MAINTENANCE FOR SUSTAINABLE ONTOLOGIES

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ABSTRACT

MAINTENANCE FOR SUSTAINABLE ONTOLOGIES

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In computer and information sciences, ontology based information systems have been seen as an opportunity to represent knowledge as to define and categorize digital reflections of physical entities, domains and relations between pairs of them. For these digital domains and entities, information oriented, ontology based structures have become popular for creation of knowledge structures for organizations. Based on this perspective, by using different ontology definitions, organizations have been building their own digital ontologies for a wide variety of reasons. However, construction of an ontology cannot be concluded with a single build; it requires maintenance, which is in parallel with organizational and organization's environmental changes. The ontology maintenance idea arises to support this requirement. In this study, to answer this requirement, previously created and maintained SWEET, Galen and Public Finance Management ontologies were studied as cases by looking at implemented ontology tasks. After that, the findings were derived from these cases and these findings were compared with the BIHAP system ontology with implementation of questionnaire to the developers and end users of the system. The validation of the questionnaire was ensured by implementation of interviews to the previous questionnaire participants. The results revealed the implementation of ontology tasks for the ontology maintenance purposes.

Keywords: Ontology, Ontology Maintenance, Sustainability, Ontology Tasks

ÖZ

SÜRDÜRÜLEBİLİR ONTOLOJİLER İÇİN İDAME

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Bilgisayar ve enformasyon bilimlerinde ontolojiler, bilgiyle fiziksel varlıkların, bu varlıkların ilgi alanlarının ve bunlar arasındaki ilişkilerin sayısal yansımaları olarak tanımlama ve kategorize etmek için bir fırsat olarak görülmüştür. Bu sayısal alanlar ve varlıklar için, enformasyona yönelik, ontoloji tabanlı yapılar örgütlerin bilgi yapılarının oluşturulmasında popüler olmuştur. Bu bakış açısıyla, farklı ontoloji tanımları kullanılarak, örgütler farklı amaçlarla kendi sayısal ontolojilerini oluşturmaya başlamıştır. Ancak, ontoloji inşası yalnızca tek bir adımda tamamlanamamaktadır; örgütün ve de örgütün bulunduğun çevrenin değişimine göre değişikliklere ihtiyaç duymaktadır. Ontoloji idamesi fikri bu ihtiyacı desteklemek için kendini göstermektedir. Bu çalışmada, bu ihtiyacı karşılamaya yönelik, daha önceden oluşturulmuş, idame edilmiş SWEET, Galen, Kamu Finans Yönetimi ontolojileri kendilerine uygulanan ontoloji görevlerine bakılarak vaka olarak çalışılmıştır. Daha sonra elde edilen sonuçlar BIHAP sistem ontolojisi üzerinde geliştiriciler ve de son kullanıcılara uygulanan anketler ile karşılaştırılmıştır. Anketlerin onaylanması, ankete katılan katılımcılara yapılan mülakatlarla sağlanmıştır. Çıkan sonuçlar, ontoloji görevlerinin ontoloji idamesi için kullanılabilirliğini göstermektedir.

Anahtar Kelimeler: Ontoloji, Ontoloji idamesi, Sürdürülebilirlik, Ontoloji Görevleri

To my wife, my brother, and my family.

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LIST OF ACRONYMS / ABBREVIATIONS

ACM	Association for Computing Machinery Digital Library
BIHAP	Bilgi Haritası Araştırma ve Geliştirme Projesi
KA	Knowledge Application
KB	Knowledge Base
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Standards Organization
MR	Modification Requirement
OA	Ontology Alignment
OD	Ontology Debugging
OI	Ontology Integration
OM	Ontology Mapping
OT	Ontology Translation
OV	Ontology Versioning
PFM	Public Finance Management
ProQuest	ProQuest Dissertation and Thesis Online Database
SK	System Knowledge
SWEET	Semantic Web for Earth and Environmental Terminology
TAMBIS	Transparent Access to Multiple Bioinformatics Information Sources
UK	User Knowledge
WoS	Web of Science/Knowledge

CHAPTER 1

INTRODUCTION

This chapter contains three sections. In these sections, an introductory idea to support the ontology maintenance concept is presented. In the first section, the need for ontology maintenance is provided. It is followed by the proposed study which is presented in the second section and finally, the thesis outline is provided in the third section.

1.1 Prologue

Ontologies have attracted the attention of many researchers for their capability of structuring semantic relations of knowledge. From scientific purposes to enterprise architectures, ontologies have been implemented in various organizations to build solid knowledge bases.

After implementation of ontologies to support organizational knowledge, the maintenance requirement urges these organizations according to the changes in the organizations and their knowledge structure. Therefore, a study on maintenance in these ontologies is needed for sustaining ontologies and organizational knowledge.

1.2 Background of the Problem

Systems are able to sustain their working conditions with maintenance. As a type of a system, the information systems are no different. In the information technology domain, the basic tools are built over software applications. Standard software can be easily created by lines of code, and the maintenance can be implemented over these codes. Since writing the first line of updates, the need for maintenance has increased its importance. Especially with the current way of digitalized life, every good system requires proper applications to answer the needs of its domain. To increase the life span of a system, answering these needs and continuously running of key operations have become necessities (Riggs,1969). Software maintenance is the key factor for answering these necessities.

By taking ontologies as knowledge bases of the existing knowledge management systems, these knowledge bases can be summarized as the systems to achieve semantic relations. Like any other similar information/knowledge system, a life cycle can start for an ontology by sensing its need of recognition. This life cycle can be ended with its retirement. It is easy to find ontologies that can follow a similar lifecycle.

In today's knowledge management systems, ontologies are sometimes called as knowledge bases. A knowledge base could be a simple book or could be a huge complex database. The common point in these separate entities is, even if they are at the end of their useful life, they could be integrated in another system or reused fully or partially as a part of new knowledge bases. This is where ontology can be distinguished from classical software systems.

The common standard for software maintenance (ISO/IEC 14764, 2006) can answer the software part of the maintenance requirement of ontologies which are the knowledge bases of applications and systems. However, the semantic part of the maintenance and its relation with the software systems stay under the shadow. Especially a general standard, that does not include semantic relation definitions ,inside cannot be sufficient enough to find an answer to the requirements.

1.3 Statement of the Problem

The problem of:

- Unfinished ontology project due to lack of maintenance coordination;
- Not using existing ontologies and reworking on building knowledge bases with different technologies;
- Wasting human, financial and other resources in the given effort of unfinished ontology projects and redundant works;
- Losing motivation and faith in ontologies, after not-collecting expected results;
- Creation of anti-knowledge sharing culture.

Is affected by:

- The organization's stakeholders, especially specialist, managers, directors, researchers and scientists.
- All the given stakeholders need to require maintained semantic structures of concepts and terms to increase efficiency and effectiveness in daily work activities and to build conceptual relations over organizations strategies.

The impact of which is:

- Unsustainable ontologies.

- Duplicated efforts by doing the same work.
- Left behind ontologies.

Ontology maintenance implementation may require implementation of ontology tasks to answer the maintenance requirements. Therefore, ontology tasks seem to be the most appropriate for the maintenance of the sustainable ontologies.

1.4 Purpose of the Study

The purpose of this study is to investigate ontology tasks implementation for ontology maintenance to support sustainability of the knowledge base requirements of the organizations.

1.5 Significance of the Study

The reason of this study is that, currently there is no clear consensus on implementation of ontology maintenance. Specifically, by looking at ontology tasks the implacability of these tasks will be investigated on different ontologies.

Therefore this study is deemed to be significant on ontology researches for focusing requirements of the maintenance.

1.6 Research Questions

The main research questions (RQ) addressed in this study is given as follows:

RQ-1: What are the indicators of ontology maintenance requirement based on ontology tasks?

RQ-2: What is the relation between user inclusion and the ontology maintenance?

RQ-3: How could ontology tasks be implemented for providing a maintenance plan for sustainability of the ontology?

RQ-4: How can the sustainable ontology maintenance be defined and therefore improved?

1.7 Assumptions

1. Previous ontology cases, related documents and codes do exist;
2. Developer and end user contact exist in at least one of the cases;
3. Participant will respond accurately to all measures;

4. In at least one of the cases, the organization will provide support to the study in the course of the research;

5. The measures that are investigated are reliable and valid indicators of the constructs investigated;

6. The study, research, gathered data, findings and conclusions represent 'good research'.

1.8 Limitations

1. The cases that are investigated in this study are limited to available documents, and codes and the participants who agree to volunteer.

2. Validity of this study is limited to the reliability of available documents, codes, instruments and subjects' honesty in responses reflected on the instruments and documents;

3. The constructs are based on self-reported measures, which may artificially inflate the relations among factors. The validity of this data is controvertible in view of potential social desirability;

4. Contextual factors may influence the results (e.g., availability of the cases, number of participants).

1.9 Delimitations

1. The scope of the study is limited to the available cases and selected organizations. Each organization may have different purposes in development and maintenance of the ontology based systems. This fact has no major effect on generalizability of the study. The conclusions derived from this study can be applied elsewhere after some modifications according to related ontology, the domain of the ontology and related environment;

2. The cases for investigation of ontology tasks confine itself to available ontologies and if available, possible end users and developer participants only from the related technical departments due to their dense technical ontology implementations.

1.10 Organization of the Study

Chapter One of the study presents the introduction, the statement of the problem, the purpose of the study, the questions to be answered, the significance of the study, the assumptions, limitations, delimitations and the organization of the study.

Chapter Two provides the results of the systematic literature review based on ontology maintenance related studies.

Chapter Three describes the details of the cases. The details of the application procedure will be given. The related details of each measure will be also provided. The cases will be provided to investigate for evidence of ontology tasks implementation.

Chapter Four gives the results of the implementation in another case study Findings from the case studies and description of the research questions, data collection and analysis method will be shared. Analyses of the measurement results are processed and later are discussed in this chapter. Validation of the findings is given as the last concept of the chapter four.

In Chapter Five, findings, contributions to the literature and discussions will be provided. The findings and application limitations will be discussed. At the end, possible future study opportunities based on the findings will be provided.

CHAPTER 2

LITERATURE REVIEW

This chapter gives the results of a systematic review and the findings that are used for building the main conceptual baseline of this dissertation. This review reveals the interactions between ontology tasks and ontology maintenance concepts. These concepts are combined to indicate development processes, validation, and scope of this study.

2.1 Systematic Review

This part of the study presents the findings related with the systematic review. It contains the implemented data sources; the publication selection methodology; the data extraction and results of the literature review and finally the results.

2.1.1 Data Source

The literature study was conducted in the Association for Computing Machinery Digital Library (ACM DL, 2014), Web of Science/Knowledge (Web of Science, 2014) and ProQuest Dissertations and Thesis (ProQuest, 2014) databases for the period from July 2001 to May 2013. ACM DL contains an archive starting from 1950s. This archive is related with the publications of computing literature from organization’s journals, magazines, newsletters and conference proceedings. Web of Science is an online database that provides access to multiple databases for inter or multi-disciplinary researches. Based on given statistical information, dated in June 13 2013, web of science contains 30000 scholarly books, 12000 journals and 148000 conference proceedings. And as the final source, ProQuest provides full-text access to dissertations and theses database which contains records over 2.4 million publications in a period between 1637 to the present.

The language that is implemented for querying of this part of the study is English. In both databases, to find ontology maintenance related sentences, the concepts are scanned in the body and the title of each academic record.

2.1.2 Publication Selection

Publications were selected via accessing the given databases [(ACM DL, 2014), (Web of Science,2014), (ProQuest,2014)]. Publications which are focused on multiple functional domains and related studies' development methods have been clearly defined. Based on the definitions the studies were prioritized. Publications were reviewed and it was observed that all the selected references are based on the study's scope.

2.1.3 Data Extraction

As shown in Table 1, total of 94 publications were identified based on the examination of abstracts and introduction parts of each publication. In order to identify the related ones, five categories were defined. First category is for the publications which were written for theoretical ontology maintenance framework based on ontology tasks with including software maintenance standard. Second category is defined as the publications with ontology theoretical maintenance framework without focusing on ontology tasks or software maintenance standard. Third category is defined for the application oriented ontology maintenance as a part of information system. Fourth category is defined for the taking ontology maintenance as a part of the system structure without directly defining ontology maintenance concepts inside. The fifth category is defined as the publications that were not directly related with this study.

After categorization, the publications were listed as follows,

Table 1 - Literature Review Results

Sources	Discovered	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5	Related
ProQuest	31	0	6	9	8	8	23
ACM	28	0	0	7	4	17	11
WoS	35	0	4	7	10	14	21
Total	**94**	**0**	**10**	**23**	**22**	**40**	**55**

ProQuest: ProQuest Dissertation and Thesis Online Database, ACM: Association for Computing Machinery Digital Library, WoS: Web of Science/Knowledge, Cat: Category

The publications obtained from the ProQuest are mostly PhD dissertations. However, five of these dissertations [(Elliott,2007), (Katsumi,2011), (Shaban-Nejad, 2005), (Wellen, 2008), (Smith,2007)] were identified as Master thesis.

