Towards Agent-Based Framework of Energy Planning Systems

Research-in-Progress

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Abstract

One of the important factors that support human life today is energy, which will ultimately affect the development of social life, economy, and environment. To meet the future energy needs, many countries perform energy system modeling. However, this process is complex and is fraught with difficulties and errors, such as incorrectness, inconsistency, incompleteness, and redundancy. This research aims to reduce those difficulties raising this research question: "How can Agent-Oriented Analysis (AOA) alleviate several challenges of energy planning process." This research project will use the Design Science Research (DSR) method and use seven Agent-Based Modellings (ABMs) including agent model, goal model, interaction model, scenario model, organization model, role model, and environment model. The research will provide an agent-based knowledge analysis framework. Practically, it will enable energy planners in many countries to perform more effective and affordable planning.

Keywords: Agent-Oriented Analysis, Energy Planning System, Agent-Based Models, Knowledge Framework

Introduction

In the life of a nation and state, energy has a critical and strategic role for achieving sustainable development goals, as well as being the driving force of economic growth (IAEA, 2001; IAEA, 2007). Currently, integrated energy planning software is developed using analytical tools to obtain an optimal solution of the national long-term energy problem (IAEA, 2001; IAEA, 2007; IIASA, 2017). These tools can provide a solution for energy planning issues by modeling existing energy system and projecting energy supply and demand into the future. However, energy planning processes are complex in nature. This includes a lack of single problem statement, scientific complexity, administrative complexity, conflicting data values, conflicting objectives, political complexity, dynamic context, repetition task, and multiple actors involved (Balint et al., 2011). One of the major complexities of energy planning, both nationally and regionally, relates to the quality and data access (Cajot et al., 2017).

In addition, the formulation of complex problems related to energy planning process has not been clearly discussed in literature (Cajot et al., 2017). Therefore, there is a need to describe and identify complexity issues in the energy planning processes (Cajot et al., 2017). Further, some case studies are necessary to identify and to frame the complexity issues systematically (Balint et al., 2011).

Therefore, the main objective of this research project is to improve energy planning process by using Agent-Based Knowledge Framework, particularly agent-oriented analysis. It aims to reduce complexities and knowledge gap in energy planning process, by raising the following main research question: "How can Agent-Oriented Analysis (AOA) alleviate several challenges of energy planning process". This research project will use the Design Science Research (DSR) method and engage seven Agent-Based Modellings (ABMs) of the Agent-Oriented Software Engineering (AOSE), including agent model, goal model, interaction model, scenario model, organization model, role model, and environment model. Then, the research question will be addressed through an agent-oriented analysis in the context of Indonesia case studies, especially Jakarta, Jawa-Madura-Bali (JAMALI), and national energy systems.

Overall, this research project will create and provide the developed knowledge framework based on Agent-Based Models in the field of energy planning process. Thus, this research project will give a significant contribution to energy stakeholders in many countries, which composed of policy makers in various ministries, energy utilities, energy planners, energy analysts, and energy researchers to facilitate them in effective energy planning. The rest of this paper is organized as follows. The next section reviews analytical tools for energy system modeling. The third section introduces agent-oriented analysis and seven agent-based models. The fourth section presents the DSR method framework and describes research scope. The fifth section provides research progress on the Jakarta Case Study, including identification of complexity issues in energy planning process, agent-based knowledge modelings, and initial knowledge analysis framework for energy planning system. Finally, the sixth section concludes with a discussion of future work.

Review of Energy System Models

This section reviews several analytical tools for energy system modeling, which can be used to perform energy planning studies in many countries. There is no single analytical tool that can be used to address all energy issues related to the energy system modeling because each energy analytical tool has a unique characteristic to meet the specific objective that must be solved (Connoly et al., 2009). This section aims to identify energy analytical tools that are suitable for analyzing some energy options (renewable energy and non-renewable energy) under several parameters, such as the number of users, scope areas, availability, and its features.

