CHAPTER 5

FINDING, DISCUSSION, FUTURE WORK AND CONCLUSION

5.1 Finding

5.1.1 Research Management

Research is a very important component of competent organization. Many organizations, including universities, realize that and attempt to achieve high quality research. Universities support their lecturers to conduct research in many ways including funding large number of budget. However, there are problems with research management on the research information to formulate research strategy and policy. The information is always incomplete and dynamic because many researchers are not willing to share their research information and, sometimes, they change their interest in research topic due to their grantors, their research resources, and new trend of academic.

In this thesis, CMU was chosen as the case study because CMU is one of the leading universities in Thailand. As same as other leading universities, CMU has been conducting research management in term of both policy and funding for a long time. Research fund is divided into 3 groups in CMU which are; 1) Seed fund group which is funded by CMU to enhance research skill of new researchers 2) Thesis or curriculum fund group which is funded by either CMU or the government to support both thesis and curriculum development 3) Research fund group is the fund focusing

on topics required from private business groups both domestic and oversea. CMU also faces with incomplete and dynamic research information as same as other universities. The lack of information makes the expertise and research direction of researchers unknown to the administrators. The information is required to answer to grantors and formulated research policies more efficiently. Those policies are about managing research fund, creating researcher evaluation mechanism, and establishing research centers of excellence.

Incomplete Information: Problem of incomplete information can clearly be seen at the information collecting process. It is found that some questionnaires sent to candidate key researchers were returned without answer in some fields, because candidate key researchers could not remember their information or let their staffs entered the data for them when, sometimes, their staffs did not know all those data. The percentage of returned questionnaires is 35%. It was quite low because of two reasons following the hypothesis; candidate key researchers forgot their information or they were so busy. Almost all of the candidate key researchers are lecturer, and they have more responsibility in teaching, researching, and doing academic services. The huge workloads made researchers ignore miscellaneous jobs such as answering questionnaire as they do not see the benefit in them. However, some cases are beyond the hypothesis, some researchers answered the questionnaires because they fear that they might offend the head of CMU Research project, also Vice president of Research Affair, even if they could not return it on time. This shows that the administrators have some effects on pushing the job forward if they are involved. Nonetheless, researchers may not answer some information that could cause disadvantages to them,

for example, the number of research fund received from outside organizations which, according to CMU's policy, the university is entitled to collect 10% of the fund. Therefore administrators have to choose between collecting the 10% from research fund and knowing the real information to manage researches more efficiency.

Dynamic of Information: Problem of dynamic of research information is not clearly shown in information collecting process, because of the limitation of CMU research team knowledge. The team could not understand all researchers' work so they would not know if researchers changed their research topic. Keyword collecting process from questionnaire and publications in electronic databases found that, sometimes, the keywords from both sources do not match. It could be implied that researchers changed their research direction. However, sometimes it was unclear because researchers might give ambiguous keywords, e.g. they gave too broad or too few keywords. Hence, CMU research team was not sure if the researchers had changed their research directions or not. A conversation with representatives of candidate key researcher found that some researchers changed their research topics because they changed their interest, changed their research to be multi-discipline, changed funding source, or changed according to thesis topic of their advisees.

Incomplete and the dynamic of information is AI problem, which text mining technique and semantic web technology are needed for solving. This thesis proposed new framework for research management using both methods.

In the proposed framework, the very sensitive process was identifying key researcher process. This step was very difficult to figure out clearly without conflicts because there are many conditions that have to be considered in this step.

Key researcher identifying: The first consideration was identifying the suitable key researcher criteria. The appropriate key researcher criteria should be proposed by public hearing with a consensus between university's administrators and representative of key researchers. The administrators cannot solely determine the criteria even though it will perfectly suit the administrators' target, but it will raise many arguments as the administrator do not fully understand the nature of all disciplines. In the public hearing meeting arranged in CMU project, everybody shared their opinion, argued, and explained all unclear points until everybody accepted framework as their commitment.

Meaning of key researcher: Another important factor that has to be considered while determining the criteria is different meaning of key researchers in administrators' opinion in each level. University administrators need key researchers in order to establish new center of excellence in variety branches. Thus, this group of key researchers has to be qualified by using criteria defined by university administrators. At faculty level, administrators require key researchers for different objective, that is, the key researchers are the research leaders, the one who can win bids for fund from outside especially from aboard, and who can be a mentor or a supervisor for new researchers. Meanwhile, administrators at department level expect the key researchers to be consultant, leader, head project researcher department, and the star researcher. Hence, the last two groups of key researchers had to qualify by using criteria from faculty administrators and department administrators respectively.

Key researcher criteria: Nature of each discipline defines the difference in key researcher criteria. For example, criterion about Impact Factor of Health Sciences and Science & Technology differ from criterion about Impact Factor of Social Sciences & Humanities because small numbers of researchers of Social Sciences & Humanities publish their papers in international journals. Most of them published papers in national journals, which no have Impact Factor value.