As seen from the Table 1, there were not any studies identified in the Category1. Even being in the Category2 there were some studies which were close to be in Category1, such as Nejad (2010). However, these studies still were not comprehended in Category1 because of specific properties. For this reason, according to results of this study, based on the publications included into this study set, there were not any publications in the Category1 definitions.

For the Category2, total of ten publications were included into result set. In this result set, ACM publications could not be included in the Category2.

For the Category3 there were 23, and for the Cateory4 here were 22 publications defined. Category5 would not be included into this study, for this reason totally 40 publications were removed from the study, and at the end 55 publications were defined in the set of this research.

2.1.4 Results

For summarizing the publications, four titles were defined. First title gives the appearance of "ontology maintenance" term in the publications. The term should be found in the title, body or reference. Under this title, publications from Category 1 to 5 were taken into the consideration.

For the rest of the titles categories in between Category2 and Catergory4 were taken into the consideration. Second category was given to show defined limitations of the publications. Third category was given to categorize studies. Fourth category gives the information about the validation techniques of these publications.

The results of the title one are summarized in the Table 2. Based on the literature review implemented in ProQuest, ACM and WoS *ontology maintenance* was identified in the text-title is ten times, in the body, ninety-one times and only given in the reference part three times. The studies which were returned based on "ontology maintenance" were the referenced studies that remained unrelated with the concept of this study.

For the "limitations" title, "why these publications are not fully related with this study" was considered. Fourteen limitations were identified from these publications. These limitations are given in Table 3. Brief ontology maintenance requirement was defined in seventeen of the publications. Three of the publications were identified only as a step of a system lifecycle. Mostly, maintenance was taken as an update procedure in the ontology.

Table 2 - Ontology Maintenance Appearance

Where the Ontology Maintenance is Given	Number of Publications
Title	10
Body	91
Only Reference	3

Table 3 - Limitations

Limitations	**Publication(s)**
Brief ontology maintenance requirement was given	(Shaban-Nejad,2005),(Alomari, 2009),(Elliott,2008),(Qu,2009), (Liu,2011), (Worblewska,2012), (Zhu,2010),(Ziemba,2011),(Soares,2009), (An,2008),(Look,2008),(Smith,2007), (Chen,2011),(Edgett,2010),(Seidenbert& Rector,2006),(Bontcheca et al., 2006), (Katsumi ,2011)
Given only as a step of a system lifecycle	(Li, 2008),(Elliott, 2012), (Bertini, 2007)
Maintenance is only considered for system correction	(Chang,2008), (Falge, 2007)
Maintenance is only considered for system debugging	(Valarakos et al., 2004)
Maintenance is only considered for system mapping	(Valarakos et al., 2004), (Mitra,2004), (Bright,2009)
Maintenance is only considered for system enhancement	(Jian, 2009)
Maintenance is only considered for system evolution	(Lister et al.,2005)
Maintenance is only considered for system update	(Mukhopadhyay & Chougule,2012), (Motta & Siqueira,2008),(Gulla& Sugumaran,2008), (Chiu & Leung,2005), (Gasevic, et al., 2011), (Liu & Zukai,2009), (Siddiqui et al., 2008), (Torniai et al., 2008),(Falge et al.,2007) , (Valarakos,2006), (Valarakos et al., 2005), (Gargouri et al., 2003), (Luczak-Roesch, 2009)

Limitations	Publication(s)
Maintenance is only considered for system matching and alignment	(Valarakos et al.,2004), (Bright, 2009)
Maintenance is only considered for system versioning	(Bachore,2012), (Grandi, 2013)
Maintenance is only considered for system integration	(Valarakos et al., 2004)
Maintenance is only considered for system debugging	(Bright,2009)
Ontology maintenance implemented in a non-ontology solution	(Ensan, 2010)
Ontology Maintenance taken as a sub task	(Menon,2007), (Patel,2009), (Ghazyinian, 2011), (YU, 2005)

One of these publications was applied to a non-ontology solution. The other limitations were built on the possible interactions between ontology tasks given in this study's model. Maintenance was only seen as an activity in two studies. One activity was related with enhancement and the other activity was related with the evolution. In thirteen publications, maintenance was only considered to update the system. Directly named tasks were mapping (three of the publications), matching and alignment (two of the publications), versioning (two of the publications), integration (one of the publication) and debugging (one of the publications). Ontology maintenance was taken as a sub task in seven of these publications. The results showed that, the tasks of debugging, mapping, integration, matching and alignment, versioning are already given as the tasks implemented for the ontology.

In some of these publications, methods, methodologies, aims, goals, and purpose of the study were defined. In this study, for the categorization purposes, these definitions were combined under different goals. Eight goals were defined in Table 4. Algorithm implementation goal were identified to build a computerized system; algorithms were defined for the specialized cases. Framework development focused on building theoretical or methodological or information/knowledge base framework development. Ontology building purpose was the creation of specified ontologies for cases. Methodology development purpose was defining the theoretical implementation of logic and some of the cases implementation of methodologies in real life cases. System implementation was defined for the publications only defined for the implementation of the systems. Prototype implementation was given for the unique idea implementation. Survey was focused on the survey study of the given cases. Theory implementation was only considered the theoretical implementation baseline for a given problem domain.

Table 4 - Goal

Goal	Publication(s)
Algorithm implementation	(Eliott, 2007), (An, 2008), (Look,2008), (Seidenbert & Rector, 2006), (Lammari & Metais, 2004), (Valarakos et al., 2004),(Mitra,2004), (Mukhopadhyay & Chougule,2012),(Liu et al., 2009), (Siddiqui et al., 2008), (Menon, 2007), (Ghazvinian et al.,2011), (Grandi, 2013), (Sun et al.,2013), (Falge et al, 2007)
Framework Development	(Qu,2009),(Zhu, 2010), (Liu,2011)
Ontology Build	(Grandi,2013), (Cheng et al., 2011), (Valarakos et al.,2004), (Valarakos et al.,2005), (Wroblewska et al.,2012), (Bontcheca et al.,2006), (Jian et al.,2009), (Gulla & Suguramaran,2008), (Luczak,2009),(Ceci et al., 2012), (Sun et al., 2013), (Gasevic et al.,2011), (Torniai et al.,2008), (Falge, et al.,2007), (Shaban-Nejad, 2005), (Ziemba,2011), (Lister et al.,2005), (Bright,2009),(Welten,2008), (Motta et al.,2008), (Alomari, 2009)
Methodology Development	(Katsumi, 2011), (Li,2008), (Elliott,2012), (Chang,2008),(Valarakos et al.,2006), (Gargouri et al, 2003), (Bachore,2012), (Patel,2009), (Ney et al,2006), (Chen et al.,2011), (Valarakos et al.,2004), (Valarakos et al, 2005), (Sun, et al, 2013), (Bertini et al.,2007),(Liu,2011), (Hepp,2006)
System Implementation	(Bertini et al.,2007), (Gasevic et al.,2011), (Torniai et al.,2008), (Falge et al.,2007), (Motta et al., 2008)
Prototype Implementation	(Ensan,2010)
Survey Study	(Soares,2009), (Smith,2007), (Yu,2005),(Hepp,2006)
Theory Build	(Edgett, 2010)

In fifteen of these publications, an algorithm implementation was identified. In these fifteen publications, three of them [(Falge et al., 2007), (Sun et al.,2013), (Lammari & Metais,2004)] were implemented under the ontology maintenance. For the framework development only three publications were identified. In these three publications none of them was directly implemented under the ontology maintenance framework development. For the ontology building purpose, twenty two of the publications were identified. In these publications, six of them [(Falge et al.,2007), (Sun et al., 2013), (Gasevic et al. , 2011) , (Chen et al., 2011), (Valarakos et al., 2004)] were directly implemented in the name of the ontology maintenance.

For the methodology development, sixteen publications were identified. In these publications only four of them [(Sun et al., 2013), (Chen et al.,2011), (Valarakos et al., 2006), (Gargouri et al., 2003)] were related with the dissertation. For the system implementation five publications were identified. In these five publications two of them (Gasevic et al.,2011) and (Falge et al., 2007) were studied for the ontology maintenance. Prototype implementation was only caught in one study and it is not directly related with the ontology maintenance. Under the survey study, four studies were identified and they were not directly related with the ontology maintenance. Only one study was categorized under theory building and this study was given as related with the ontology maintenance.

To proof the given concepts, the methods which were implemented in these studies were categorized under five titles, case study, experiment, expert review, prototype and survey, see Table 5. Because most of these studies were considered development of theories, algorithms, framework, ontology and system, case studies and experiments have high implementation rate as the validity method. Totally twenty-two case studies, twenty-five experiments, five expert opinions, four prototype implementation and two surveys were implemented to prove the validity of the studies.

In the case studies, three of them were done directly related with the current content [(Sun et al., 2013),(Gasevic et al.,2011), (Chen et al., 2011)]. Similar to case study three studies were implemented for the experiment for the ontology maintenance [(Falge et al.,2007), (Edgett,et al.,2010), (Valarakos et al., 2006)]. In the expert opinion only two studies [(Gasevic et al.,2011), (Gargouri et al., 2003)] and for the prototype and survey none of the studies were related with the ontology maintenance. The studies of Luczak, 2009 and Lammari & Metais,2004 were even given as directly related with the ontology maintenance, no specific validity method was defined.

Table 5 -Validity

Validity	Publication
Case Study	(Valarakos et al.,2004), (Li, 2008), (Elliott, 2012), (Chang, 2008),(Chen et al.,2011),(Valarakos et al.,2004), (Valarakos et al.,2005), (Wroblewska et al., 2012),(Bontcheca et al.,2006), (Gulla & Sugumaran, 2008), (Sun et al.,2013), (Bertini et al., 2007), (Shaben-Nejad,2005), (Motta et al.,2008), (Chiu & Leung,2005), (Qu,2009), (Seidenbert & Rector,2006), (Li,2008), (Menon,2007), (Gasevic et al.,2011), (Torniai et al., 2008), (Ceci et al., 2012)
Experiment	((Mukhopadhyay & Chougule ,2012), (Ghazvinian et al., 2011),(Seidenbert & Rector, 2006),(Elliott,2007), (An,2008), Look, 2008), (Liu et al.,2009),(Siddiqui,2008) , (Zhu,2010), (Grandi,2013),(Valarakos et al., 2006), (Patel, 2009), (Noy et al., 2006), (Liu,2011), (Jian et al., 2009), (Falge et al.,2007), (Lister et al., 2005), (Bright,2009), (Hepp,2006),(Edgett,2010), (Mitra, 2004), (Menon, 2007),(Bachore,2012), (Edgett et al.,2010)
Expert Opinion	(Gargouri et al. 2003), (Ziemba,2011), (Wellen,2008),Gasevic et al.,2011),(Torniai,2008)
Prototype	(Katsumi ,2011), (Alomari ,2009), (Bachore,2012), (Ceci, 2012)
Survey	(Soares ,2009), (Smith,2007)

Another important point that requires attention is the knowledge related studies. Thirteen publications [(Falge et al.,2007) , (Alomari,2009), (Gulla & Sugumaran,2008), (Chen et al., 2011) , (Smith, 2007) , (Bontcheca et al.,2006) , (Seidenbert &Rector,2006) ,(Bachore, 2012) , (Wroblewska et al, 2012), (Brigh, 2009) , (Li,2008), (Mitra, 2004), (Chang,2008)] were identified as the knowledge referenced publications under knowledge management. These publications directly relate each ontology studies with the knowledge management. However, in most of these studies only model was given with the SECI model [Nonaka & Takeuchi, 1995]. There are not any models which relate ontology maintenance with the knowledge management.

With respect to extracted literature review the following contributions were identified;

- Reviewing what have been done under the ontology maintenance;
- Identification of the implemented methods, validation method and limitations of these studies;
- Identified opportunities for the ontology task based, in the software maintenance concept.

It was concluded that, given the studies which have “ontology maintenance” given inside, they were not totally parallel to the required content with this study. A general model for the ontology maintenance is still missing for all publications.

The most important additions of this literature review is the identification of this thesis needs. These could be given as follows;

- The tasks that will reveal the ontology maintenance;
- The standard requirement for drawing borders of the maintenance.

The possible cases were also identified as a result of the literature review. Even though there were some other projects, systems and ontologies were given in the publications, only three ontology names were extracted from these studies as common in these publications. These ontologies are Semantic Web for Earth and Environmental Terminology (SWEET), Galen and Transparent Access to Multiple Bioinformatics (Tambis). The ontologies and related references are given in Table 6.

Table 6 - Selected Ontologies and Given References

Ontologies	**Publications**
SWEET	(Ersan,2010), (Wellen,2008)
GALEN	(Shaban-Nejad,2005), (Shaban-Nejad, 2010), (Mitra, 2004), (Bright,2009), (Seidenbert & Rector,2006),(Lammari & Metais,2004)
TAMBIS	(Qu,2009),(Shaban-Nejad,2005), (Shaban-Nejad, 2010)

2.2 Maintenance and Ontology Tasks

Based on the findings in part 2.1, this section is built over the publications which are revised and the important points are given. Standard for Software Maintenance, ontology and ontology maintenance and related ontology tasks are given accordingly.