This research project has reviewed 35 energy-modeling tools, which used in various energy systems as shown in Table 1. These tools are categorized in this research based on its scope areas (global/national/island/regional/all scales) and number of users (very high/high/medium/low number of users). Then, this research project has categorized these energy-modeling tools, which have broader scope area, and high number of users based on its several functions. For instance, one of the function is to classify whether the energy-modeling tools can be operated as simulation tool, scenario tool, equilibrium tool, top-down policy tool, bottom-up policy tool, operation optimization tool, or investment optimization tool.

Table 1. A typical application of energy system tools

List of energy-modeling tools		
AEOLUS (Rosen et al., 2007)	H2RES (H2RES, 2017)	ORCED (ORNL, 2017b)
BALMOREL (Balmorel, 2017)	HOMER (Bekele and Palm, 2009)	PERSEUS (Perlwitz et al., 2005)
BCHP Screening Tool (ORNL, 2017a)	HYDROGEMS (Zoulias et al., (2006)	PRIMES (NTU, 2017)
COMPOSE (Energyinteractive, 2017)	IKARUS (Martinsen et al., 2006)	ProdRisk (SINTEF, 2017b)
E4Cast (E4cast, 2017)	INFORSE (Inforse-europe, 2017)	RAMSES (Cutsem & Aristidou, 2014)
EMCAS (CEEESA, 2017a)	Invert (Invert, 2017)	RETScreen (NRC, 2017)

EMINENT (Segurado et al., 2008)	LEAP (SEI, 2017)	SimREN (Herbergs et al., 2017)
EMPS (SINTEF, 2017a)	MARKAL (IEA, 2017)	STREAM (EAEA, 2017)
EnergyPLAN (Lund et al., 2003)	MESAP PlaNET (Schlenzig, 1999)	TRYNSYS (SEL, 2017)
EnergyPRO (EMD, 2017)	MESSAGE (IIASA, 2017)	UniSyD3.0 (Leaver et al., 2009)
ENPEP-BALANCE(CEEESA, 2017b)	MiniCAM (Brenkert et al., 2003)	WASP (IAEA, 2001)
GTMax (CEEESA, 2017c)	NEMS (EIA, 2017)	

(Note, the complete references in Table 1 does not show in this paper due to space limitations).

Based on several criteria above, this research suggests that the MESSAGE software (Model for Energy Supply System Alternatives and Their General Environmental impacts) is the preferred tool to conduct a case study on energy system planning because it has the following features and advantages:

- It can be used for the analysis of global, regional or national energy systems.
- It has a significant number of users; more than 115 IAEA (the International Atomic Energy Agency) member states are actively using MESSAGE.
- It can be used for the analysis of a very long timeframe; users can define the scenario duration of more than 50 years.
- It has many features that allow being used as a simulation tool, scenario tool, equilibrium tool, bottom-up tool, operation optimization, and investment optimization at the same time.

Agent-Oriented Analysis

This section introduces several important theoretical and technical issues related to the agent-oriented analysis. The term 'agent' is defined as a person or thing that acts, or is capable of acting, or is empowered to act, for another (Guralnik, 1983). It shows that there are two important points that we can make: i) the agent can perform a task or job, and ii) agent perform a task or job in certain capacities for something else. Based on these two points, Caglayan et al. (1997) define a software agent as an entity of computer software that allows the user to delegate tasks to software agent autonomously. Then another researcher has added one more point that the agent should run within the network environment (Brenner et. al., 1998). The paradigm of system development where multiple agents interact, negotiate, and coordinate with each other to carry out and complete the tasks is called the Multi-Agent System (MAS) (Al-azawi and Ayesh, 2013; Beydoun et al 2005). This architecture has proven effective in a number of complex applications where interactions between stakeholders is extensive e.g. Peer-to-Peer community based searching systems (Tran et al 2007; Beydoun et al 2011) and supply chain management (Xu et al 2011).