Furthermore, some criteria are different even if researchers are in the same discipline but in different subject. For example, criterion about Impact Factor of Biotechnology and Engineering are different because average Impact Factor of Biotechnology is around 3.2 while Engineering average Impact Factor is around 0.8. If the criterion determines the minimum Impact Factor to be 3.0, it is impossible for engineering researchers to pass the criterion. Therefore, criteria should be flexible and suitable for all exception condition as well.

From the reasons above, representatives of candidate key researcher advise the researchers from low Impact Factor department to co-publish with other department with high Impact Factor. For example, Mathematics should publish with Biology researcher to obtain the Impact Factor 10. However, some departments cannot solve the problem with this method because the content of subject might not relate to any other subject.

Impact Factor criteria: From the study about Impact Factor found that papers published in high Impact Factor journals do not mean the citations are also high because Impact Factor might be high because of another papers. Likewise, low Impact Factor journals may have high citation. Consequently, Impact Factor value cannot

determine who the key researchers are, and other criteria such as citation value should be considered as well.

However, using citation as criterion leads to the problem of researchers' self citation to increase their citation value. Sometimes researchers agreed with their colleagues to cite each other papers to increase their citation numbers as well. This is a very sensitive case in every university and the university should plan to handle this in the future.

Publication criteria: For criterion of publication, the meeting with CMU library staffs, librarians suggested that another electronic database should be used aside from ISI Web of Science and Scopus, i.e. SciFinder Scholar, Academic Search Premier, H.W. Wilson, and PubMed to increase the accuracy of publication information. The testing of SciFinder found that most of its information matches with information retrieved from Scopus, but with fewer results. Furthermore, other electronic databases do not have impact factor and citation value. Thus, CMU research team decided to use only Scopus and ISI Web of Science.

Social Sciences & Humanities criteria: Defining the criteria for Social Sciences & Humanities discipline is the problem of this thesis because the research nature is very different from Health Sciences and Science & Technology discipline. Representatives of candidate key researcher suggested that key researchers of Social Sciences & Humanities should be identified by interviewing researchers in Social Sciences & Humanities discipline or evaluating their recognition. The recognized researcher is researcher who has high potential in research and his/her research results

have high social impact. The recognition should be evaluated by researchers who work in the same field, and this might raise problems if they were in conflict individually, because the evaluation might be bias. This problem should be studied elaborately to find suitable solution in the future.

Representatives of candidate key researcher and librarians of CMU library recommended Social Sciences & Humanities department that if Social Sciences & Humanities department focuses mainly on publishing their papers in Thai journals, then it should considers only on top Thai journals, journals produced by institutes or government, or professional journal acknowledged and accepted by academic social. Furthermore, articles should be classified into two levels, analytical article or general academic article. However, from information collecting process found that librarians had indexed only 101 journal titles from 206 journal titles. Hence, CMU research team was not sure that all articles of researchers were examined. Additional researchers' articles did not only have different content, but also different in number of pages and written style. If researchers were compared by only the number of articles, it might raise many arguments. Due to ambiguous publication criteria, the criteria used for this study for Social Sciences & Humanities researcher is that the researcher must *published at least one article in international scientific journal that has impact factor*. Nonetheless, more suitable publication criteria should be defined in the future.

Some Social Sciences & Humanities researchers published their articles in newspapers, which CMU librarian suggested that newspapers should be divided into two groups, hard news and soft news for classifying level of newspapers. However, articles in newspapers were still different as same as articles in journals. Thus,

evaluating value of articles is a time consuming process and should be done by specialist, and this study has to ignore this criterion due to time limitation.

Academic conference criteria: From the conference arranged by Office of the Higher Education Commission, some researchers asked why participation in academic conference does not count as one of key researcher criteria. From the study found that the difficulty level of each academic conference is different. If CMU research team compared only participation number in conferences without considering their difficulty, the result might not express the truth. Furthermore, conferences do not have any index to measure the quality of those conferences as Impact Factor of journal. At present, there are no databases that provide complete information of conferences. Some electronic databases offer conference information such as IEEE/IEE Electronic Library, SciFinder Scholar, Web of Science and, ACM Digital Library, but they still do not cover enough conferences information, especially national conference. Therefore, participation in academic conferences does not count as one of key researcher criteria in this thesis. But if electronic databases are developed and provide more information about conferences, then such kind of criterion may be considered in the future. However, the level of participation might be considered and classified as well, i.e. participation as keynote speaker, invited speaker, general participant and so on.

Award criteria: The criterion about research award is a believable criterion because most of the research awards are already confirmed by the owners of those awards; especially *learned man* award which is widely recognized. However, the

weakness of this criterion is that some high potential researchers do not apply for any award. These researchers did not receive any award corresponding to their ability, so other criteria should be used in parallel since the administrators could not identify these researchers.