2.2.1 Standard for Software Maintenance

For continuous operability to satisfy user requirements, maintenance implementations turn into a necessity. For the ontologies that were built to support software systems, looking for software related maintenance attempts could be also implemented for ontology maintenance. However, for this implementation, a guideline is required to give direction to the possible maintainers.

The guidelines prepared for the software system is a proper start point. There has been variety of standards to answer the software maintenance requirements. These standards have been also published by a variety of organizations. In 1992, IEEE Standard for Software Maintenance was published by IEEE with the code of IEEE Std 1219-1992. A revised version was published in 1998. In 2006, ISO/IEC 14764 was published by ISO/IEC. The merge of Std 1219-1998 and Std 14764-2006 was established in the second edition of ISO/IEC's standard. This standard could be called as a Meta standard because it was published to apply any kind of software product's maintenance.

Std 1219-1998 and Std 14764-2006 defined the maintenance requirements as the modification request (MR). In both standards, four main types of maintenance have been identified. In Std 1219, to overcome the problem caused by the system or the environment, emergency maintenance was defined. Emergency maintenance was moved under corrective maintenance in Std 14764.The preventive maintenance was included in this standard. The main four maintenance types of the latest Std 14764 defined as follows;

- Corrective, to correct a problem in the system,
- Adaptive, to adapt the environmental changes which the system is in,
- Perfective, to add new features to the system which was not in the initial stage,
- Preventive, to overcome possible problems that could be triggered by software, this maintenance implemented after delivery of the product.

In Std 14764-2006, the relationship between these types and MR defined within two classifications, correction and enhancement. In this standard, this relation visualized as in Figure 1;

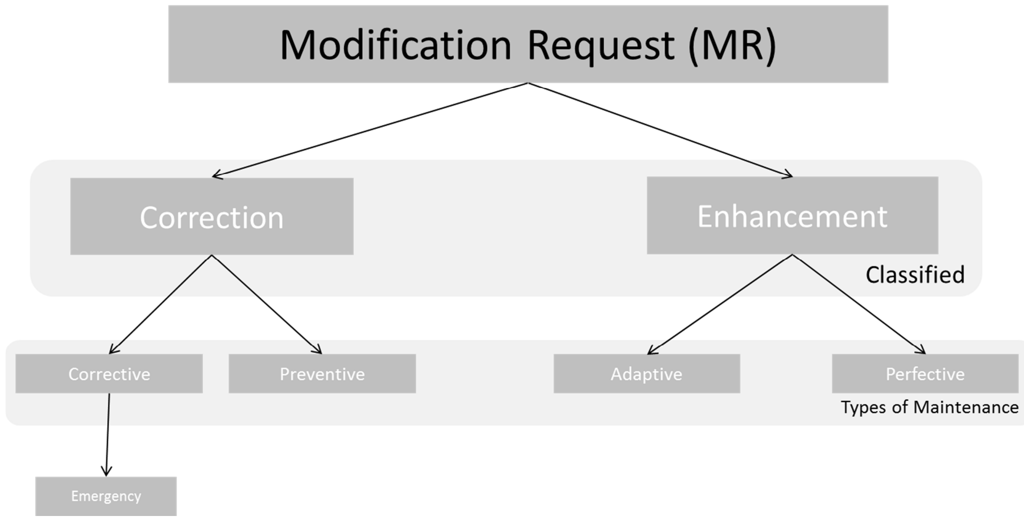

Figure 1 - Modification Request Defined in Std 14762-2006

This standard basically defines the iterative process activities as maintenance phases for management and execution of software activities. In Std 14764-2006, six activities are defined. The activities and their definitions are given as follows:

1. Process Implementation, plans and procedures to follow during the maintenance processes are established;
2. Problem and Modification Analysis, though MP and problem report (PR), analyses and problem verification activities are established to reach modification options;
3. Modification Implementation, Modification of the software develops and tests;
4. Maintenance Review/Acceptance, To ensure activity for corrective and accomplishment for MR and PR of modifications;
5. Migration, if a new environment exists to implement modification, this step is implemented to ensure migration to the different environments;
6. Retirement, the steps for the retirement of the software.

From the step 1 to 4, these steps are required for the implementation of any type of maintenance, however to apply 5 and 6, special conditions are required. These conditions could be an implementation on a new Operating System or time to move to a new software system by retiring the old system. With an iterative perspective, the relations between these steps could be given as in Figure 2.

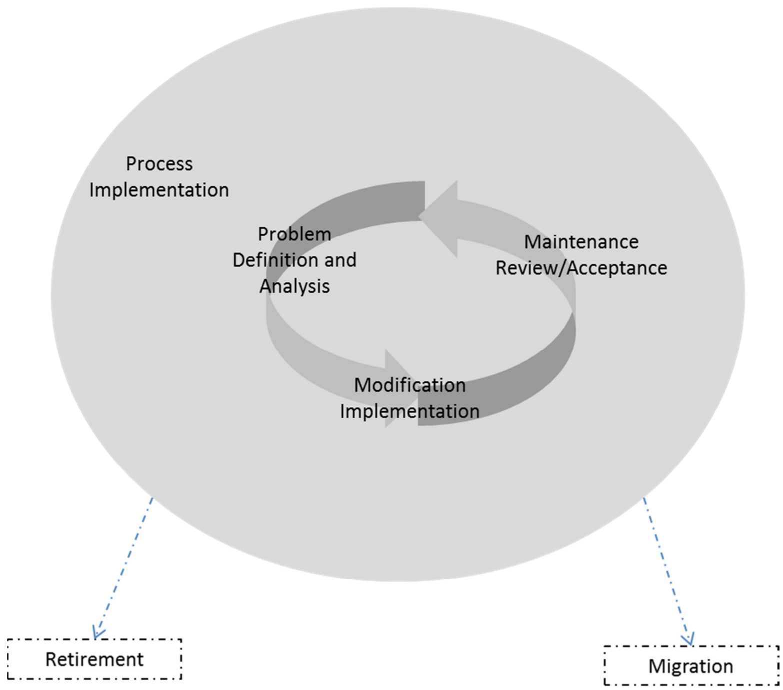

Figure 2 - Maintenance Process as Defined in Std. 14764:2006

According to Konar, 2000, no properly defined maintenance strategy for knowledge based system exists, taking an ontology as a knowledge based system only increases the complexity of the problem. The ontology maintenance is required to include discussion of this complexity.

In the following section, starting with the ontology definition, ontology maintenance will be discussed by looking at software maintenance.

Ontology and Software Maintenance

In the nature of ontology, domain conditions mostly dictate to carry a heavy burden of defining requirements over software systems. For the software part, a simple software oriented strategy can answer maintenance requirements. For the semantic part, there is no easy answer that can satisfy semantic requirements. To satisfy the semantic part of maintenance requirement, an ontology which is focused on maintenance could be helpful for implementation.

In the literature, when ontology maintenance is queried, the result is unexpected. In the study of Menon (2007), ontology maintenance was given with the ontology cleaning. Ontology cleaning concept is discussed under merging of two or more different ontologies. For handling the inconsistencies in an ontology, ontology maintenance was used by the Ensan (2010). There are also different ontology development methodologies and lifecycle perspectives for the ontologies. In the work of Bachore (2010), these methodologies were given and maintenance stage was briefly shown. As pointed out by this study, especially for the dynamic domains, maintenance was highly required. The semantic relations' complexity increases with the dynamic domains that have high tendency to update these semantic relations.

Creation of different versions of an ontology could also require maintenance activities. In the study of Klein and Fensel (2001), to solve the interoperability problem that is triggered by evolving ontologies, a method has been proposed. By including the cost of maintenance in medical ontologies, this concept carried the discussion of ontology maintenance into a new level (Mitra,2004). Changes in ontologies need to be verified. In the study of Li (2008) this need is reflected through the need of maintenance. A good maintenance process could achieve reusability of the ontologies. Unfortunately, this requirement also stays as a desire. However similar to the previous researches, this cannot be included as the main purpose of the study.

The implementation of the software could be taken as a step for ontology maintenance. Most of the time, this implementation requires the inclusion of domain expert. Actually this is similar to most of the knowledge based systems which follows knowledge management task methods to measure the ability of the systems from the perspective of the domain experts. In the study of Mitra (2004), this concept was implemented to answer the maintenance needs of their ontology. However, versioning problem arises with the further steps of their ontology.

System life cycle was taken into the consideration by Chang (2008) for ontology based product design. Ontology maintenance was given as a feedback mechanism to detect errors and casual factors against system aging. The incorrect or inconsistent slot values; repeated or missed concepts in classes and improper relations are given as the main indicators for the need for an ontology maintenance.

Especially with the knowledge management studies, knowledge based system has increased its importance. As a knowledge based or knowledge management system, ontologies are used for information sharing to refer to formal description of particular domains (Lacy,2005). To share information, ontologies have become essential for explicit representation of Semantic Webs (Ding,2006). However "how can we categorize ontology as a knowledge management system?" should be the next question to ask to define maintenance requirements. Based on Laudon and Laudon's categorization of Knowledge Management Systems (Laudon & Laudon,2006) ontologies could be included under Enterprise-Wide Knowledge Management Systems. For the categorization of knowledge, knowledge could be reflected as structured or unstructured. Ontology could easily find its place for categorizer of the structural or un-structural existence for collecting, storing, disseminating and reuse of the content and knowledge. Ontologies could be tools for the discovery and applicability of knowledge in domains. This tool condition makes it a software tool for Knowledge Intelligence.

As a software standard, Std 14764 maintenance structure could be easily applicable to the ontology, however, as a knowledge categorizer, it needs to be a more concentrated approach. To build up this part of an ontology, it is required to take ontology under knowledge management systems first. Also in most of the cases, categorizer of the knowledge and tool for knowledge intelligence cannot be separable. In engineering discipline, process is the definition of set of interrelated tasks for transformation of inputs into outputs. In most of the knowledge management systems, knowledge is an input and also an output. Based on Nonaka and Takeuchi (1995) the knowledge is embedded as explicit in the processes in a tacit form. For maintenance, implemented ontology tasks are important indicators of the ontology maintenance. To understand the dynamics of maintenance which is focused on the ontology, the tacit knowledge in the ontology tasks are required to be extracted.

2.2.2 Ontology Tasks

There are several different ontology task definitions found in the literature. To see the implicitly embedded knowledge in the ontology tasks, these tasks require specific identification.

In the study of Flouris and his colleagues (2007), ontology morphism, articulation, diagnosis, repair, evolution and merging were defined as additional tasks. However, again based on their definition of these tasks, they can be combined with the related main ontology tasks; morphism with mapping, articulation with ontology matching and alignment, ontology diagnosis and repair with debugging, merging with integration. For evolution, it is basically defined for the maintenance itself.

Maintenance approach could be found under different studies with different titles. In the study of Nejad (2010), from the perspective of change in the system management, a semi-automated agent-based framework was implemented. According to Nejad, ontology maintenance should focus on defined ontology change management to merge non-static domains. The mapping, matching and alignment, translation, debugging, versioning and integrations are the defined basic tasks. By looking at these definitions in the related researches, these tasks are detailed as follows;

- *Ontology Mapping*. This task simply was defined in the Couto et al. (2007) as the task of finding and measuring semantic similarities in an ontology. In the study of Flouris et al.(2007), the purpose of this task was defined as the resolution of heterogeneity in two ontologies. When a single ontology is insufficient to support required task(s), mapping would be required to support multiple applications that need to access other ontologies (Kalfoglou & Schorlemmer,2003). With this way, mapping could provide a common layer for these applications. Mapping could also provide interoperability among different ontologies and throughout this way, it could be helpful to support maintenance (Ehrig & Sure, 2004). Similarity base approaches mostly were implemented for ontology mapping (Couto et al., 2007).

- *Ontology Matching and Alignment*, The task of matching and alignment was defined as the relation between entities of different ontologies (Euzenat &

Shvaiko, 2007). Similar to the mapping, heterogeneity resolution and interoperability of ontologies are also the goals of this task (Flouris et al., 2007). The task goal could be also extended as finding relationships in between entities of the separate ontologies (Ziembicki, 2006).

- *Ontology Translation*. The task of reusing the ontologies by implementing different algorithms and languages was defined for the ontology translation in Corcho,2005. In Flouris et al. (2007), translation to a different ontology language and implementation of vocabulary mapping were included into this definition. The translation definition was expanded within different studies. In the study of Corcho (2004), to be able to use a part or entire ontology, a language or tool should be implemented and this job defined as translation. In Klein's study (2001), a framework's main job was defined to combine different ontologies announced as translation. Chalupsky (2000) was looked translation task for symbolic representation of knowledge to translate one to another. According to Kalyanpur, et al., (2006) for maintaining a system and understanding ontology, translation is given as an important tool. In these perspectives, translation of one ontology language to another is the main goal.