The Agent-Oriented Software Engineering (AOSE) methodology is a business process of system development by using different concepts and modeling tools of an agent (Akbari, 2010), and put agents as central modeling to evolve system development paradigm (Wooldridge, 1999). In line with the increasing complexity of projects related to software engineering, many AOSE methodologies have been created to develop an agent-based system, and to solve various types of problems in software engineering (Akbari 2010). There are many studies that discuss AOSE methodologies, for instance: MaSE (DeLoach, 2005), O-MaSE (DeLoach and Valenzuela, 2007), MESSAGE (Dam, 2003), Gaia (Wooldridge et al, 1999), Promotheus (Padgham and Winikoff, 2005), CoMoMAS (Glaser, 1996), MAS-CommonKADS (Iglesias et al., 1998), and Tropos (Mouratidis, 2009).

This research project will engage seven agent-oriented models to capture the knowledge framework for energy planning process. These models are easily derivable from a generic metamodels for MAS development. They cover more than 20 AOSE existing methodologies (Beydoun et al. 2009, Lopez-Lorca et al. 2016). They have also proven effective in engaging stakeholders in eliciting complex requirements for simulation systems (Miller et al. 2014), and in mapping disaster management knowledge (Inan et al. 2015) to a unifying format from (Othman et al. 2010). The seven agent-oriented models include the following:

- Goal model: to describe a system's purpose and goal's hierarchy.
- Role model: to define some roles to fulfill the system's goal.
- Organization model: to reflect the relationships between roles, and interactions between agents.

- Environment model: to describe each environment entity used by the MAS.
- Agent model: to define the individual agent classes that cover the roles.
- Interaction model: to set the basis for protocol models (system design phase).
- Scenario model: to provide detail descriptions of event sequences to achieve system's goal.

Research Methodology

There are two research methods in the field of Information System (Hevner et al. 2004). First, the behavioral science method, which has usually been used in natural science research. This method aims to explain human or organizational behavior by developing and verifying some existing theories. Second, the Design Science Research (DSR) method, which is usually used in engineering science research. This method aims to improve the capabilities of human or organization by constructing and designing new artifacts. This research project will use the DSR method to assist a problem solving through effective and efficient analysis of information system. The purpose of the design science method in this research project is to create and develop a knowledge analysis framework in the field of energy planning process that often been used by energy stakeholders to analyze and plan energy systems, for the short-term or long-term period.

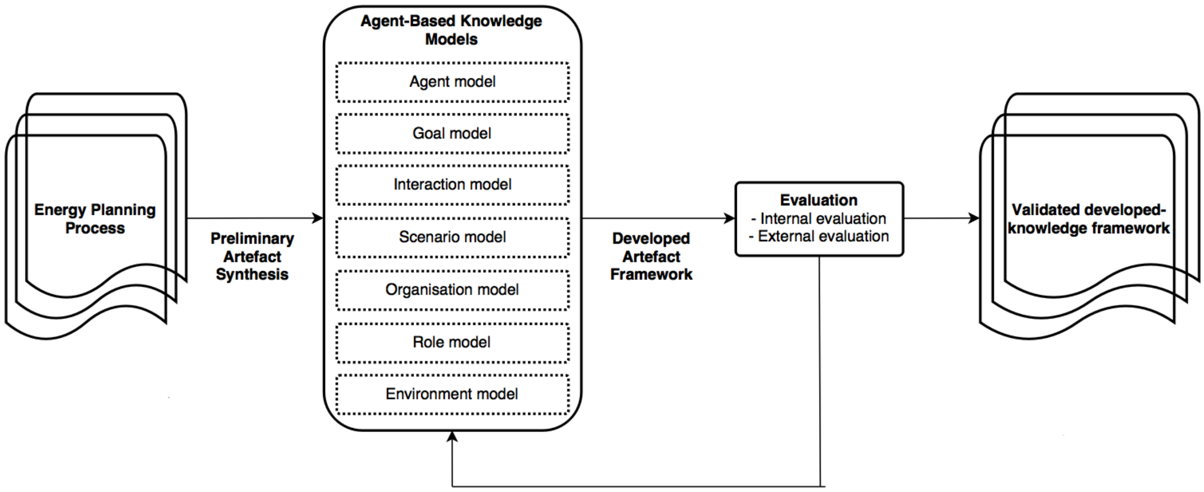

Figure 1. The DSR method framework.