Patent criteria: Representatives of key researcher suggested that 1 patent, *created a recognized innovation or patent*, is not enough to evaluate key researchers. Patent should be further classified as national patent or international patent. This could be determined by using EUROPEAN Patent Office website (http://ep.espacenet.com/advancedSearch?locale=en_EP) or USPTO website (http://appft1.uspto.gov/netahtml/PTO/search-adv.html). Although only two results were found when searches for Chiang Mai University in EUROPEAN Patent Office website, but if CMU administrators formulate as one of CMU policies in the future, the researchers would credit CMU in their patent.

Social capital criteria: One more criterion proposed by representative of key researchers is Social capital. Researchers with high social capital are researchers who contribute to the research for a long time and many people recognize and respect them. These key researchers are identified by administrators, because they are known by works. However, sometimes, administrators do not recognize them because the administrators are from different fields or they are new and come from other organization. To solve this problem another solution should be used.

In addition, social capital might refer to the capital of capability of group of people to cooperate based on trust. In this study social capital was analyzed by keywords of all candidate key researchers.

Keyword identifying: Defining new keyword identifying expertise and research directions of candidate key researchers is the troublesome process. The early keywords of candidate key researchers were defined by Research Deputy Dean, and these keywords were too broad. The result was most of candidate key researchers in the same department seem like they were doing the same research topic. CMU research team tried to use other way by sending questionnaires to candidate key researchers. Although direct information was received but some keywords were too broad, some keywords were too narrow, and sometimes the keywords are not cover all researchers' expertise, because researchers did not know the objective of keyword collection. Thus, CMU research team had to take more time to collect keywords by phone call, which CMU research team was able to explain more and researchers could give clearer keywords. However, this took more time and sometimes researchers were not happy to answer because they were busy and think it is impolite to ask via phone. The other problem is most of keywords were technical term that CMU research team could not understand clearly so they could not record perfectly. In addition, some items in the questionnaire were not returned, so CMU research team used the keywords collected from candidate key researchers' publication instead. The keywords from publication were too narrow and hard to analyze. That is why ontology was chosen to store this kind of information, and the result of this step was

CMU ontology commitment. It is represented in hierarchical format and all narrower keywords or specific keywords can be interpreted by using their superclass.

Due to many different sources of keywords, the keywords from questionnaires were used as the primary source. The keywords were then classified by card sorting technique into three groups; Application, Methodology, and Subject. The limited knowledge of CMU research team made this step difficult as they did not know which card to put under a topic and which card should be used twice. The team asked some of candidate key researchers to help running this process, and the result was more accurate and precise to the truth because candidate key researchers know each other well and they usually know more detail than information on the cards.

The public hearing with the representatives of candidate key researcher suggested that researchers should define their own keywords based on research strategic of Office of the Higher Education Commission. Card sorting will be done easier and faster by following research groups of Higher Education Commission. In addition, card sorting will be more efficient if researchers do it by themselves. However, some keywords were not mentioned in Higher Education Commission but they were niche of CMU which already had high skill and research potential. Thus, this kind of keywords could be counted as one group of research cluster.

Card sorting technique: Representatives of candidate key researchers suggested that some research clusters from card sorting technique could be used to create new research network with other universities, for example, CMU Archaeology could cooperate with Chiang Mai Rajabhat University to strengthen the research group. Some keywords could be linked to each other such as *Multimedia* and *Textile*

& *Fashion* to establish multi-discipline research group and support research direction of CMU. However, in practice, researchers from two groups might not want to cooperate because of individual problem or they use different KPI. Therefore, the university, faculty, and department policies have to be revised.

Due to recommendation of candidate key researchers that researchers should do card sorting by themselves, Dr. Nopasit Chakpitak, one of CMU research team, arranged the workshop at The Social Research Institute and faculty of Agro-Industry. Participants were composed of lecturers and related staffs. Dr. Nopasit Chakpitak started by lecturing about the theories of Knowledge Management for basic understanding of all participants. After that, card sorting technique was applied for creating semantic model or root ontology and research groups were created based on keywords of those researchers. The observation found that all participants were happy and enjoyed building their own ontology commitment, and everybody helped each other to solve problems while Dr. Nopasit helped with the technical issues. The result was ontology commitment that is precise to real expertise and research directions of researchers, and it is accepted by everyone as well. This method was very useful to built ontology commitment but it took a long time to proceed.

Other way to build research cluster was analyzing the social network of researchers who had co-published before with *Cytoscape,* the open source software used to generate this network in graph format. Representatives of key researchers said that this manner was very good for showing overall image of research group. This also showed the key researchers' ability to work with other people broadly, leading to new research networks and teams. Each research group was identified by a keyword or name that describes the overall expertise of this group. Moreover, it should cover

all keywords in social network which are the strength of CMU, and it should be in use modern terms, not outdated technology.