- *Ontology Debugging*. The task of extracting and cleaning of inconsistencies and incoherencies from the ontology was defined as debugging (Flouris et al.,2007). Also for removing an ontology, ontology debugging could be implemented. However in this research, if an ontology is un-merged into other ontologies, it is not called as ontology debugging. Debugging concept was implemented in Kalyanpur, et al.(2006) for repairing unwanted concepts in an OWL ontology. With including translation, in Flouris et al., (2007) any kind of change reflected through ontology debugging. For fixing semantic defects, debugging concept was also implemented by Sirin et al. (2007).

- *Ontology Versioning*. The task of managing different versions of an ontology defined as ontology versioning by Klein and Fensel (2013). According to Kohantorabi (2006), domain changes, adaptations of different tasks, concept changes could trigger versioning. Versioning management could also be required in distributed environments (Helflin et al., 1999). If a document base system defined with ontology, changes in documents could also be supported by ontology versioning (Helfin et al, 2004).

- *Ontology Integration*. The task of integrating one or more ontologies into other ones as a whole or part is the ontology integration, Pinto, Perez and Martiz, 1999. In this definition, building a new ontology by using old ontologies as a part, or with merging several separate ones as a one whole ontology defined as integration According to Flouris et al.,(2007), taking knowledge from ontologies and integrating it to the similar or identical domains were defined as the integration. For integrating different ontologies, Pinto and Martins looked at the how to implement integration as a process and in the study of Klein (2004) for change management, integration was reflected as a part of distributed ontology change management.

These tasks are important to draw a conceptual map for the methodological definition. In the next chapter these parts will be combined in the study definition.

2.3 Tasks before the Measurement

Based on the literature review's results, the ontology tasks, related inputs, implemented methods and results are combined in Table 7.

Table 7 - Ontology Task Base Method Implementation

Ontology Task	Input	Methods Implemented	Result
Mapping	More than two heterogeneous ontologies	Frameworks, methods and tools, translators, mediators, techniques, theoretical frameworks, experience reports, surveys, Automated, semi-automated approaches, such as neural network approach implemented.	Mapped ontologies based on terms and relations.
Matching and Alignment	More than two heterogeneous ontologies	Similar approaches could be implemented as in mapping	Related ontology terms An intermediary ontology to match ontologies.
Translation	An ontology and target ontology language; Ontologies and related map	Automated approach through Ontology translator. Semi-automated or manual approach	An equivalent ontology New retrieval method included ontology.
Debugging	An inconsistent/ incoherent ontology	Survey with domain experts Mapping and/or Matching Implementation	A consistent/coherent ontology.
Integration	More than two ontologies. New terms and relations	Matching and Alignment of new terms and relations	New integrated ontology.

Ontology Task	Input	Methods Implemented	Result
Versioning	An ontology	Implementation of other tasks could create different versions.	Different Version of Ontology

Even if all the tasks were implemented independently, the following relations between other tasks could also be drawn as given in Figure 3. With respect to literature review and the cases studied, a similar figure could appear in any maintenance implementation. As an example, from Figure 3, mapping could trigger matching and alignment and matching and alignment could lead debugging and finally if version management is supported by the system, it could end with versioning.

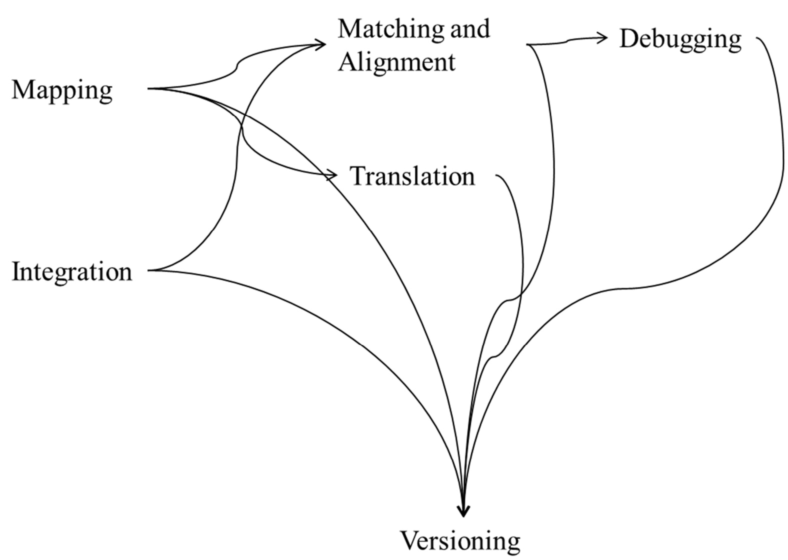

Figure 3 - Ontology Tasks and Possible Relation between Each other

In the next chapter, by looking at the findings, a research methodology will be identified to show ontology tasks and maintenance perspectives.

2.4 Summary of the Literature Review

The literature review was focused on the “ontology maintenance” subject. ACM, Web of Science and ProQuest journal and thesis databases were studied. In 94 results, 55 results were defined as the related publications. These publications were studied based on limitations, goals, validity and ontology cases titles.

In the second part of this chapter, maintenance and ontology tasks are investigated starting from standard for software maintenance and discussed with ontology and software maintenance. To understand the implemented maintenance structure, ontology tasks were taken as a base line. The determined ontology tasks are, ontology mapping, ontology matching and alignment, ontology translation, ontology debugging, ontology integration and ontology versioning.

The results of the tasks nature were also presented based on the findings of the literature review. The implemented tasks and their considered input, methods and results are given in a summary table. Also, the given connections that were extracted from the literature review are presented in Figure 3.

CHAPTER 3

RESARCH METHOD

The purpose of this study is to find the evidence of ontology tasks implementation in the ontologies to support ontology maintenance for sustainability. For this reason this research was designed as a case study to explore ontology maintenance evidence in the ontologies by revealing them with three data collection instruments (ontology codes, interviews and ontology development documents).

The chapter begins with a brief introduction to the case study and a brief discussion of why this approach is appropriate for this study. The next section is about the cases of SWEET, Galen and PFM ontologies. In the last section, the measurement details are given.

3.1 Research Questions

To reflect ontology tasks and ontology maintenance relations, the research questions will be answered by implementing research instruments.

The research questions (RQ) are given as follows;

RQ - 1: What are the indicators of ontology maintenance requirement based on ontology tasks?

Method Used for Answering RQ - 1: The findings of the literature review and the ontology tasks implemented. The ontology tasks are selected as the indicator of ontology maintenance. The existence of ontology tasks is questioned in BIHAP case with questionnaire measurements M2.1 to M2.6. After this collection, the degree of maintenance will be determined.

RQ - 2: What is the relation between user inclusion and the ontology maintenance?

Method Used for Answering RQ - 2: M2.7 is defined for collecting user information to compare M2.1, M2.2, M2.3, M2.4, M2.5 and M2.6. The results of the comparison will reveal the real effects of the user inclusion in the ontology maintenance.

RQ - 3: How could ontology tasks be implemented for providing a maintenance plan for sustainability of the ontology?

Method Used for Answering RQ - 3: The SWEET, PFM and Galen cases gave an initial start. By looking at the Part III Question 3 results, the maintenance requirement could be defined based on each participant groups (end users, developers and both). Which ontology task is required for the each developer, end user and both participant groups could be identified.

RQ - 4: How can the sustainable ontology maintenance be defined and therefore improved?

Method Used for Answering RQ - 4: With the collected feedbacks taken from case studies and interviews with the project stakeholders, structure will be refined and improved.

Table 8 - Research Question, Data Source, Instrument and Data Analysis

Research Question	Data Source	Instrument	Data Analysis
Question 1	Previous Researches, Case Ontologies and Questionnaire	Literature Review, Case Study, Questionnaire	Number of Ontology Tasks in each identified case. Questionnaire Part II questions measurements of M2.1, M2.2, M2.3, M2.4, M2.5 and M2.6 are related. M3 implemented for self-validation of Questionnaire.
Question 2	Part II first 6 questions and Part III	Questionnaire	Scoring M2.1 to M2.7 together and comparing
Question 3	Scores of M2.1 to M2.6 and M3.	Questionnaire	M2.1 to M2.5 scores compared with each other.
Question 4	Interview Results	Interview	Interview Results and Questionnaire results compared based on indicated ontology task.

3.2 Methodology

Methodology definition is required to answer the following issues,

- Determining the applicability of ontology tasks in Sustainable Ontology Maintenance,
- Specifying the applicability of ontology tasks under maintenance,
- Including human perspective in an interface supported ontology based system.
- Reaching consensus with project owner in sustainability support of the system.
- Getting feedbacks to refine and improve the ontology.
- Defining involvement of developers and users in the maintenance.

These issues that are investigated with the implemented methodology are based on the given objectives;

- *To identify the tasks that can be implemented to satisfy the maintenance need of an ontology:* Most of the ontology maintenance related studies are concentrated on software development activities. However the tasks that could be related with ontology maintenance are mostly defined in separate studies. For each task, maintenance effort focused on one specific objective and relations with other tasks and ontology maintenance are mostly unclear. This study will be unique for bringing all these separate studies under ontology maintenance roof.

- *To provide a structure that will be built over the software maintenance standard:* In the current literature review, one problem is the missing connection between software maintenance standard with the ontology maintenance studies. Based on the literature review, some of the studies showed the connection of the ontology related studies with the knowledge science, knowledge engineering and knowledge management [(Falge et al.,2007) , (Alomari,2009), (Gulla & Sugumaran,2008), (Chen et al., 2011) , (Smith, 2007) , (Bontcheca et al.,2006) , (Seidenbert &Rector,2006) ,(Bachore, 2012) , (Wroblewska et al, 2012), (Brigh, 2009) , (Li,2008), (Mitra, 2004), (Chang,2008)]. By extracting implicit knowledge in the ontology tasks, software maintenance standard is discussed.

- *To show the required maintenance needs based on the defined ontology tasks:* The identification of the ontology maintenance requirement with respect to identified tasks is one dimension of this study. Moreover, the other dimensions are recommendations related with the identified task. After identification of the tasks, the organization will be able to implement maintenance based on the identified tasks.

3.2.1 Case Study Design

Based on the given issues and objectives, case study is identified as the preferable methodology. Case study method is mostly preferable in examining contemporary events when the relevant behaviour cannot be manipulated (Yin, 2009). Case study method can be implemented in a large variety of domains such as law, business, medicine and public policy. With this flexibility, this research method is applicable in a large variety of academic fields.

In Yin's definition, the data collection and analysis strategies are required to be identified as a technical requirement for the investigators. Especially in the conditions which are of lack of standardization and in which distinct system structure exists, the case study is required. This is the reason why the case studies are mostly implemented in the Information Technology and Information System oriented researches (Steel & Hakim, 2009).

In Information Systems (IS) and Information Technology (IT) fields, for the implementation of the case study, not only a single case, but also a combination of multiple case studies may be required. Especially with the current maturity level of ontology based information system, there is a lack of ontology method description exists (Jansen & Brinkkemper, 2009). To build a theoretical model, distinct system structures need to be studied over documents and software parts.

To be able to reach a proper base line for the ontology maintenance, the relation between ontology tasks and software maintenance must be properly defined and structured.

By following Yin's perspective and Janses and Brinkkemper's multi case study suggestions, the following steps are defined for this study;

Figure 4 - Developmental Research Stages in This Study

The main task of each stage is defined as follows;

- *Define:* Define ontology tasks and candidate ontology cases.
- *Investigate:* Investigate the implementation of the ontology tasks for each case.
- *Evaluate:* Evaluate ontology tasks with another case by including developers and users participants.

3.2.2 Instrumentation

During each stage of this study, different kinds of instruments were implemented. These were;

- Document Investigation,
- Code Investigation,
- Questionnaire,
- Interview,
- Expert Opinion.

Document Investigation

Documents related with the cases were investigated to find evidence of ontology tasks implementations. These documents were design documents, web pages and related articles.

Code Investigation

Codes related with the cases were investigated to find evidence of ontology tasks implementations. These codes were ontology language codes related with the specific ontology implementations.

Questionnaire

The questionnaire was specifically prepared for the developer and end user groups of the BIHAP case. The question's aim was to collect evidence of ontology tasks implementation for the maintenance requirements.

Interview

Interviews were personally conducted with the developers of the BIHAP system. The questions were open-ended questions. The background, ontology tasks implementations and desired ontology tasks were asked to the participants of the interview.

Expert Opinion

BIHAP project leader's opinion on the questionnaire and ontology tasks has an important effect on the BIHAP case study. For finalizing the questionnaire questions and coordination of collecting the questionnaire had been coordinated with project leaders monitoring.

Validity and reliability issues of instruments are evaluated in the 'Reliability and Validity Issues of the Study' sub-section.

3.2.3 Procedures and Data Collection

In each stage of this study (define, investigate and evaluate), the instruments (document and code investigation, questionnaire and interview) were implemented to respond the requirements of each stage.

Define Stage

In this stage, document investigation, which is mostly concentrated on publication study, was implemented. Two main goals are;

- Identification of main ontology tasks
- Identification of ontology cases.

There are some standards, which have been written to support the maintenance of the software based information systems. By looking at these standards, the possible maintenance types should reveal for the ontology maintenance.