Figure 1 illustrates that the DSR method employed in this research project is performed in four phases. The first phase (problem identification in the energy planning process) aims to provide a robust research justification in the actual research context and to contribute to the knowledge framework innovation. The second phase (development of knowledge analysis framework) is to develop an artifact for solving the research problem identified in the previous phase. The existing knowledge of energy planning process is used as an input in the knowledge analysis framework. It will be analyzed and structured comprehensively using seven agent-based models, including goal model, role model, organization model, environment model, agent model, interaction model, and scenario model. The output of this phase is the knowledge analysis framework that will be evaluated internally and externally in the next phases. The third phase (internal framework evaluation) is intended to find the effective way to solve the research problem (Hevner et al., 2004). The internal evaluation of the knowledge framework prototypes is conducted through validation of all artifacts that drawing up the developed knowledge framework by using specific case study. It aims to evaluate the reliability of the early versions of artifacts through several feedbacks and to develop the initial knowledge framework. The feedbacks that will be obtained in this phase are used as input for improvement before evaluating the framework externally with another real case study. The fourth phase (external framework evaluation) aims to assure that the developed knowledge framework can be implemented in the field of energy system modeling, particularly in the energy planning process, in different contexts. The external evaluation will be performed with another real case study, which is more widespread.

In short, this research focusses on how the agent-oriented methodology contributes to solving several complexity issues in energy planning process. It considers seven agent-based knowledge models, i.e. agent model, goal model, interaction model, scenario model, organization model, role model, and environment model. It will employ three case studies that use MESSAGE energy tool for their energy systems planning. The selected case studies are Jakarta, Jawa-Madura-Bali (JAMALI), and national (Indonesia) energy systems.

Ongoing Research (Jakarta's Energy Planning Case Study)

Jakarta energy planning process

According to the Jakarta Governor Decree No. 989 Year 2017, the study team of the Regional Energy General Plan (REGP) of the Jakarta province consists of six main organizational elements, including university, districts, regional planning agency, regional secretariat, regional department, and regional technical institution. The Jakarta's REGP may involve other national energy stakeholders as experts to support and provide data required for the study team.

Figure 2 presents the Jakarta's energy planning process, which consists of six main steps, including energy issues and study goal identification, an overview of existing energy system, calibration of energy system modeling, energy demand projection, energy supply projection, and analysis of result plausibility.