Keyword from social network: CMU research team defined keywords as metaphors Immunology - Toxicology – Biochemistry. This keyword was different from old keyword because it expanded research boundary and reduces the difference of subjects, departments, faculties, and institutes. This kind of keywords will allow researchers to cross research cover more fields. Furthermore, these keywords are also used to mobilize new knowledge and bring in new research fund in the future as well.

The obtained social networks can be use as guideline for creating new social networks. The way to support this kind of networks is formulating policy such as setting up new research fund for these groups or encouraging them to publish more.

Applying Framework: The proposed framework in this thesis can be applied to any university, but detail of each step might have to be adjusted. For example, identifying the key researcher criteria should be determined by administrators and researchers of each university, and each university may focuses on different point. Some universities focus on research patents while some focus on consulting projects or academic services. In additional, the complete of each research database might be different as well. If research database of some universities is complete, especially information about conference participation of researchers, they can use it as one of key researcher criteria.

Electronic database: Another different process in framework is electronic databases used for collecting researcher publication. Each university always subscribes different databases from existing databases. They may use ISI web of Science or Scopus, or they might use any other suitable journal index without impact factor and citation values instead.

Researcher criteria: When apply this framework, not only university administrators and representatives of candidate key researcher take responsibility to define key researcher criteria, but it involves the faculty and department administrators too. This depends on who will use those key researchers. Furthermore, stakeholder of the research such as grantors, and users of research results should be involved as well. However, stakeholder of Social Sciences & Humanities discipline may not be able to define clearly because the stakeholders are the social and community.

Intellectual capital: Due to unstable of criteria, researcher performance should be collected completely and correctly by Skandia model to support changes of the criteria in the future. Skandia Model is the efficient tool to present the actual capital, including financial and intellectual capitals, produced by researchers. Some capitals may not be in term of money but it would generate money in the future, i.e. patent, citation, and Impact Factor. University administrators should not overlook this kind of capital as grantor can use it allocate research fund. This capital is trust capital or intelligent capital that could be used as key researcher criteria in the future. Current

researchers in universities try to generate this kind of capital by developing more research performance based on the grantors or KPI of their university.

Even though Skandia model could specified all intellectual capital, some capitals are too subjective to measure or compare quickly without bias such as fame or the reputation of key researchers. Identifying key researchers is a very sensitive process, and using an evaluation that does not provide concrete proof may result in arguments and disagreements in the future. Nonetheless, stakeholders will still follow their own value perception from intellectual capital model whether the researchers agree or not.

Many good subjective criteria can be used as one of criteria in the future, but the point is who will evaluate these criteria as each university may interpret them in different ways. Furthermore, appropriate techniques for transforming these criteria to objective value should be defined to populate these values into Protégé. The examples of these techniques are peer-to-peer scoring by candidate key researchers and Delphi technique by representative of candidate key researchers, but those techniques take time to run and the result could be bias if there are some conflicts between researchers.

Public hearing: Public hearing between administrators and candidate key researchers for considering key researcher criteria should be conducted. It is a very important process in the framework as it made the rest of working step easier. Participants of the meeting should compose of all disciplines in universities. The advantage is many good suggestions will be contributed by all disciplines. In addition, the idea from brain storming will refine the proposed framework more suitable,

practical, and creditable. Another advantage is the alliance between most of the researchers and the administrator.

Research cluster: Policy formulation for research management is a very important process to establish research network that fits the current situation of university research. Four groups of research were set up from the pilot project.

1.) The high potential research cluster

2.) The niche research cluster

3.) The new trend research cluster

4.) The research cluster from social network

By using the framework, CMU was able to plan the development of each research cluster related to market share and market growth of the world. The first research cluster has high market share and high competitiveness, and this cluster has the potential to establish the center of excellence. The second group has low market share but it is CMU niche, so the administrators should keep pushing this group for the benefit of the communities and the new generation. Market share of new trend research cluster is low but the market growth is high, so CMU should develop more researchers to support this trend. The last group is very interesting, because this cluster exists in the form of co-publishing, creating the social network. Keywords of the publishing network are used to synergize key researchers such as Immunology - Toxicology – Biochemistry. These groups have the potential to submit for research fund in many branches because of the broad keywords.

Even though the university had formulated good research policy and strategy, knowledge workers should be managed as well. Thus, conference should be organized

for each Research Deputy Deans to present research direction of their faculties, so others faculties will acknowledge these topics which they could join or link with their faculties. This is the alignment for synergizing and increasing multi-discipline research groups. For new researchers this conference might inspire them and let them know which research direction they can link to or extend further.

Moreover, Health Sciences and Science & Technology should develop more inter-discipline research with Social Sciences & Humanities to avoid the situation where researchers work solely on sciences and overlook the element of human and society.