Implementation of maintenance should be built over some tasks. By looking at literature review under ontology maintenance, these tasks should be revealed.

Before starting the second stage of the study, the key maintenance types, and the ontology tasks concepts are expected to be ready.

The details of this stage can be found in Chapter Two.

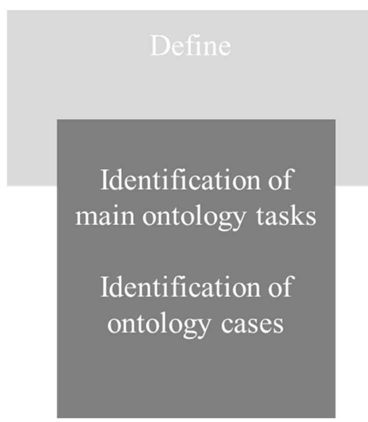

Figure 5 - Define Stage and Stage Goals

Investigate Stage

After identification of ontology tasks and ontology cases, available documents and codes were studied to find evidence of implementation of ontology tasks in each case. The activities implemented in this stage were historical and document based exploration-oriented case studies. The details of this stage are evaluated in the 'Conducting Case Study' sub-section.

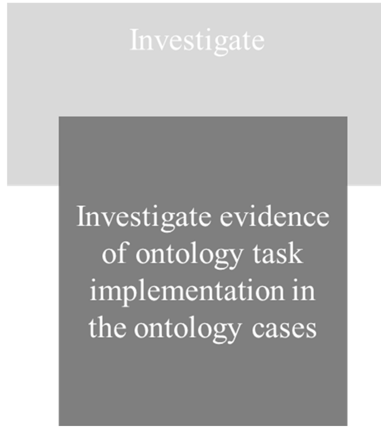

Figure 6 - Investigate Stage and Stage Goal

<u>Implementation Stage</u>

The identified and approved tasks were investigated in a real life case. During Define and investigation stages, this case was identified. Questionnaire, interview and expert opinion were the basic tools implemented. The evaluation of this stage is given in the 'The Structure' section.

Figure 7 - Implementation Stage and Stage Goals

3.2.4 Data Analysis

Each stage of this study contains unrelated case studies. Each case is unrelated because they were built with different goals in different domains. Therefore, different data collection and analysis methods were implemented. The details are provided in Table 9.

Table 9 – Stage, Data Collection, Data Analysis

Stage	Data Collection	Number of	Data Analysis	Time Frame
Define	Document	94 Publications	Content Analysis	2013 September-December
Investigate	Document	50 Document (Case documentations and web site images)	Content Analysis and Descriptive Analysis	2013 September-2014 May
	Code	Nearly 50000 lines of ontology code		
Implementation	Questionnaire - Pilot	12 Participants	Content	2014 May
	Questionnaire-Main	26 Participants	Descriptive Analysis	2014 June-September
	Interview	6 Participants	Content	2014 October

Content Analysis (CA); CA was implemented in all stages, especially in Define and Investigate stages. Content analysis was mostly implemented to define qualitative data. In Define stage, CA implemented for ontology tasks identification and ontology cases decisions. In Investigation stage, CA implemented for finding ontology task implementation evidences in each case. In the Implementation stage, the questionnaire content was analysed based on the understandability of the pilot study participants with the BIHAP project leader opinion. For the interview, the content of the interview texts were studied.

Descriptive Analysis (DA); in Investigation and Implementation stages, DA was implemented. In Investigate stage, the quantitative values were extracted from case documents, web site images and ontology codes based on the ontology tasks implementation. These values were the frequencies of each ontology tasks implemented in the cases. In the implementation stage, the participants' perspectives reflected over the result of median values.

3.2.5 Reliability and Validity Issues of the Study

As stated in the nature of the multi-case study (Steel & Hakim, 2009), qualitative and quantitative research methodology implementation required. In this study, the qualitative nature has more effect; therefore, with respect to this natural condition, the validity and reliability level of the instrumentation required more dedicated focus.

Validity of the study is discussed under credibility, transferability and generalizability, dependability and confirmability subjects.

- *Credibility;* to ensure credibility, under literature review, document investigation applied to find ontology tasks under ontology maintenance. The ontology tasks existence and the connection with ontology maintenance are studied accordingly. With BIHAP project participants included member checking and data gathering are used to increase is subject of the validity. Member checking achieved by returning to feedbacks of the ontology tasks and verified over interpretations or conclusions. Data gathering is applied with obtaining case study results from code and document investigations and questionnaire implementations.

- *Transferability and Generalizability;* the members checking and data gathering tasks implementation descriptions provided for the credibility support transferability and generalizability of the study for other cases and similar possible studies.

- *Dependability and Confirmability;* this subject of validity is achieved by the study diaries and worksheets that contain the researcher's schedule insights, related coding and reasoning parallel with the methodological decisions.

Reliability of the study is discussed under internal and external reliability subjects.

- *Internal Reliability;* Ontology tasks checking between the decided cases are one dimension of the internal reliability. The other dimension is the interview with the BIHAP project developer team which has members of PhD and MSc graduates with the academic and professional project experience. Therefore this interview supports the internal reliability of the questionnaire.

- *External Reliability;* this reliability subject achieved by the description of the data collection and analysis method and the researcher's status in the BIHAP project.

3.2.6 Researcher's Effects

The researcher worked for the BIHAP project. He worked as an expert in the project. His position gave opportunity to reach developer and user groups. The outputs of the study might be influenced for the future maintenance of the BIHAP's ontology.

3.3 Conducting Case Study

The first phase of case study concentrated over studying three ontology cases, SWEET, Galen and PFM. Each ontology's architecture and the ontology development strategy are different. For this reason, with concentrating on existing documents and ontology codes, different study strategies are implemented base on multi-case study research perspective.

3.3.1 Ontology Cases

Ontology Alignment, Ontology Debugging, Ontology Integration, Ontology Mapping, Ontology Translation and Ontology Versioning tasks could be implemented in any ontology to answer the need of ontology maintenance. However their possible implementation logic needs to be investigated. For this reason, as a part of this section, some of the well-known ontologies are investigated. Originally, as a result of literature review, Semantic Web for Earth and Environmental Terminology (SWEET), Galen and Transparent Access to Multiple Bioinformatics (Tambis) ontologies were identified as cases. However, because Tambis ontology files and related documentation cannot be reachable due to cancelation of the project (Tambis,2014) and the original link was not available for the web archive research, another ontology is identified as a candidate ontology. Finance Public Finance Management (PFM) ontology is a Turkish ontology which is built for the Ministry of Finance (PFM, 2013) is included as the third ontology.

The tasks and their position in the defined structure are identified after the discussion of the ontologies. The methods which are implemented for these ontologies are different because of their nature. SWEET ontology, PFM ontology and Galen ontology will be investigated accordingly.

Different stages of a lifecycle could be easily seen in these ontologies. Ontologies that are nearing retirement are SWEET and Galen. Already retired/cancelled ontology example is the Tambis and the ontology in the early stages of lifecycle is PFM. In order to extend the lifespan of an ontology and its related system and to be able to use it efficiently and effectively in its lifetime, maintenance must be applicable to all these separate stages of lifecycle.

3.3.2 Case1: Semantic Web for Earth and Environmental Terminology

In the Internet, there could be plenty of open ontologies available for researchers. However, it is not easy to find one with previous versions available for research. Semantic Web for Earth and Environmental Terminology (SWEET) ontology (2013) found as a result of literature review.

SWEET was started with the aim to improve understanding of the integrated Earth system and its components. This ontology evolved to an upper level ontology, which is ready to use by the other systems of NASA and other researchers. Even in the current web page, previous versions of the ontology are available for use, but this is not enough to look into the full ontology history of the SWEET.

In this part, NASA SWEET ontology images are used from webarchive.org (2013) (Internet Archive), evolution of NASA SWEET ontology was investigated according to type, tasks and challenges dimensions. Each version of the ontologies are reachable from the webarchive.org and mainly, these ontologies are investigated line by line. The results cannot be discussed with the SWEET team members. For this reason, even there is strong evidence of the implementation of these tasks, these tasks are given as possible tasks implemented on each versions.

Evolution of SWEET

The evolution of SWEET ontology was investigated with the webarchieve.org images, in the period between 2002 to 2012. For this reason the time of the maintenance could be different from the NASA's records. The defined ontology tasks were investigated under this part. From 2002 to 2012, the ontology tasks were grouped by years.

In 2002 the first SWEET ontology implementation was built with OilEd ontology editor. The implemented ontology language was DAML+OIL. This version was started with fifteen elements. However this first version and related implementation tasks were not taken as one of the ontology maintenance step. This was the first skeleton structure for populating the ontology. For this reason, ontology population could be defined as the first task implemented over SWEET ontology. As a result, the number of elements defined in this structure increased from fifteen to seventeen.

In 2003, the implementation language of ontology system was changed to support basic requirement that was expected from the ontology based system. This could be a challenging process for the developers. However, because the system is in the early stage of its lifecycle, the decision was taken. For this reason, this change was called as a major change. This major maintenance appeared on October 20th 2003 according to web achieve records. The ontology moved from DAML+OIL to OWL. The language change also triggered to decrease the number of elements from seventeen to nine. Until that point, name of the semantic entities "elements" changed to "ontology". The first maintenance task could be taken as ontology translation for changing the language from DAML+OIL to OWL, and decreasing number of ontologies could be taken as ontology integration. Probably this task requires matching and alignment of these ontologies to match and align related ontology parts in the new version. For removal of unnecessary relations and items and categories, to support new structure, ontology debugging was implemented. Totally, four maintenance tasks were implemented in 2003.

In 2004, the year was started with a task, which is not directly related with ontology structure itself. To make the version of the ontology available to public, a web interface was included to the SWEET ontology web page. However this change is not included as an ontology maintenance task. On August 1st, SWEET revised and validated and the number of ontologies increased to eleven. On October 10th, a new revision and validation activity was implemented and number of ontologies increased to thirteen. As a result of these activities, matching and alignment tasks were also implemented. In 2004, four maintenance tasks were implemented.

In 2005, the record of March 5th of web archive, the insertion of a new ontology has been detected, and the ontology integration was also implemented with it. As a result, the number of ontologies increased to fourteen.

The April 5th image brought the indication of a new maintenance task. According to this record ontology revision and validation was implemented on March 29th. Ontology debugging task was implemented to one of these ontologies through revision. Also, new ontologies became part of an existing structure with implementation of integration matching and alignment tasks.

On September 13th record, the third and the fourth maintenance tasks were located. According to these on June 15 and August 11, two debugging tasks had been implemented to the six ontologies.

A probable maintenance could be implemented between September and the end of December, because when starting with the December 12th image, the project that was implemented to SWEET was given. There may be additions to the structure of this ontology to support the interoperability between these projects, however this information was not reachable. So this will not be given as maintenance in the result part.

For 2006, there are some records taken by webarchieve.org. However, only February 22nd record indicates a maintenance task established on January 26th. According to this record, SWEET's structure was revised and validated. This is a potential debugging task. From that date to the end of 2006, no new maintenance task has been located in the SWEET.

The 2007 is important for the first appearance versioning in SWEET ontology. The first image from 2007 shows that a new beta version was published as version 1.1 beta. The old version that was in use was published as version 1.0. These versions are applied in different projects in parallel. Parallel usage of different versions requires ontology versioning task and ontology mapping between different versions. There were changes and removing of ontologies in this beta version, which leads ontology integration, ontology matching and alignment tasks and ontology debugging tasks implementation on SWEET. At this beta stage, the number of ontologies could be the same. However, nearly half of the ontology structures, especially relations, are different. The same entities were in use, so for this version, it was not necessary to take ontology population task implement as first stage.

The 2008's first record (February 11) shows that, SWEET ontology version 1.1 was introduced. There were no major changes identified. Because this version was announced as a new version and other versions were also available for public access, it requires ontology versioning.

Second maintenance stage was seen on the record of September 14th. Here, beta 2.0 version was published. Similar to the 2007 maintenance, same tasks also were implementable. The main change is the increased number of ontologies from fourteen to ninety. Actually it is an important indicator of turning SWEET ontology to an upper level ontology for different project implementations.

The work on SWEET beta 2.0 version continues in 2009. In the first image taken from that year, the number of ontologies increased from ninety to ninety-six.

2010 has two important maintenance stages. In June 2010, the SWEET beta 2.0 version had been reached to 188 ontologies. It seems that there has not given a direct concentration on the previous versions. The new changes did not reflected on other versions. However, because 2.0 is a beta version, it supposed to have ontology version tasks. The other stages are the same.

The second maintenance became visible on November. SWEET 2.1 directly announced without publishing a beta version, and it became visible. The previous versions 2.0 and 1.1 were announced as older versions and changes inside of both versions were stopped changes inside of both versions and no new ontology versioning tasks were required for 2010. The number of ontologies increased from 188 to 193.

From the record of July 2011, SWEET 2.2 was published and SWEET 2.1 became older. The number of ontologies has increased from 193 to 206 ontologies.

As a result of the second maintenance, the number of ontologies has reached 225.