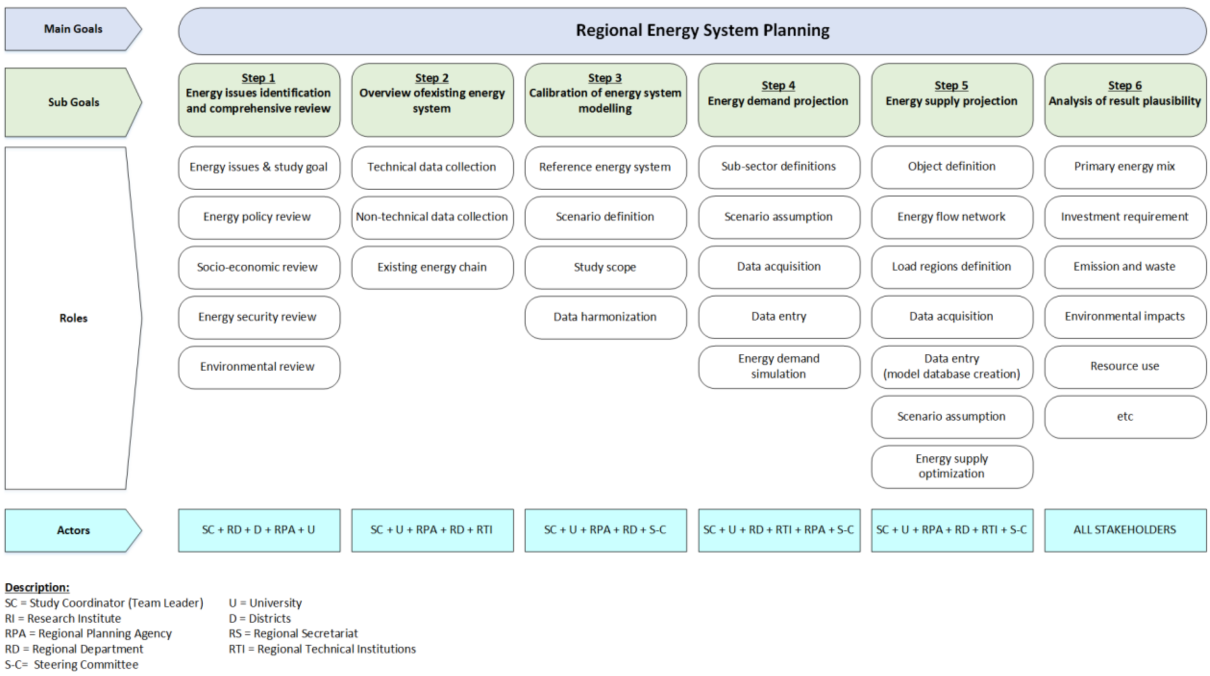

Figure 2. The Jakarta energy general plan process.

The first step aims to identify current energy issues and to define study goals. The second step involves the collection of existing techno-economic data and generation of existing energy chain. The third step aims to define study scenarios and study scope by harmonizing all existing data collected in the previous step, and calibrating the existing energy chain using IAEA's approach to obtain a reference energy system. The fourth step engages a MAED software (Model for the Analysis of Energy Demand), which is one of the IAEA's energy tools, to provide a detailed projection of sectoral energy needs based on several scenario assumptions, such as demographic developments, technological advances, economic structure, behavioral changes, and economic growth. The fifth step engages a MESSAGE software (Model for Energy Supply System Alternatives and Their General Environmental impacts) to formulate and evaluate alternative energy supply strategies in accordance with some defined constraints, in order to obtain energy supply projection. The sixth step involves all team members and stakeholders to analyze the projection results of energy supply and demand, collect several critical information from the study implementation that can be useful to solve the existing energy issues and the future energy challenges, and draft the Regional Energy General Plan (REGP) report.

Complexity Issues in Jakarta's energy planning process

Based on the Jakarta energy planning process (see Figure 2), this research identifies complexity issues (including *incorrectness, inconsistency, incompleteness,* and *redundancy*) in the following steps:

- The identification of energy issues in step 1.
- The harmonization of techno-economic data and study scenario characteristics in step 3.
- The sub-sectors definition of energy demand in step 4.
- The creation of future energy demand scenario assumptions in step 4.
- The object definition of the existing regional energy system in step 5.
- The load region definition in step 5.
- The creation of energy supply scenarios in step 5.
- The techno-economic data collection in step 2.
- The data collection for energy demand projection in step 4.
- The data collection for energy supply projection in step 5.

Agent-Based Knowledge Models

As illustrated in Figure 1, this research analyzes the Jakarta's energy planning process using seven agent-based models in order to obtain the agent-based knowledge models and the initial knowledge analysis framework as shown in Figure 3. This initial knowledge framework for energy planning process will be evaluated internally and externally, and verified using another case study to obtain the developed-knowledge framework for energy planning process.