5.1.2 Methodology

Semantic web technology was used to solve problem of dynamic and incomplete research information, and then semantic model or CMU ontology commitment was implemented in Protégé. After that, inference step and SPARQL was used to increase efficiency of analyzed research information.

Semantic web technology: Technical process found that the design of semantic web technology was the most difficult part, because good ontology designer should have experiences in database design as an appropriate design will be able to support all predicate logic statements in the future. Writing up the conditions or restrictions with predicate logic will be hard or impossible if the ontology design is not suitable. An important thing is the designers should understand all options supported by Protégé for designing the functional ontology.

Ontology design: The criteria in the thesis were complicate so the designed ontology was also complicate. Even though ontology was designed in variety ways following key researcher criteria, but sometimes it did not work, such as criterion about publication, because the ontology does not support this kind of problem or the ontology design is wrong. Currently, Thailand lacks the experts in semantic web technology who can confirm the design. Thus, experts in this field should be developed to support variety of knowledge base in the future.

In the future, requirement of administrator might change and become more complicate, i.e. each criterion has different priority. Award criterion might be more important than patent criterion, and patent criterion might be more important than publication criterion. Writing the predicate logic for this condition is a challenge. Sometimes not only predicate logic is changed but also the ontology design as well, but these new predicate logic statements will increase the intelligence of the system. The old predicate logic statements do not become useless as they will be collected in the system as rule base even if they are in conflict with the old rule base. The system will be smarter, similar to the learning human brain. All learning of the system might not be required at present, but they might be needed when situation changes in the future. Similarly, the appropriated rule base could be called immediately when the input variable changes. This means ontology can be created by deductive method.

Protégé: Creating OWL file from the designed ontology in Protégé is more convenient than using other editor. There are many options supporting variety functions. However, the problem with Protégé is the lacks of manual or instructions for new version. There are a lot of tutorials for older version of Protégé, but new

version has new options and different menu so it takes time for learning without the tutorial. Also, the new version of Protégé does not support the OWL file developed by lower version.

Inference engine: A non-open source add-on program called Racer Pro needs to be downloaded for inference step. Although Racer pro has academic license, which is free for academic use, but it still has expiry date. Therefore, it does not suit noncommercial organization.

Query Language: Syntax of SPARQL used to query ontology in Protégé was a problem. It has different style of query language to relational database, so users who are familiar with relational database might need to adapt themselves because SPARQL is more complicate. Moreover, the interface for writing SQARQL is not user friendly as its syntax error was not clear and users took more time to correct it.

The problems above show that if semantic web technology can be upgraded to be real AI, one branch of knowledge engineering. The problems could be solved easier than this.

5.2 Discussion

From information collection process, there were many techniques for storing research information. The detail of each technique is discussed as follows.

Survey: Initially survey was used to gather direct research information. However, the number of questionnaires returned was low so the statistic result does not reflect the reality. In additional, some researchers did not complete the

questionnaires and some of them misunderstood the questions. When CMU research team received the right information, new statistic value took more time to recalculate. Furthermore, relying only on survey cannot answer administrator questions such as identifying the key researcher, because the information received from survey comes in quantity, not quality.

RDBMS: RDBMS was used for storing information after the survey. RDBMS helped speed up information retrieval and analyzed the information in many point of views generated with query language. However, the complicate questions were the difficulty in transforming to queries, because sometimes queries are written to be more complex to support complicate questions such as identifying key researchers.

OODB (Object Oriented Database): OODB was tested for storing information while finding suitable technology. It was found that OODB could solve problem of identifying key researcher in each level of management by using override method. This method was coded based on key researcher criteria in superclass and it was overridden in subclass, which was key researcher group in the others level of management. For example, if superclass was Science & technology key researcher, then the subclass is Engineering key researcher. Method for identifying Engineering key researcher would be to override at minimum of impact factor with the new one. However, it was found that OODB could not solve the problem on the meaning of researcher keywords.

Semantic web technology: The experiment found that storing information with semantic web technology or ontology was better than using RDBMS, because information was organized similar to the information in human brain. Human brain stores information related to each other to remember. Human always remembers keywords as sets of synonym, metonym, and related terms. The format of those sets is hierarchy and there are relationships between each hierarchy. After organizing information in this format, the outputs can generate both quantity and quality information. Furthermore, key researchers identification does not require complicate queries, unlike using RDBMS, especially key researcher identifying for each level of management (university level, faculty level, and department level).

When researchers change their research topic, the information in the system will be out-of-date as well. The system was able to give the research topic of each researcher if the new topic is not far from the old topic or they are in the same field. For example, researcher changed the topic from *intellectual capital theory* to *learning in action theory*, the system would answer that expertise of this key researcher is *knowledge management* by looking at higher level (super class) of the old keywords. In a worse case, if the researchers changed their topic entirely to a different field, text mining technique should be used for collecting new keywords automatically.

