Chapter 9
Conclusion and Future Work

9.1 Conclusion

This thesis attempts to answer the questions that an asset manager usually asks when he is about to make a decision on whether or not the existing distribution feeder shall be rehabilitated and what rehabilitation project he shall adopt in order that the benefits of all stakeholders can be compromised. To help the asset manager fulfill his task, the thesis has developed the novel decision support system to assist the asset manager collect all necessary information and analyze the options before ending up with the best possible decision. So the decision support framework has been established based on the hypothesis that:

- The power distribution network asset can be modeled to provide a variety of information and knowledge required to perform the assessment and decision making task.
- The risk potential of distribution feeder failure can be determined by systematically assessing the condition rating of the network assets as well as their operational and environmental stressors.
- The costs associated with feeder failure and preventive action can be methodically quantified.
- And the subjective consideration such as social and environmental issues can be modeled and included in investment decision.

The explanation, discussion and demonstration made throughout the thesis have proved that by systematically resolving those research hypotheses the novel decision support system could be established. In addition, the case studies presented in the thesis have also demonstrated the applicability and effectiveness of the system in the practical application. The outcome of study results in the novel perspectives that can be concluded in the following paragraphs.

In the context of knowledge representation, this thesis proposes the novel asset categorization to the power distribution network asset knowledge which in turn used for the risk and cost assessment as well as the multicriteria decision analysis processes. The categorization approach is primarily based the CIM/RDF/XML standards. Although the CIM has been used for modeling power system assets for some times, it is mainly used in the area of power system control. Moreover, although it has recently been extended to cover power distribution system management (DMS), there seems to be no evidence to claim its real application in distribution network asset management, especially the application in risk and cost assessment and multicriteria decision making objectives. The results of the study shows that the asset model can provide all necessary information and knowledge required for assessment and decision making tasks. Furthermore, the model is developed in such a way that

can offer expressivity, interchangeability, extensibility, reusability and integratability; it thus makes the model robust and flexible.

In the context of risk assessment, the use of fuzzy reasoning techniques has made the assessment task effectively bring up the percentage of failure risk occurrence based on the available asset information of visual inspection records and operational and environmental stressors of use. The technique of fuzzy closely replicates the problem solving of human being which has been already proved to be the most successful problem solving approach. This thus makes the assessment tool immune to the vagueness and impreciseness of the data. Furthermore, the inclusion of Markov chain offers the possibility to predict the risk potential at any time instance along the life time of asset. The results of the study demonstrate that the assessment approach works well with both the simulated and real data and also bring about the sensible outputs.

For cost evaluation context, two main cost components: outage and resolution costs are focused on the study because these two figures can be methodically quantified. Both customer and utility outage costs are computed based on customer types and reliability indices of existing feeder. The interrupted energy rate (IER) is use to quantify the outage cost. The resolution cost is the expenses that utility spends to reinforce its distribution network. It depends on the type of network reinforcement. Work breakdown structure (WBS) is employed to break down the feeder into individual components and calculate its associated costs to obtain the overall cost of each resolution option. Furthermore, the supplement of risk potential value on the cost figure makes the decision system consequently offer cost idea to the decision maker along the entire life usage of the assets. The results of the study reiterate the confirmation of such claim.

In the context of decision making process, the employment of analytic hierarchy process makes it possible to numerically compare the subjective judgment based on the same ground. By using the AHP, all key factors associated with power distribution network asset management such as technical, financial, social and environmental aspects are taken into account; it thus makes the proposed decision support system comprehensive and rigorous.

It can be clearly seen from the results of the study that the novel decision support system offers the necessary and useful information to assist the decision making process. However, it shall be worth noting that the decision support system does not make a decision on its own; the final decision making has to be performed by human decision maker, i.e. asset manager.

The research essentially offers the theoretical, academic and practical contribution as the followings.

1) Theoretical perspective: The DSS has been developed based on the decision making process of human being which is able to deal with the problems attributed with insufficient and imprecise information. The research has successfully demonstrated the utilization of theoretical approaches of CIM/RDF/XML, fuzzy logic, Markov chain, and AHP to assemble the decision support tool to resolve the distribution network asset management problems where information on asset are somewhat inaccurate and scarce.

2) Practical perspective: The proposed DSS has been successfully solved the practical problems of distribution feeder rehabilitation investment decision. The utility manager would be better informed in asset condition, risk potential, cost detail, and is allowed to transform the subjective opinion to objective value in order that the options can be quantitatively comparable.

3) Academic perspective: Although the DSS has been developed to solve the power distribution asset management problems which primarily focusing on the distribution feeder rehabilitation investment decision, the proposed approach can accordingly apply to manage any kinds of infrastructure assets. Only the additional works of capturing, analyzing, and modeling the knowledge components in those domains are to be performed. However, the asset categorization, risk assessment, cost evaluation and multicriteria decision analysis framework proposed in this research can be straightforwardly applied to obtain the required knowledge and assemble the DSS to resolve the asset management problems in the above mentioned domains.

9.2 Future Work

Future works related to this research study can be concluded as follows.

1) The focus of the research presented in this thesis is to propose the methodologies to assess the risk of ongoing use of existing overhead distribution feeder and proposed the mitigating solution including the undergrounding alternative. However, many utilities are now experiencing a majority of their underground cables which have been in use for a long reaching its designed age; these feeders also require the rehabilitation. The assessment framework proposed in this thesis can be straightforwardly applied for underground feeder. The only discrepancy is the procedures and knowledges required for underground cable inspection. The components, materials, environment of use and behavior of underground network asset to operational and environmental stressors differ from those of overhead; it is interesting to investigate into all these aspects in order to make the rehabilitation of distribution network inclusive.

2) Usually the power distribution utility like MEA would possess also another networks rather than distribution feeder. The networks usually include sub-transmission lines, substations, distribution feeders, and low voltage networks. The proposed asset categorization framework work well with and can provide useful information for managing the distribution asset, i.e. balancing cost, risk and performance; it would certainly offer even greater benefits to the utility if the framework is to extend to cover the rest of transmission and distribution facilities. This would offer the possibility to distribution utility to develop the asset categorization scheme for its entire networks and facilitate the establishment of asset management system for utility's transmission and distribution system.

3) This thesis does not intend to offer the full range of computerized decision support tool application; it rather recommends the framework for implementing such decision support tool. The data recording/retrieval and computation are thus done manually in order to show the applicability and effectiveness of the proposed framework. However, it might be interesting and more useful to realize if the entire procedure of decision making can be automated. What is meant by automation is that

the users only provide all the necessary data inputs once and the system will numerically process and automatically offer the choices of solution including associated useful data such as the risk percentage, the money value of cost, or the ranking score of each solution option. In order to establish such automated decision support system, the skills on database analysis and design as well as computer programming are required; but it is worth attempting however.