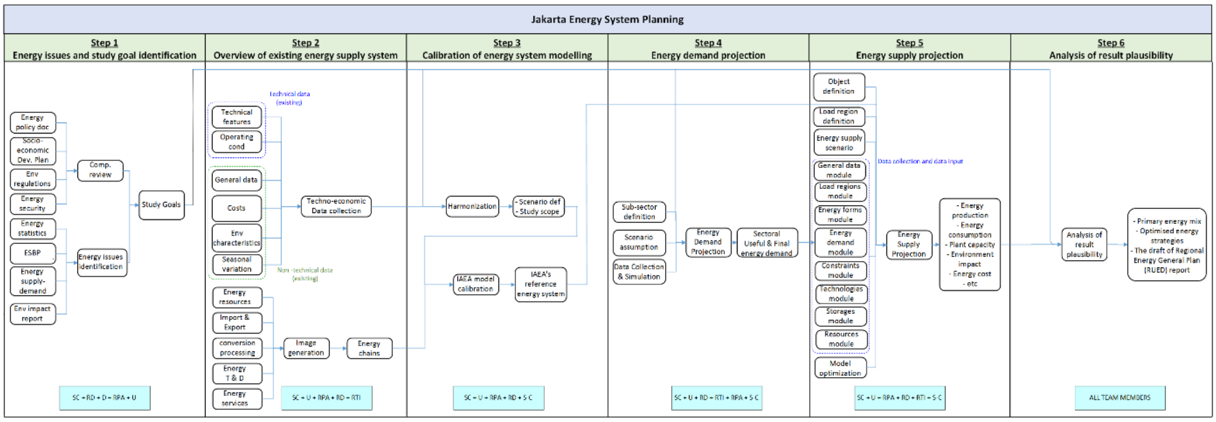

Figure 3. Initial knowledge analysis framework

The agent-based knowledge models obtained in this research are as follows. Due to space limitations however, only the main goal model is shown in this paper (Figure 4).

- The goal model and 17 sub-goal models cover almost all activities and steps (about 90) in the energy planning process.
- The 36 role models explain the responsibility of 36 actors/agents involved in the energy planning process, based on the Governor Decree No. 989/2017 and from actual experience.
- The organization model describes the work relationship and coordination between 36 actors/agents.
- The interaction models connect several activities with some actors. Each connection represents an activity that has to be done to achieve the goals/sub-goals.
- The 12 environment models where each environment entity has some attributes.
- The 36 agent models explain more detail about all activities, trigger, action, and environment entities of each actor.

- The 17 scenario models explain how each scenario starts and ends. It has extensive information such as scenario trigger, series/parallel activities, roles and environment entity involved in each scenario.

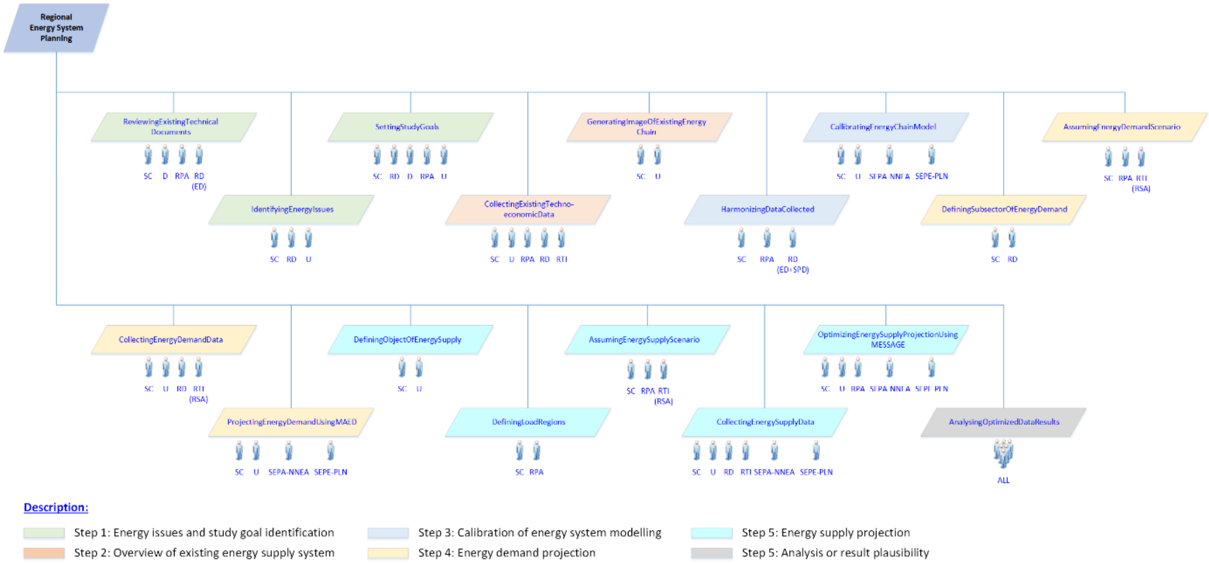

Figure 4. The main goal model of Jakarta Energy Planning Process.