Finally ontology was the best solution for the conditions of this thesis. Furthermore, ontology was able to support more complicated questions such as which research cluster should be established and what is priority of each research cluster.

Development of research management with information technology: The proposed solution of this thesis could be considered as the development of research

management for applying information technology and knowledge management in universities. Literature review found that research management of universities was developed by implementing information technology in many ways. Some of them applied information technology to improve their efficiency such as developing portal web and data repositories in research, using blog or weblog to establish a social network to discuss and exchange opinions with other researchers in the same field, or using electronic databases to find articles in each field to follow the advancement in the field (Castellanos, & Rodriguez, 2004), or developing research repository or research management system as database system and management information system (MIS). Furthermore, knowledge management has been used to enhance the capacity of research management as well, for example, motivating skilful researchers to share their knowledge to other researchers by establishing research repository and portal (Kidwell, Linde, & Johnson, 2000), creating research management system to preserve research information such as research proposal, publications, and research funds (Davey & Tatnall, 2007; Leung & Low,2005; Palomo, Veloso & Schmal, 2007), strengthen decision-making ability in research management by searching for the key drivers of key success factor (Castellanos, & Rodriguez, 2004). Current semantic web technology technique such as ontology is applied to research management as well, for example, improving the search in knowledge management system (KMS) to increase knowledge sharing among researchers (Wang, Yang, Kong, & Gay, 2003), and build knowledge management portal to provide lecturer profile and knowledge assets, e.g. lecturer teaching load research, publication, etc. In this portal taxonomy was used for storing researcher performance (Hashim, Hamid, Selamat, Ibrahim, Abdullah, & Mohayidin, 2006).

When users want to evaluate teaching workload for lecturers, complex programming code had been written, which indicates that information in taxonomy form did not answer complicate questions easily.

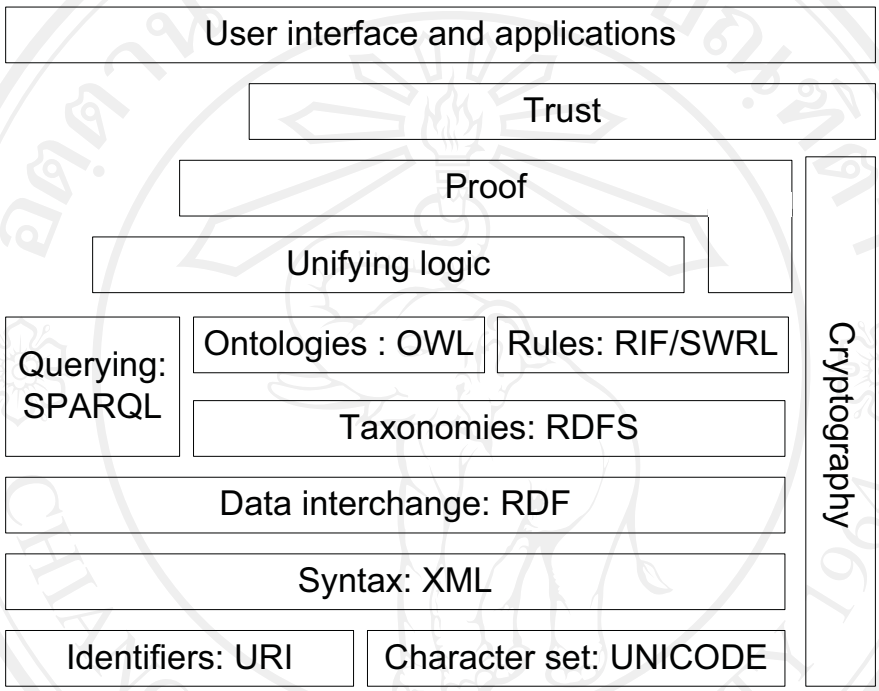

Figure 5.1 Semantic web stack ("Semantic Web Stack", 2010)

Figure 5.1, semantic web stack shows that taxonomy is in the level lower than ontology, because taxonomies represent data in hierarchical format without relationship. Thus, taxonomies cannot represent the relationship between two hierarchies, and it cannot answer more complicate questions involving two hierarchies.

This study found that there were many hierarchical trees related to each other in the research, e.g. hierarchical tree of researcher related to hierarchical tree of subject, application, and methodology. That is why by using ontology the more complicate

questions could be answered, for example, who applied the research in rice? This question has to use both hierarchy of researcher and hierarchy of application to find the relationship between two hierarchies.

Present semantic web technology is mega trend for organizing of web documents. Additional web technology has been conversed to ontologies and used SPARQL as query language.