In 2012, works on SWEET ontology were probably stopped because there has not been any maintenance reflected on their web page, which means to the web archive. However, there could be other maintenance stages, which are not publicly visible to the Internet users.

Results

For the study of results and evaluation, basically, the number of ontologies has been investigated. Also, to understand which tasks were implemented, in ontology terms, relations and categories have been also investigated. The maintenance tasks were implemented in each year and total number of maintenance and the distribution of the ontology tasks in these activities have been taken into the consideration. In the following part, some years were divided into the sub years, such as 2004_01 means first maintenance of the year 2004, and 2004_02 is the second maintenance of the year 2004.

Number of ontologies

Between 2002 version to 2008's first maintenance version (2008_01), there have not been any radical changes in the number of ontologies. After the announcement of SWEET version 1.1, the number of ontologies started to increase. This was probably due to the inclusion of other projects to the SWEET project.

In 2008, at the SWEET web page, 10 more projects were announced as the users of the SWEET ontology. These are important indicators that SWEET becomes an upper level ontology for all these projects and new potential ontologies.

The speed of increase in the number of ontologies had been reached to its highest acceleration between 2009 version and 2010's first version. In here, the number of ontologies increased from 96 to 188. However, to see real maintenance, it is required to name all tasks.

From the first record of SWEET web page, it is concluded that, the initialization was 2002. At that time, only population and main semantic structure was in this skeleton structure. For this reason, these tasks were not taken into the account as the maintenance.

With the changes in the semantic structure of the SWEET ontology, the number of ontologies also started to change. In 2003 Ontology Translation, Ontology Debugging, Ontology Integration, Ontology Mapping and Alignment were the main tasks implemented into the SWEET. Until 2007, number of tasks did not go beyond three tasks because, there was not any versioning mentioned in the web site's images, but with the announcement of version 1.0 and beta version 1.1 probably more complicated tasks were required, such as Ontology Mapping and Ontology Versioning to execute and manage maintenance. Between 2007 and 2011, SWEET matured from version 1.0 to 2.3 and as parallel, nearly all tasks continued with these versions. However, with 2010_02 maintenance, with the announcement of successor versions, the previous one was announced as the old version. In here, it is concluded that, for the outdated versions, there is no need for ontology versioning.

In 2011, the SWEET ontology reached its final version. Even though there could be possible changes implemented into the ontology and the system, these changes have not been reflected to the system.

Total number of implemented ontology tasks and distribution of these ontology tasks in each year are summarized in Table 10.

Normally, change in ontology language is not expected at the early stages of ontology life cycle. When a migration or an important version change is required, translation should be implemented. In SWEET, after the first year, it was decided to migrate the language into OWL.

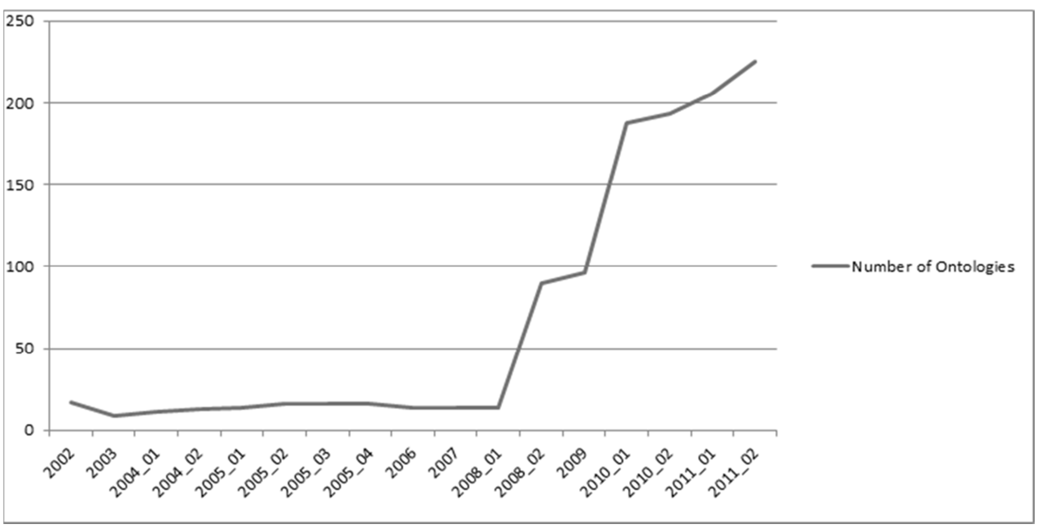

Figure 8 - Changes in the Number of Ontologies from 2002 to 2011

Nearly every year, ontology debugging, ontology matching and alignment and ontology mapping tasks are implemented together.

Table 10 – Implementation of the Ontology Tasks

	Years									
Tasks	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Total**
OT	1				1	1	1	2	2	**8**
OD	1		3	1	1	1	1	2	2	**12**
OI					1	1	1	2	2	**7**
OMA	1	2	1		1	1	1	2	2	**11**
OM	1	2	2		1	1	1	2	2	**12**
OV					1	2	1	1		**5**
Total	**4**	**4**	**6**	**1**	**6**	**7**	**6**	**11**	**10**	**55**

OM: Ontology Mapping, OMA: Ontology Matching and Alignment, OI: Ontology Integration, OT: Ontology Translation, OV: Ontology Versioning, OD: Ontology Debugging

With the increase in complexity, the number of maintenance has increased until 2011, except 2006. Actually it is quite understandable; it was the last year before the announcement of other projects in SWEET.

As it can be seen from the Table 10, the most active year was 2010.Ontology debugging and ontology mapping were implemented twelve times. For implementation of ontology versioning task, all tasks were required for the implementation.

From the published versions of the SWEET ontology at the project web page, from version 1.0 to 2.2, from 2007 to 2011 every year a new version was published. However the reality is different; by counting on different versions based on the number of ontologies inside, there are fourteen different versions. However, from the ontology task implementation, this yields seventeen versions. Again, it is not easy to tell the number of versions just by looking at webarchive.org records.

However this indicates a need for implementation of ontology maintenance. There could be a possibility of a decrease in the number of ontology tasks which were implemented based on a model. Probably, if a model was implemented previously, the need for new versions would not be necessary.

3.3.3 Case 2: Galen

Similar to SWEET, there has been other scientific ontologies such as Galen (2014) and Tambis (2014). Galen project files and old versions are still reachable. However for the Tambis, the project was cancelled and only a web page remained. This web page only gives conceptual content without the old versions of the ontology. There were some other ontologies that could be studied, however among them, only Galen has enough references are able to show enough relevance with the literature.

Galen was established to support healthcare services of clinical applications. Galen was developed over clinical terminology, which is called as GALEN common reference model. From 1980's to 2010's Galen maintenance created eight different versions. The project was cancelled in 2012, and according to web page, it is no longer active.

The terms and relations are still open for share. Rather than SWEET and PFM, these important assets are available for study. In this thesis, only relations (in Galen, it is called as semantics) are given. The implemented tasks were identified based on ontology files and the semantic structure was provided in Galen,2014.

In these periods, changes in each version's semantic entities were studied. The results are given as follows;

Version 1 to Version 2

The major implemented task was the ontology translation to the owl based system. However this transformation also brought debugging, mapping, matching and alignment and integrations tasks together. Total number of semantic entities and number of appearance of these entities were taken as the same.

Version 2 to Version 3

From version 2 to version 3, the number of semantic entities increased from 371 to 384. However in these entities only 28 entities were new to the ontology. 15 of these entities were removed from the ontology. 164 of the entities remained same. However, number of appearances of each entity increased for 157 entities. On the other hand, 35 of these entities were declined based on their appearance.

Version 3 to Version 4

From version 3 to version 4, the number of entities reached to 401. 21 new entities were included compared with version 3. 174 entities remained the same and 196 of these entities increased in appearance in the version. The number of entity appearance declined for 10 of these entities.

Version 4 to Version 5

Number of entities has reached to 427. The number of new entities which were included to the ontology was 30 and four of the entities were removed from the system. 209 entities remained unchanged. 172 of these entities appearance increased and 16 of them were decreased.

Version 5 to Version 6

For the version 6, number of entities decreased only one and reached to 426. No new entity was included into the system and 355 of these entities remained unchanged. 51 of the entities appearance increased and 20 of them were decreased.

Version 6 to Version 7

The size of the ontology remained same. No entity was removed from the ontology. 376 of the entities' appearance remained same and 38 of the entities' appearance increased. 12 of the entities' appearance decreased.

Version 7 to Version 8

Number of entities remained same for the version 8. No new inclusion or no removal of the entities was seen for the version 8. 375 of the entities appearance remained same and 49 of the entities appearance increased. 2 of the entities appearance decreased.

Version 8 to Version 9

The number of entities increased to 456. Number of new entities increased to 30. No removal from the ontology was seen and 40 of the entities appearance remained the same. The number of appearance increased to 386.

Version 2 to Version 9

When comparing version 2 with version 9, the number of ontology entities increase from 371 to 456. 18 entities were new in version 9. 103 entities were removed from the version2. 61 of the semantic appearance remained same. 281 of the ontologies appearance increased and 11 of them decreased. For all these two ontologies, two of the entities were not included in both.

In each version, whenever these changes are in appearance of the entities, debugging, mapping, matching and alignment are triggered. Integration starts when new entities were added into the ontology. Based on the analysis of ontology version, the result table could be given in the Table 11 and 12 and 13.

Similar to SWEET, Galen also translated its ontology into OWL in the second version.

Although Galen announced to have eight versions, the integrated version was also taken as the ninth version for this study.

As it can be seen from this table, versioning has not been implemented in any of these ontologies. The reason is that versions are not connected with each other. For this reason, the need for version management between the versions is not necessary.

Again similar to SWEET, in each version, OMA, OM and OD were implemented. In addition to these tasks, integration was implemented in two times, when the first version was translated to OWL and when all separate ontologies were combined together.

Table 11 - Versions and Number of Semantic/Ontology Entities

Versions	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**
Number of Semantic Entities	371	384	401	427	426	426	426	456

Table 12 - Changes in Versions

	V2 to V3	**V3 to V4**	**V4 to V5**	**V5 to V6**	**V6 to V7**	**V7 to V8**	**V8 to V9**	**V2 to V9**
New Entities	28	21	30	0	0	0	30	18
Removed Entities	15	4	4	1	0	0	0	103
Unchanged Entities	164	174	209	355	376	375	40	61
Increase in Appearance	157	196	172	51	38	49	386	281
Decrease in Appearance	35	10	16	20	12	2	0	11

Table 13 - Galen Ontology Versions and Implemented Tasks

Tasks	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	Total
Debugging	1	1	1	1	1	1	1	1	8
Mapping	1	1	1	1	1	1	1	1	8
Matching and Alignment	1	1	1	1	1	1	1	1	8
Integration	1	1	1	1				1	2
Translation	1								1
Versioning									0

3.3.4 Case3: Public Finance Management

"Decision Making and Performance Management in Public Finance" is a project financed by the European Union and managed by the Ministry of Finance's Strategy Development Directory. The closing meeting was held on 28 January 2014. As a byproduct of this project, an ontology was developed. Although, the main aim of this project was not building an ontology based system at first, the inclusion of ontology helped to create a common main language between different stakeholders of the ministry.

There are different versions of the ontology, which were developed and maintained for the purpose of this project. In the following sections, these versions will be studied based on the ontology tasks applied on each version. To reach these previous versions, mainly previous ontology screenshots and documents were studied. From version 1 to version 6, ontology was recreated on MySQL 2008 R2. Version 7 and version 8 also were converted into this database. By using SQL language, each version was compared with each other. Related result tables are given in the Appendix part.

The ontology was studied based on terms, categories and relations. After each step, the basic document space increased from 25 to 41 reference terms and then when the ontology reached out its current version. At the end, 1525 items (including terms, relations, categories etc.) were defined as items in the project space, however all of these items were not included into the ontology itself. Only selected few (302 terms, 8 sub-ontologies or categories, 294 relations) were defined as items of the last version.

Here, to concentrate on the main purpose of each version and its successor version, the following data were collected in respect to implemented ontology tasks.

Version 1

First version of the ontology was started as a simple finance dictionary that relates English terms with Turkish ones. However there are some problems in relating these terms, there could be more than one Turkish term to define an English term and same for some Turkish definitions in English. Normally there are 1468 single records which were defined in this ontology, however, if the Turkish terms are taken as separate terms, with edition of 1466 terms (there were two missing Turkish parts in these records) this increases to 2934 records. Also, these numbers are changing with the inclusion of 37 English terms and 262 Turkish terms that were defined to explain each related Turkish and English terms. Also unintentionally, there were 81 records that define relations rather than English to Turkish term relations. The results were summarized in the Table 14;

Table 14 - PFM Version 1 Summary

Terms, Based on Each Record	
English:1468	Turkish:1466
Hidden Terms inside of the Records	
English:37	Turkish:262
Number of Relations That Were Not Defined	81

Version 1 to Version 2

First version shows that, every finding which was included into the ontology space was reflected without considering its importance. For the second stage, the ontology debugging task mainly implemented for term reduction. The number of records decreased to 310 terms. For Turkish, 3 terms are missing to relate English terms. However, similar to the version 1, 103 hidden terms for English terms and 28 hidden terms for Turkish were appeared. Also, the number of hidden relations has increased to 86. Version 2 summary is given in Table 15.