Conclusion and Future Research

This research aims to improve energy planning process by reducing complexities issues in the energy planning process. The research methodology uses the Design Science Research (DSR) method and engages seven Agent-Based Modellings (ABMs) including agent model, goal model, interaction model, scenario model, organization model, role model, and environment model. To date, the research outcomes are as follows: Firstly, a literature review of energy system modeling that found MESSAGE software as an important energy tool in this research project. Secondly, a literature review of agent-oriented analysis that summarized only seven agent-based models used in this research project. Thirdly, complexity issues identification of energy planning system that found ten real problems in the Jakarta energy planning system. Fourthly, agent-oriented analysis of the Jakarta energy planning system that created several agent-based knowledge models and the initial knowledge analysis framework.

In order to reduce complexity issues of energy planning system and solve the problem statements, this research project will perform the third and fourth phase of the DSR method, namely the internal and external framework evaluation. It means that the initial knowledge analysis framework as knowledge framework prototype will be evaluated internally using seven agent-based models for another case study (JAMALI energy planning case study). The aims of the internal evaluation are as follows:

- To evaluate the function of each artifact, whether each of those artifacts meets the requirements expected in this research project;
- To assess whether the knowledge framework works properly to solve research problems; and
- To identify a discrepancy between the design and the needs before further testing is done in the next phase.
- To provide several feedbacks and to reveal the lacks of the beginning of the versions of artifacts.

Therefore, in the next phase, this research project will evaluate the developed knowledge framework externally using the other real case study (the national energy planning case study) to complete the assessment stage of the developed knowledge framework comprehensively. The external evaluation will be performed through the validation of several dimensions related to the scope case study, which is more widespread and involves several stakeholders with considering various backgrounds and characteristics. Finally, the output of this external evaluation is expected can assure that the developed knowledge framework can be generalizable implemented in the field of energy planning system modeling, particularly in the energy planning process, and applicable for any background of different countries.

References

Akbari, Z. 2010. "A Survey Of Agent-oriented Software Engineering Paradigm: Towards its Industrial Acceptance," *Journal of Computer Engineering Research* (1), pp. 14-28.

Al-Azawi, R., and Ayesh, A. 2013. "Comparing Agent-Oriented Programming versus Object-Oriented Programming", in *Proceedings of The 6th International Conference on Information Technology*, Jordan: IEEE Jordan Chapter, pp. 24-29

Balint, P. J., Stewart, R. E., Desai, A., and Walters, L. C. 2011. *Wicked Environmental Problems: Managing uncertainty and conflict*, Island Press.

Beydoun, G., Tran, N., Low, G., Henderson-Sellers, B. (2006) Foundations of ontology-based methodologies for multi-agent systems. In: Kolp M, Bresciani P, Henderson-Sellers B, Winikoff M (eds) Procs. AOIS2005 LNAI 3529. Springer, Berlin, pp 111–123

Beydoun, G., Low, G., Henderson-Sellers, B., Mouratidis, H., J. Gomez-Sanz, J., Pavon, J., and Gonzalez-Perez, C. 2009. "FAML: A Generic Metamodel for MAS Development," *IEEE Transactions on Software Engineering* (35:6), pp. 841-863.

Beydoun, G., Low, G., Tran, N., & Bogg, P. (2011). Development of a peer-to-peer information sharing system using ontologies. *Expert Systems with Applications*, *38*(8), 9352-9364.

Brenner, W., Zarnekow, R., and Wittig, H. 1998. *Intelligent Software Agents: Foundation and Applications*, Springer-Verlag.

Caglayan, A., Harrison, C., Caglayan, A., and Harrison, C.G. 1997. *Agent Sourcebook: A Complete Guide to Desktop, Internet, and Intranet Agents*, John Wiley & Sons Inc.

Cajot, S., Peter, M., Bahu, J.M., Guignet, F., Koch, A., and Maréchal, F. 2017. "Obstacles in Energy Planning at the Urban Scale," *Sustainable Cities and Society* (30), pp. 223-236.

Connolly, D., Lund, H., Mathiesen, B.V., and Leahy, M. 2009. "A Review of Computer Tools for Analysing the Integration of Renewable Energy into Various Energy System," *Applied Energy* (87), pp. 1059-1082.

