framework which has some limitations.

6.2 Research Novelties

This main objective of this research is to explore the new practical method for enhancing the inspection maintenance skill of the PEA substation maintenance staff. The game based knowledge management framework is developed. This framework is developed based on serious game methodology. In this research, this framework was utilized to construct the PEA 22kV switchgear maintenance game prototype. Then this prototype was evaluated by asking the substation maintenance operators to play the game. They were interviewed after finished the game. The results of testing show the

new findings of the HRD intervention especially in engineering knowledge development. These novelties found in this research are summarized in this section.

6.2.1 Holistic competency analysis

This framework proposes the classification model in order to develop the Scenario Selection Machine of the knowledge game. The first step of this model development is the knowledge, skill, and attitude analysis. This model is developed such that it is in compliance with the Malcolm Baldrige National Quality Award (MBNQA). It proposes the holistic model of competency develop framework by consolidating all aspects of MBNQA. The main originality of this aspect is the proposed competency analysis table, which integrates human resource development with knowledge management, risks management and management information system. Rather than performing these tasks separately for continuous quality improvement, the organization can practically plan and perform the quality improvement related tasks spontaneously. The proposed competency analysis table is developed according to the State Enterprise Performance Appraisal (SEPA) in Thailand, which represents a lesser version of MBNQA. Essentially, SEPA provides the framework to improve performance and competitiveness of the organization by considering six separate parts. Normally, the HRD, the knowledge management, risk management and the management of information system of SEPA are considered separately from each other. This results in more burdens to the organization to fulfil these parts separately. Furthermore, it results in duplication of similar and overlapping works. However, for an organization development to be fully efficient, HRD needs to be integrated with other parts of organization development holistically. In this research, an alternative analysis method to construct the competency model is proposed. This competency analysis table defines the organization into strategic tasks representing community of practices. It then further defines the knowledge and skill set of required by personnel to perform that task. Finally, risks associated with that task can be identified.

6.2.2 Maintenance Engineering Maturity Model

The application of the capability maturity model to classify knowledge and skill of the maintenance tasks into maturity levels is another academic value presented in this research. The proposed model gives the benefit to PEA with the capability of classifying capability of the switchgear maintenance personnel. This is potentially more beneficial for the human resource development staff than using traditional methods (current competency model) in the sense that it provides the information on how to develop a specific skill of the employees. It can be used to identify the capability level of personnel. Comparing to the current PEA substation maintenance competency model, the framework proposed in this research is more appropriate for training and development purpose. This is because the proposed framework not only identifies the capability level of specific competency, but it also provides information and detail of maturity development for enhancing the employee performance. This is particularly for the inspection skills of maintenance engineers. Even though this research was developed and tested by using the PEA's switchgear maintenance task as the case study, it is also possible to apply for the development of classification capability maturity of any other fields.

The framework proposes the structured method to apply knowledge engineering methodology to capture and analyze the detailed competency of the specific task. Hence, competency can then be developed according to both practical knowledge/experiences required in the field and repository. Moreover, the competencies as part of the proposed framework are set up based on knowledge and experience of subject matter experts with the utilization of knowledge engineering method. It means that the personnel performance is evaluated by comparing to the maintenance expert. With this maintenance capability classification model, the specific knowledge and skill can be defined to train the personnel in each level. Then, the organization can use the list of knowledge and skill to develop a proper development program in the future to enhance the individual personnel performance. Furthermore, the proposed framework needs the effort of subject matter experts only in data gathering phase and validation step. This implies that the proposed framework consumes less of the experts' time than the current PEA competency model method.

6.2.3 Game Scenario Development by Knowledge Engineering

According to the job review, the visual inspection skill is a specific knowledge necessary for switchgear maintenance job. This skill training is quite difficult and more complex than normal skills. The trainees should have the opportunity to do and learn by trial and error in a real situation. Therefore, the research proposed the game based knowledge management or knowledge game as the alternative performance development method to enhance the inspection maintenance knowledge. This game is an effective tool for training the player in this skill. The knowledge game provides opportunities for the trainees to be involved in the training process and creates an active learning. This research proposes the framework for producing the game scenarios of the visual inspection knowledge game. The game scenario developed by knowledge engineering is the another originality of this research. This novelty is concerned with the knowledge collected and stored in KM cycle. The knowledge engineering methodology has been used for eliciting the knowledge and experience of the subject matter experts. This research selects the CommonKADs because it provides a method to model knowledge of the organization and represent knowledge with notation. It gives the benefit to develop the knowledge systems that support selected parts of the business process. Moreover, CommonKADS provides the common knowledge model templates to elicit knowledge and experience from the experts. These templates can be used as a guideline to set up the questionnaires for the knowledge elicitation process. By this knowledge engineering technique, the knowledge elicition needs the effort of subject matter experts only in knowledge capture meeting and case study meeting. This implies that the proposed framework consumes less of the experts' time.

Moreover, the study proposes to structure the storyboard of game scenarios based on knowledge engineering. As knowledge engineering allows the organization to add the new knowledge into knowledge model. It means that by knowledge engineering the game developers can increase or add more game contents any time as they need. The results have shown that scenarios can be systematically constructed and provide flexibility for future modification.