Human Behavior: Even though technology is able to increase efficiency of research management, but human behavior is other issue that should be considered. The experiment found that researchers are not willing to give their own research information to CMU. This is the problem about researcher behavior. Text mining technology was used to correct this but researcher behavior should be adjusted as well. If researchers were willing to input data, research management will be done easier and more efficiently. To achieve this, administrators should formulate incentive policy for research information contribution. This should cover everybody who provides the information, i.e. candidate key researchers themselves, new researchers, and related staffs. The example of incentive policies are research information contribution can be considered as personal workload for increasing salary, research information contribution can be counted as score for increasing bonus, or research information contribution can be one of quality assurance index. These policies might improve researcher behavior finally.

Administrator behavior is another important issue that every organization should take interest in, because administrator is an important person who can push the

achievement of research management. The experiment found that administrators should have characteristics and behaviors as follow:

1. Administrator should understand the nature of research in every subject in his/her organization, not only his/her subject, for his/her management to be fair and suitable in every subject.

2. Administrator should be open-minded, respect others' opinions, and able to accept different working style, because Health Sciences, Science & Technology, and Social Sciences & Humanities are different in many aspects. Many processes dealing with these three disciplines are sensitive so administrator should consider them more carefully and thoroughly. Only one rule could not work with all subjects, and any rule or any criterion set up have to be flexible. Therefore, the team should compose of staffs from every discipline to suggest their aspects.

3. Administrator should support research management by word, action, and budget to every discipline. Even though research management is the background process without seeing the obvious results, need time to proceed, and need much more and many more man power and money, but it is necessary to do for the benefit of management in the future.

4. Any decision made by administrators should be confirmed in public hearing meeting before implementing, because researchers will be satisfied and agreed to follow rules. This also makes researchers want to share their opinion in a long term as they are sure that their recommendations will be accepted and implemented if they are good and suitable, resulting in practical management under real situation.

5.3 Future Work

Pruning algorithm: Even though storing research information with semantic web model is more appropriate than RDBMS, but the problem is the increasing size. This made information presentation hard to generate and read. Consequently, pruning algorithm should be created and performed for presenting only necessary nodes and branches.

TCM: Result from using TCM to set up research clusters' priority could be used in formulating strategy plan of research management as follow:

1. Falling Star region: The research clusters in this region have high market share and Thailand has high competitiveness, but market growth is low. This group does not need to do more research, but the knowledge should be spread or this group should be researched with other countries lacking this kind of knowledge, for instance, Rice & Grain group could be research with China.

2. Star region: The research clusters in this region have high market growth and they should try to bid for research fund from private organizations instead of government fund as many companies want to support this kind of research. For example, Meat & Poultry could bid fund from CP.

3. Opportunity region: The research clusters in this region is a new trend, but the potential in Thailand is still low. Thus, graduate students should be educated more to support this trend.

4. New wave region: The research clusters in this region needed to submit for grants from government because private organization might not perceive their importance such as research in metal.

5. Trouble region and Question mark region: The researchers research in this region should be pushed and moved to region 1-4 to increase the interest in the research.

From TCM, research clusters in Question mark region has high market share and high competitiveness, but it is hard to apply for research fund because market growth is low. Administrator should move researchers in this region to region 1-4 by considering research potential of each group. This requirement challenges the administrators to find new technique for solving this such as mathematical simulations.

Text mining: Text mining should be developed urgently for collecting keywords automatically in the future. Current research information is stored in many sources and in variety of formats, i.e. document, web page, MIS, DBMS both in local database and electronic database. Though text mining could not be developed for every source but one possible source that should be experimented is the electronic database as it has complete information of journals and articles. Furthermore, it also provides information about the index quality of journal and citation, and it also has many options for searching comfortably as well.

However, applying text mining technique with electronic databases has to have complicate design algorithm and take time to process it because they are large

databases and the process has to do remotely. Another easier method that can be done is researchers upload their research topic and abstract into the system, including thesis topic of their students to decrease the size of information. Then text analysis was used to analyze this information. It will save time and give more direct information than accessing from electronic databases.

Even though text mining technique was the best solution for the mentioned problem, but the difficult process comes after it. All received keywords have to be evaluated and entered into suitable position in hierarchical tree of ontology. The question is how to do this automatically, where is the appropriate node of each keyword, what is the suitable relationship between researcher and keyword, etc. These questions are the challenge for the engineers.

Business Intelligent tools: All new techniques proposed in this thesis and suggested as future works should be complied as online set to support administrators decision making as *dashboard* or *cockpit* or *war room*. This kind of tool are as same as Business Intelligent tools (BI tools) designed to report, analyze and present data for research management.

Assessment of journal indexes: One more interesting future work is the assessment of journal indexes, which indicate the quality of journals and articles. Using only Impact Factor or citation value for evaluating quality of journal or article is not enough because Impact Factor is the index developed by Institute for Scientific Information (ISI) or Thompson ISI former name. So some quality journals that were not indexed by ISI would not have the Impact Factor. Thus, many researchers are

disadvantaged if they published their journals elsewhere. Therefore, others index should be considered for solving this problem. There are many journal indexes as follow:

1. Journal Immediacy Index: This indicates how quickly articles in a journal are cited. It measures the average number of times that an article, published in a specific year within a specific journal, is cited over the course of the same year (The Thomson Corporation, 2008).