Dam, K. 2003. *Evaluating and Comparing Agent-oriented Software Engineering Methodologies*, Ph.D. thesis, School of Computer Science and Information Technology, RMIT University, Australia.

DeLoach, S., and Valenzuela, J. 2007. *An Agent-Environment Interaction Model*, Agent-Oriented Software Engineering VII, Springer Berlin Heidelberg, 4405:1-18.

DeLoach, S. 2005. *Multiagent Systems Engineering of Organization-Based Multiagent Systems*, ACM SIGSOFT Software Engineering Notes (30:4).

Glaser, N. 1996. *Contribution to Knowledge Modeling in a Multi-Agent Framework (the CoMoMAS Approach)*, Ph.D. Thesis, The L'Universtite Henri Poincare, Nancy I, France.

Guralnik, D.B. 1983. *Webster's New World Dictionary*, Prentice Hall School Group.

Hevner, A.R., March, S.T., Park, J., and Ram, S. 2004. "Design Science in Information System Research," *MIS Quarterly* (28:1), pp. 75-105.

IAEA. 2001. *Wien Automatic System Planning (WASP) Package*, International Atomic Energy Agency, Vienna, Austria.

IAEA. 2007. *Analyses of Energy Supply Options and Security of Energy Supply in the Baltic States*, IAEA-TECDOC-1541, International Atomic Energy Agency, Austria

Iglesias, C., Garijo, M., Gonzales, J.C., and Velasco, J.R. 1998. "Analysis and Design of Multiagent Systems using MAS-CommonKADS," in *Intelligent Agents IV (ATAL97)*, Springer-Verlag, pp. 313-326.

IIASA. (2017, 3 May). Energy Modeling Framework. International Institute for Applied System Analysis 2017. Retrieved from http://webarchive.iiasa.ac.at/Research/ENE/model/message.html.

Inan, D. I., Beydoun, G., and Opper, S. 2015. "Towards Knowledge Sharing in Disaster Management: an Agent-Oriented Knowledge Analysis Framework," in *Proceedings of the 26th Australasian Conference on Information Systems* (ACIS2015), Adelaide, South Australia, pp. 1-13.

Lopez-Lorca, A. A., Beydoun, G., Valencia-Garcia, R., and Martinez-Bejar, R. 2016. "Supporting Agent-Oriented Requirement Analysis with Ontologies," *International Journal of Human-Computer Studies* (87), pp. 20-37.

Miller, T., Lu, B., Sterling, L., Beydoun, G., & Taveter, K. (2014). Requirements Elicitation and Specification Using the Agent Paradigm: The Case Study of an Aircraft Turnaround Simulator. *IEEE Transactions on Software Engineering., 40*(10), 1007-1014.

Mouratidis, H. 2009. "Secure Tropos: An Agent-Oriented Software Engineering Methodology for the Development of Health and Social Care Information Systems," *International Journal of Computer Science and Security* (3:3), pp. 241-271.

Othman, S.H., Beydoun, G. (2010) A disaster management metamodel (DMM) validated. Knowledge Management and Acquisition for Smart Systems and Services: Springer. pp. 111–125.

Padgham, L., and Winikoff, M. 2005. "Prometheus: A Practical Agent-Oriented Methodology," in *Agent-Oriented Methodologies*, B. Henderson-Sellers and P. Giorgini (eds), London: Idea Group Publishing, pp. 107-135.

Tran, N., Beydoun, G., & Low, G. (2007). Design of a Peer-to-Peer Information Sharing MAS Using MOBMAS (Ontology-Centric Agent Oriented Methodology). In W. Wojtkowski, W. G. Wojtkowski, J. Zupancic, G. Magyar, & G. Knapp (Eds.), *Advances in Information Systems Development: New Methods and Practice for the Networked Society* (pp. 63-76). Boston, MA: Springer US.

Wooldridge, M., Jennings, N.R., and Kinny, D. 1999. "A Methodology For Agent-oriented Analysis and Design," in *Proceedings of the third annual conference on Autonomous Agents*, pp. 69-76.