6.2.4 The plug-in game structure

Presently, the contents of the training program are developed based on the experience of the instructors. Many training programs are not suitable for some training courses where trainees have diverse level of knowledge such as the PEA switchgear maintenance training program. Moreover, the contents of switchgear maintenance are dynamic. The technology and processes often change. The fault events from workplace always occur. These result impacts the contents of training program which cannot be updated immediately. Therefore, this research proposes the game narrative with plug-in structure. The game narrative of this framework is not linear story line. The game story line cut scenes into 6 parts regarding the competencies in maintenance capability classification model. This plug-in structure gives the benefits of the maintenance performance development. This structure allows the trainer to assign the most appropriate contents for individual trainee. Individual is provided training content base on his capability level which is placed by placement scenario. Moreover, this structure also benefits the game developer in order to create a new game scenario which concerned the new event or new technology with no need to change the whole contents of the training program.

6.2.5 The game theory

The other KM novelty of this research is the game theory application. The game theory is adapted to analyze the optimal strategy selection in the scenario selection of the knowledge game. The information and knowledge captured from operators is used to perform the payoff matrix. The organization can utilize this payoff matrix for managing the game scenario selection to enhance the efficiency of knowledge transfer. Moreover, both employee and organization are considered to gain the maximum benefit in playing the game.

6.2.6 Knowledge Transfer Evaluation based on Expert Performance

The knowledge transfer evaluation method in the game is another benefit of this framework. This research proposes to evaluate the knowledge sharing and transfer by

comparing the decision scoring and time consumption of trainees compared to those of the experts. In this research, the time limitation and the scoring system of each activity are set up based on expert performance. This process was done by asking the expert to perform the activity. The time taken and the score received by the expert, are used for setting the limited time and reference score of the activity. The time and score are set up based on performance of subject matter experts. It means that the personnel performance is evaluated by comparing to the maintenance expert, or in other words how closes to the performance of the experts. This novelty concerns the KM evaluation in KM process.

6.3 Future Study

As present in Chapter 1, this research is limited with some constraints. Therefore, this part presents the future works to cope these limitations. Some ideas of the future study are proposed in this section as follows;

- In order to motivate the trainee to learn using this knowledge game, the reward of the game should be with the incentive system of organization. For example, due to PEA set up the professional certificate project to certify the ability level of their staffs especially in engineering job. Therefore, the knowledge game can be used as a prerequisite training program of the trainees who need to promote their ability level. By this matter, the knowledge game can be more motivated staffs to learn because the staffs can be got both reward and knowledge.
- This research is not developed the proactive maintenance contents. From the knowledge capture interviewing process, it is found that although PEA did not explicitly complete the organizational learning model with maintenance activities, PEA experts have implicitly accumulated the knowledge in proactive maintenance task. Therefore, the future study should develop the game which covers the proactive maintenance knowledge. In the future study, the researcher can apply knowledge management methodology to develop the

best practice and create the proactive maintenance knowledge. Referring to the learning model on maintenance activities, the assessment inference template can be used to capture the knowledge of proactive maintenance task. This CommonKADs inference template can be used as guideline to identify the existing knowledge of PEA experts in order to assess the lifetime of the equipment. Then, the study can combine this existing knowledge with proactive maintenance theory (related engineering theories) to develop the best practice in proactive maintenance task. This best practice can then be used to develop the game scenario.

- This research focuses only on physical inspection. It does not cover the knowledge for inspecting the condition of equipment by analyzing the information in the reports. Therefore, the future study has to capture the know-how of experts in order to inspect the condition of equipment based on the data and information on working report. The contents of game should cover work-instruction, theory, and inspection databased. Moreover,the knowledge should be classified into 4 levels including procedural knowledge, semantic knowledge, episodic knowledge, and declarative knowledge.

- In this research, the 22 kV switchgear maintenance knowledge and experience is captured only from the head office experts and PEA N3 experts. The game environments are based on the PEA N3 maintenance work. Therefore, if PEA prefers to use this knowledge game for PEA switchgear maintenance skill development, PEA should capture more knowledge from other experts. This process can be done with the focus group interview. The focus group should include the expert from all area offices. Moreover, it was found that PEA did not explicitly complete the organizational learning model on maintenance activities. However, PEA experts have implicitly accumulated the knowledge in proactive maintenance task. Therefore, PEA can apply knowledge management methodology to develop the best practice and create the proactive maintenance knowledge. Then the framework can be applied this knowledgeand the best practice to develop the game scenarios.

- This research develops the prototype game based on pen-and-pencil method. This prototype is the instructional design of the knowledge game. Therefore, the next step of work will be the animation and graphic interface development. In this step, the game developers should select the appropriate platform and technology tool in order to create the final version of the game. The presented game technology, such as Torque Demo, will be used to develop the game animation. The game scenario, placement scenario, and game story which are developed in this research, will be used for developing the final version of the knowledge game. It can serve as the guideline for the game designer and programmer to develop the game engine, avatar, game character, game environment, rule, animation, and interface in the game design process.