Table 15 - PFM Version 2 Summary

Terms, Based on Each Record	
English:310	Turkish:307
Hidden Terms inside of the Records	
Engslish:103	Turkish:28
Number of Relations That Were Not Defined	86
Number of Terms Came From Previous Version	
English:53	Turkish:30

Version 2 to Version 3

From version 2 to version 3, some terms were dropped and some new terms were included to the ontology. Also, categorization starts with the version 3, most are mixed with the relations (nearly half). Ontology debugging and ontology population were the main activities implemented in this stage. However, in 312 records, there are 116 terms that does not have Turkish terms. Also, hidden terms for English and Turkish have been seen in version 3. The results are summarized in Table 16.

Table 16 - PFM Version 3 Summary

Terms, Based on Each Record	
English:312	Turkish:196
Hidden Terms inside of the Records	
English:173	Turkish:11
Number of Relations That Were Not Defined	218 (nearly are defined as categorization)
Number of Terms Came From Previous Version	
English:73	Turkish: 58

Version 3 to Version 4

In version 4, the categorization was implemented and 12 categories defined. Also, for the first time, relations have been defined for three categories (in Turkish). The English term distributions are given in Appendix C.

Three ontology tasks have been implemented in this stage, first, ontology mapping for categorizing terms, second, ontology debugging for cleaning and removing unnecessary terms and third, population for defining relations between terms inside of three categories. Also, hidden terms and relations were removed from the ontology. Version 4 summary is given in Table 17.

Table 17 - PFM Version 4 Summary

Terms, Based on Each Record	
English:299	Turkish: 239
Number of Relations	37
Number of Terms Came From Previous Version	
English:241	Turkish: 174

Version 4 to Version 5

In version 5, there were small updates from version 4. Number of categories decreased to 11. The terms were integrated under the related categories. Also, ontology population continued with the inclusion of new terms and relations. With the new relations, terms were related with other terms with ontology mapping. New relation(s) started to include in English. Version 5 summary is given in Table 18.

Table 18 - PFM Version 5 Summary

Terms, Based on Each Record	
English: 217	Turkish: 141
Number of Relations	37
Number of Terms Came From Previous Version	
English: 214	Turkish: 147

Version 5 to Version 6

Version 5 is the last version that has Turkish terms and relations. With version 6, number of categories decreased to four and number of terms decrease to 115. The number of terms decreased to build a skeleton structure for the project. Version 6 summary is given in Table 19.

Table 19 - PFM Version 6 Summary

Number of Terms	115
Number of Relations	92
Number of Terms Came From Previous Version	14

Version 6 to Version7

In version 7, another change in strategy happened and categories were removed. Number of terms increased to 271. Ontology integration is the main task which was implemented. The relations are given in Table 20.

Table 20 - PFM Version 7 Summary

Number of Terms	271
Number of Relations	280
Number of Terms Came From Previous Version	99

Version 7 to Version 8

From version 7 to version 8, the big ontology was separated into 8 sub ontologies, and to do that, ontology translation was implemented. The previous versions were implemented on hozo ontology language (the file extension was *.ont), but for this version, owl versions were created. At the end, the created ontology was turned into an upper level ontology. Version 8 is summarized in Table 21.

Table 21- PFM Version 8 Summary

Number of Terms	302
Number of Relations	294
Number of Terms Came From Previous Version	271

Results

For the first maintenance, between version 1 and version 3, ontology debugging and ontology population are the two basic tasks which were implemented. With the start of categorization, in version 4, ontology mapping was also included. From version 2 to version 6, there was a tendency to increase the number of terms and relations, however in version 6, number of terms has reached its lowest value. However, for creating a solo ontology structure, in version 7, terms, relations and categories were combined together. For this reason ontology integration was implemented in version 7. In version 8, to support manageability of the ontology and to turn ontology into a higher-level ontology, ontology itself was divided into sub ontologies based on categories previously created. Also a new task was implemented to change ontology language and ontology translation. Ontology Versions and related tasks are summarized in Table 22.

Table 22 - Ontology Versions and Ontology Tasks

Ontology Versions	Ontology Tasks
Version 1 to Version 2	Ontology Debugging
Version 2 to Version 3	Ontology Debugging
Version 3 to Version 4	Ontology Debugging, Ontology Mapping,
Version 4 to Version 5	Ontology Debugging, Ontology Mapping,
Version 5 to Version 6	Ontology Debugging, Ontology Mapping,
Version 6 to Version 7	Ontology Integration
Version 7 to Version 8	Ontology Translation, Ontology Integration, Ontology Mapping and Ontology Alignment

As it can be seen, it was not easy to define when to implement which ontology task in ontology maintenance. For this reason, in the main passage, these ontology tasks were tried to divide out to the stages.

To be able to reach the last version of the PFM ontology was not easy. According to experts of PFM ontology, they started to implement ontology tasks without any knowledge. Most of the implemented tasks matured within the sixth version of the ontology. Even the project was closed in the early 2014, the ontology was left in the early stage of the lifecycle. For this dissertation, still it provides important value to build up a structure for sustainable ontology maintenance. The tasks and implementation under each ontology maintenance stage is given in Table 23.

Table 23 - Ontology Tasks Implemented in each Maintenance Stage

	OM1	OM2	OM3	OM4	OM3	OM6	OM7	Total
Versioning							1	**1**
Debugging	1	1	1	1	1			**5**
Mapping			1	1			1	**3**
Matching and Alignment						1	1	**2**
Integration						1	1	**2**
Translation							1	**1**

3.3.5 Conclusion

To reach proper information and knowledge, search methods and algorithms are also needed to be considered. Their definition is more close to the ontology translation logic. For this reason, searching or querying in ontology will be considered under ontology translation.

By looking at the results of the ontologies, all the ontology tasks, except versioning was implemented for both ontologies' maintenance. However for versioning, in the Galen maintenance, ontology versioning related activities were not implemented. In Galen, each version is independent from each other; therefore version management could be unnecessary.

Another point that requires discussion is the type of maintenance implemented in the ontologies. In these cases, the ontology tasks can be seen, however the reasons of the maintenance and implementations stay under the shadow. For this reason it is not possible to say anything whether they have corrective or perfective nature.

As concluded from these ontologies, rather than direct user inclusion, system base interfaces have more value. However, in BIHAP, user inclusion is also required to define proper maintenance requirements. In this dissertation, user inclusion is added as a knowledge task for this reason. In here, *user inclusion* is used for defining user interaction between users and systems. Also, at the end, it is expected that the maintenance nature could review the corrective and perfective reason of the maintenance.

A pilot questionnaire is implemented to find the proof of ontology tasks in an ongoing ontology. This questionnaire questions are prepared based on Usability and user experience surveys (2013) guide. This pilot study was implemented to the Yıldırım Beyazıt University Management Information Systems Department Students, the pilot questionnaire was given in Appendix A. 12 undergraduate students were included in this study and the participation to this study was in voluntary base. The questions and their relations between ontology tasks are given in Table 25. Before implementation of the study; the BIHAP system and its relation with the Ministry of Development was explained. After then, from the demo link of BIHAP, 15 minutes was given to the students for using the system. The questionnaire was implemented after this period. Based on the feedback collected from the students and BIHAP project leader, the questionnaire reached its final version. For the final version please see Appendix B.

In the pilot study, relation of the ontology tasks in each question was defined without consulting the project leader. For implementation of the questionnaire, the question and ontology tasks relations were updated based on the collected feedbacks and project leader suggestions.

SWEET, GALEN and PFM ontologies were implemented without direct user interfaces. For the implementation of BIHAP project, user interfaces were created and user has a higher level of inclusion in the system. Also more important user level is the system developers. It is required to include all two groups into this research.

3.4 The Structure

In both cases, the ontology systems were accessible through software interfaces. There were not any user interfaces to interact with the users. For this study, user inclusion was related with questions that have been added to show ontology tasks and user interface interactions. Pilot version of the questionnaire was created to reflect all ontology tasks. Two additional group of questions included to reflect users knowledge (UK) and system knowledge (SK) of the system and ontology concepts. In the questions of the questionnaire, the implemented scores for each question were given in Table 24.

As a result of collected feedbacks and expert opinion of the project leader, this structure was updated. Only ontology task related questions and user inclusion related questions asked in Part II. Part I is only concentrated on measuring participants' knowledge on ontologies and similar visualization systems. Part III questions implemented to see participants awareness of the current system. The scoring is provided in Table 25.

The questionnaire reached its final version. The Part II and related ontology tasks is provided in Table 26.

Table 24 - Pilot Questionnaire and Ontology Tasks Relations

	Questions	Ontology Tasks							
		OT	OD	OI	OA	OM	OV	UK	SK
Part I	1							X	
	2							X	
	3							X	X
	4							X	X
	5							X	X
	6							X	X
Part II	1	X	X				X		X
	2						X		X
	3	X	X	X	X	X	X		
	4	X	X	X	X	X	X		
	5	X	X	X	X	X			X
	6				X	X			
	7				X	X			
	8		X						
	9		X						
	10		X						
	11		X						
	12		X						
	13				X	X			
	14				X	X			
	15		X						
	16				X	X			
	17				X	X			
Part III	1		X		X	X			
	2		X		X	X			
	3								
	4	X	X	X	X	X	X		
	5	X	X	X	X	X	X		
	6	X	X	X	X	X	X		
	7			X	X	X			

OT: Ontology Translation, OD: Ontology Debugging, OI: Ontology Integration, OMA: Ontology Matching and Alignment, OM: Ontology Mapping, OV: Ontology Versioning, UK: User Knowledge, SK: System Knowledge

Table 25 - Questionnaire Questions, Answers and Scoring

Questions	Answers	Scoring
Part I, Question 1	a	3
	b	2
	c	5
	d	4
	e	1
Part I, Question2	a	1
	b	1
	c	1
	d	1
	e	1
Part I, Question3	i	1
	ii	2
Part II Q1 to Q24	Strongly Disagree	1
	Disagree	2
	Maybe	3
	Agree	4
	Strongly Agree	5
Part III, Q1 to Q3	a	2
	b	1
Part III, Q4	The number of choices is counted.	

Table 26 - BIHAP Questionnaire and Task Relation

	OT	OD	OI	OMA	OM	OV	UI
PartII							
1							X
2							X
3							X
4							X
5							X
6							X
7					X		
8					X		
9				X			
10				X	X		
11					X		
12				X			
13			X	X	X		
14	X						
15	X					X	
16		X					

	OT	OD	OI	OMA	OM	OV	UI
17		X					
18		X					
19		X					
20	X					X	
21			X				
22			X				
23						X	
24			X		X		
OT: Ontology Translation, OD: Ontology Debugging, OI: Ontology Integration, OMA: Ontology Matching and Alignment, OM: Ontology Mapping, OV: Ontology Versioning, UI: User Inclusion , X, related ontology task in the given question							

3.5 Application Procedure

The questionnaire is implemented for participants composed of developers, end users and the individuals with both characteristics. The collected results will be used to calculate given measurements. The measurements are crucial to show tasks that require maintenance and the different user perspectives in the current ontology system structure.

The results will be provided in Chapter 4 of this dissertation. The conclusion will be written based on the findings of this research.

3.6 Details of Measure

Details of the measures are given in characteristics, sub-characteristics and measurement headings. The detailed table representation of this part is given in Appendix D. The details of these measurements are provided in Table 27. All the characteristics and related measures are summarized in Table 28.

Table 27 - Measurement Details

Name	Name of the measure
Code	Code of the measure
Purpose of the Measure	Reason of implementation
Detail	Information about measurement.
Inputs	Required inputs for measurement
Measurement Formula	Measurement formula and explanation of the elements
Used For	Reason why this measurement is used

Participant measures indicate participants' individual level of knowledge in knowledge visualization and ontology concept. Measuring the awareness of the participant in knowledge visualization will provide this relation.

The General Measurement measure the awareness of all participants in knowledge visualization is used in this study. This measurement is mainly dependent on result of M1 and M3.

Table 28 - Characteristics and Related Measures

Characteristic	Sub-Char	Measures	Measurement
User	Participant	Participants Knowledge	M1a
	General	General Knowledge	M1b
Task	Mapping	Participant	M2.1a
		General	M2.1b
	Matching and Alignment	Participant	M2.2a
		General	M2.2b
	Integration	Participant	M2.3a
		General	M2.3b
	Translation	Participant	M2.4a
		General	M2.4b
	Versioning	Participant	M2.5a
		General	M2.5b
	Debugging	Participant	M2.6a
		General	M2.6b
	User Inclusion	Participant	M2.7a
		General	M2.7b
User Expectation	Awareness	Participant	M3.1a
		General	M3.1b
	Ontology Task	Participant	M3.2a
		General	M3.2b

3.6.1 Task Characteristics

Part II's questions from 7 to 24 aimed to find the ontology tasks requirement. Ontology Mapping, Ontology Matching and Alignment, Ontology Integration, Ontology Translation, Ontology Versioning and Ontology Debugging are evaluated from the perspective of the Developer, End User and Both participant groups. User Inclusion is calculated from the Part II's questions from 1 to 6 implemented for this calculation. The measurement title with M2 yields these characteristics.