2. Cited Half-life: It is a measurement used to estimate the impact of a journal. It is the number of years, going back from the current year, that account for 50% of the total citations received by the cited journal in the current year (Thomson reuters, 2010).

3. h-index: It is an index that attempts to measure both the scientific productivity and the apparent scientific impact of a scientist. The index is based on the set of the scientist's most cited papers and the number of citations that they have received in other people's publications. The index can also be applied to the productivity and impact of a group of scientists, such as a department or university or country (“h-index”, 2010)

4. g-index: It is an index for quantifying the scientific productivity of physicists and other scientists based on their publication record (“g-index”, 2010). It is similar to h-index but it can solve some problem of h-index such as h-index value is stable even researcher do not publish any paper any more.

5. Eigenfactor™ Score (EF): A measure of the overall value provided by all of the articles published in a given journal in a year (Thomson Reuters, 2009).

6. Article Influence™ Score (AI): a measure of a journal's prestige based on per article citations and comparable to Impact Factor (Thomson Reuters, 2009).

Those journal indexes currently are supported by many electronic databases e.g. ISI Web of Science, ScienceDirect, and Scopus including free databases such as Google Scholar, PubMed, Eigenfactor, and SCImago.

Each index has both pro's and con's. Thus, key researchers identifying should be employed in more than one index. Hence, comparison among indexes should be studied including the suitable situation for each index which should be analyzed as well.

Social networking tools: Other tools should be tried to find social network of researchers, which is analyzed via publications such as SCImago Journal & Country Rank. These websites analyze and compare publication information, and do citation of researches in countries, including the journals subscribed in Scopus of Elsevier (SCImago Research Group, 2007).

Recognition criteria: For Social Sciences & Humanities discipline, recognition is an important criterion that should be measured because the nature of this discipline is different from Health Sciences and Sciences & Technology. Some good research from Social Sciences & Humanities can be achieved without using much money and had high impact on the social widely. This is because research result comes from insights and long term experiences of key researchers without using expensive equipments or tools. Those researchers are recognized without gaining enormous

research fund or registered patent. However, the difficult part is how to measure the recognition of researchers and what is the level of the recognition of each researcher (global/regional/local). The evaluation of recognition should be done by many techniques such as Delphi technique, peer-to-peer, assessment matrix, and judgment technique. The evaluators of this process should be researchers in the same field with candidate key researchers and the evaluation should cover both researchers' capability and ethic as well.

Key researcher criteria: Another future work is defining of suitable criteria for other subjects that have unique characteristic such as Mathematics, Engineering, and Social Sciences & Humanities, especially Fine Art. The research results of this subject has special characteristic, which cannot be evaluate with normal techniques. This kind of subjects should have their own criteria. In 2007, researchers from faculty of Fine Art, CMU, researched in topic named *The Creation of Procedures in Creative Art Research, Faculty of Fine Arts, Chiang Mai University*, and the result of this study revealed real characteristics of art production (Jantratid, Suksawat, Chaiyakut, Damrikun, Kast, & Rasdjarmreansook, 2007). Therefore, the result of this research should be considered for defining key researcher criteria of Fine Art researchers, and the criteria will fit to the real situation without raising arguments. This kind of research should be initiated for the research of Social Sciences & Humanities as well.

5.4 Conclusion

The experiment found that semantic web technology can solve the problem of dynamic of research information very well as it is the problem about meaning. Therefore, if researchers changed their research topic, administrators still know what their expertises are. However, the problem of incomplete information needs more technique such as text mining to increase the efficiency of the system to pick up keywords regarding a research automatically.

Furthermore, semantic model or CMU research ontology can be used for synergizing the university research by using keyword describing expertise and research direction of key researchers as a common vocabulary which also called CMU ontology commitment. Since ontology represents the commitment of CMU research direction between administrators and researchers, it can be used for communicating not only between CMU administrators and researchers, but also between researchers themselves. Administrator can track the current expertise and research direction of CMU and plan to establish new center of excellence support the research group. In addition, new researchers can look at CMU ontology commitment and make decision in choosing existing research group that match to their own ability as well.

Moreover, CMU ontology commitment helps administrators to identify key researchers more efficiently than using database management system in complicate condition, because it is hard to determine the key researchers in CMU. The criteria for identifying key researchers changes with different management level (university level, faculty level, and department level) as different level has differences in criteria

consideration. However, by using inference step with CMU ontology commitment could efficiently identify key researchers in each level.

Lastly, CMU ontology commitment can be used for forming multi-discipline research clusters and recommending these research clusters' priority as well.