Mapping

Individual and all participants' ontology mapping expectations are measured from the individual users and all user perspectives.

From each individual perspective, M2.1.a measurement is used Part 2 questions 7,8,10,11,13 and 24 are used to define the mapping requirements.

For showing the general perspective of the participants, M2.1.a is used as the main input for the measurement of M2.1.b. All participant results compared with developer, end user and users with the both characteristics.

Matching and Alignment

Individual and all participants' ontology matching and alignment expectations are measured from the individual users and all user perspectives.

From each individual perspective, M2.2.a measurement is used Part 2 questions 9,10,12 and 13 are used to define the matching and alignment requirements.

For showing general perspective of the participants, M2.2.a is used as the main input for the measurement of M2.2.b. All participant results compared with developer, end user and users with the both characteristics.

Integration

Individual and all participants' ontology integration expectations are measured from the individual users and all user perspectives.

From each individual perspective, M2.3.a measurement is used Part 2 questions 13,21,22 and 24 are used to define the integration requirements.

For showing general perspective of the participants, M2.3.a is used as the main input for the measurement of M2.3.b. All participant results compared with developer, end user and users with the both characteristics.

Translation

Individual and all participants' ontology translation expectations are measured from the individual users and all user perspectives.

From each individual perspective, M2.4.a measurement is used Part 2 questions 14,15 and 20 are used to define the translation requirements.

For showing general perspective of the participants, M2.4.a is used as the main input for the measurement of M2.4.b. All participant results compared with developer, end user and users with the both characteristics.

Versioning

Individual and all participants' ontology versioning expectations are measured from the individual users and all user perspectives.

From each individual perspective, M2.5.a measurement is used Part 2 questions 15,20 and 23 are used to define the versioning requirements.

For showing general perspective of the participants, M2.5.a is used as the main input for the measurement of M2.5.b. All participant results compared with developer, end user and users with the both characteristics.

Debugging

Individual and all participants' ontology debugging expectations are measured from the individual users and all user perspectives.

From each individual perspective, M2.6.a measurement is used Part 2 questions 16,17,18 and 19 are used to define the debugging requirements.

For showing general perspective of the participants, M2.6.a is used as the main input for the measurement of M2.6.b. All participant results compared with developer, end user and users with the both characteristics.

User Inclusion

Individual and all participants' user inclusion expectations are measured from the individual users and all user perspectives.

From each individual perspective, M2.7.a measurement is used Part 2 questions 1, 2,3,4,5 and 6 are used to define the user inclusion requirements.

For showing general perspective of the participants, M2.3.a is used as the main input for the measurement of M2.3.b. All participant results compared with developer, end user and users with the both characteristics.

3.6.2 Maintenance Expectation and Awareness Measurement

The results obtained from this measurement are used for comparison with the results from M2, M3 and M4 to support validity of the study.

Awareness

For the individual participant point of view, it will measure "what will be expected after using the system" from the perspective of single user. M3.1a is the code of this measurement.

To show general perspective from all participants point of view, "what will be expected after using the system" will be looked. M3.1b is the code of this measurement.

Ontology Tasks

The aim of this title is to re-measure the ontology tasks that are required to implement in BIHAP. This part code is M3.2

To measure "what will be expected from ontology tasks after using the system" from the perspective of a single user, the measurement code is M3.2a.

To measure "what will be expected from ontology tasks after using the system" from the perspective of all users, the measurement code is M3.2b.

3.7 Implementation and BIHAP Case

Ministry of Development's BIHAP (Bilgi Haritası Araştırma ve Geliştirme Projesi) project, Knowledge Map Research and Development Project) was started in April 2013. Under normal conditions, the project was expected to end in November 2013, however, it was extended October 2014. The main aim of the project is the development of a knowledge management system to support visualization of Ministry knowledge. To do that, an ontology was constructed. In the present condition, including all the departments of the ministry, more than 10.000 ontology entities were created. In the future, the implementation area is expected to expand into other government bodies. For this reason, this project required a proper model for the maintenance of the ontology.

As a part of this project, a sustainability document was expected to guarantee the evaluation of the system. The findings of this study also present a great potential for the preparation of this document.

The BIHAP case has been investigated to support these expectations. The main implementation tool is the BIHAP system sustainability questionnaire. The results are given in Chapter 4.

3.8 Summary

The SWEET, Galen and PFM cases defined as the result of literature review of the Chapter 2. This part of this study started with the section to identify case study research and identification of the purpose and the design of the case study. The objectives of the study also defined in the following section. The case studies conducted in the "Conducting Case Study" part. The structure, application procedure that will be implemented in the BIHAP questionnaire is identified after this step. The details of t measure were also given in another section.

The tasks characteristics base on the identified ontology tasks reflected at the end of this chapter.

In Chapter 4 provides a detailed analysis and presentation of the results for the current study.

CHAPTER 4

THE CASE: BIHAP ANALYSIS

In Chapter 2, the ontology tasks are identified under ontology maintenance. In Chapter 3, the existence of these tasks was investigated in the selected ontologies. In these ontologies, systems were re-built for supporting system-to-system connections through system interfaces. The Graphical User Interfaces in these systems, were either very simple, such as a query screen without knowledge visualization, or do not exist at all. Only system-to-system interfaces were under discussion. Another important missing aspect is the lack of human connections. In these cases, for Semantic Web for Earth and Environmental Terminology and Galen, the data and related information were collected over the Internet by focusing on and studying available Internet documents and code fragments. For Public Finance Management ontology there were only a few existing documents and codes, which were collected from few experts who were not directly related with the development of the system.

BIHAP case is important because of its focus on development of Graphical User Interface and the face to face meeting opportunities with experts from developer and end user groups. In this chapter, the details of the case study design are presented in research questions, settings, interpreting headings of case study findings headings. At the end of the chapter, the given research questions of the case study are answered.

4.1 Pilot Study

In order to verify whether the questionnaire questions were understandable by the participant or not, a pilot study was conducted. For implementation of this pilot, undergraduate students who have basic understanding of Information and Knowledge Management Systems were chosen. Yıldırım Beyazıt University Management Faculty, Management Information System department students were proper candidates for this reason. Twelve students have attended to this study. For the justification of the questions with the collected feedbacks from the pilot study, series of discussion meeting arranged with the BIHAP project leader. The aim of the pilot study was to identify any potential misleading content, such as terms and questions. The pilot version is given in the Appendix A. This version was updated based on the collected feedbacks and results (provided in Appendix B) and with the expert opinion of the project leader. The removal of the question and determining the questions and relations of ontology tasks are the most challenging tasks. Repeated and unrelated questions were removed. The clarity of the remaining questions was also improved based on these feedbacks. The final version is implemented in the main questionnaire implementation sessions of this study. This final version of the questionnaire is provided in Appendix B.

4.2 Participants

The questionnaires were sent to thirty-five people by e-mail. The coordination was in the responsibility of the BIHAP project leader. Twenty-six participants filled these questionnaires voluntarily. Among these participants, three groups are identified, developers, end users and both. Developers are identified as the system and ontology developers. Users are the end users who will potentially use this system as ministry content experts for implementation of the semantic relations. "Both" was defined as the participants who have both characteristics of developer and end user groups. "Both" could be defined as the knowledge managers or semantic relations developers who are experienced in information and knowledge base systems. In these questionnaires, nine participants are identified as developers, eleven participants are identified as end users and remaining six participants are identified as both.

Because of the collected sample size, non-parametric statistics was implemented. The statistical analysis of the similarity between these groups was calculated on SPSS 15. The level of significance is set at a p value of 0.05. Pairwise comparisons were done with the Mann-Whitney U test to detect differences between groups. Group 1 is defined as end users, group 2 is defined as developers and group 3 is defined as both. Base on the results only group one and group two had difference in results of part 1 of the questionnaire. No significant differences were calculated in the scores of the other comparisons.

Table 29 - Participant Groups 1 and 3

	Groups								p value
	1				3				
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	
Part 1	6.67	1.73	3.00	8.00	9.17	2.71	6.00	12.00	0.94
Part 2	82.78	4.79	77.00	94.00	76.17	8.86	61.00	86.00	0.17
Part 3	5.11	.60	4.00	6.00	4.83	.75	4.00	6.00	0.42
Total score	94.56	5.41	88.00	107.00	90.17	6.97	78.00	97.00	0.34

Table 30 - Comparison of the Scores of Groups 1 and 2

	Groups								
	1				2				p value
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	
Part 1	6.67	1.73	3.00	8.00	8.36	1.43	6.00	11.00	**0.03***
Part 2	82.78	4.79	77.00	94.00	77.27	15.59	39.00	94.00	0.65
Part 3	5.11	.60	4.00	6.00	4.68	.84	3.50	6.00	0.26
Total score	94.56	5.41	88.00	107.00	90.32	15.87	51.00	108.00	0.97

*Significant difference was found between group 1 and 2 ($p<0.05$).

Table 31 - Comparison of the Scores of Groups 2 and 3

	Groups								
	2				3				p value
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	
Part 1	8.36	1.43	6.00	11.00	9.17	2.71	6.00	12.00	0.52
Part 2	77.27	15.59	39.00	94.00	76.17	8.86	61.00	86.00	0.46
Part 3	4.68	.84	3.50	6.00	4.83	.75	4.00	6.00	0.73
Total score	90.32	15.87	51.00	108.00	90.17	6.97	78.00	97.00	0.52

As shown in Table 29, Table 30 and Table 31, most of the groups answers are similar except for the Part I questions of Group 1, End users and Group 2 Developers. This means that, each participant groups expectations from ontology, knowledge requirements and similar system experience are different.

4.3 Data Collection and Analysis Procedure

By including pilot study and two data collection activities, questionnaires and open-ended interview questions, the following figure is created. Time line of the events is provided in Figure 9.

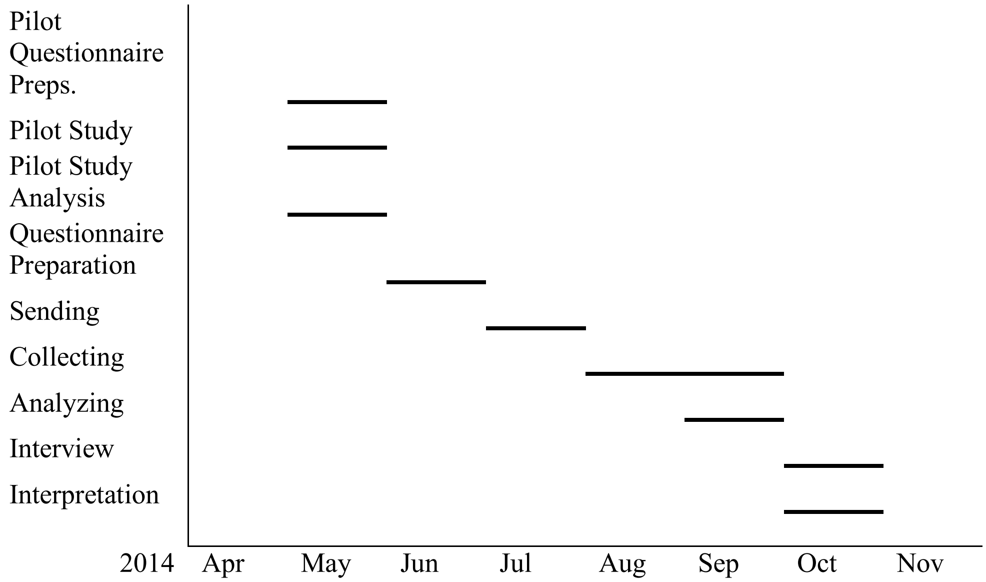

Figure 9 - Data Collection Activities TimeLine

As seen from the figure, the most challenging part was collecting the questionnaire from the participants. Base on the collected data, the following measurement results were scored.

4.3.1 Participants Profile (Measurement M1 and M3)

Based on the answers given in part I, the following results are collected. In twenty-six participants, only two users were identified as the users without any ontology knowledge. Nineteen users have moderate knowledge and five users have a high level of knowledge.

In addition to the current answers, participants' needs for the ontology; participants' awareness of the ontology after using the system, and the current system condition to answer knowledge requirements were collected. In Table 32, information is given as follows;

Table 32 - All Users

	Need for Ontology	Awareness to Ontology	Answering Knowledge Requirements
Yes	9	5	16
No	17	21	10

The distribution of the answers based on participants groups is given in Table 33;

Table 33 - Distribution of Answers According to Group

	Yes/ No	Developer	End User	Both	Total
Need for Ontology	Yes	2	5	2	**9**
	No	7	6	4	**17**
Awareness of Ontology	Yes	0	4	1	**5**
	No	9	7	5	**21**
Answering Knowledge Requirements	Yes	6	6	4	**16**
	No	3	5	2	**10**

Need for an ontology and awareness of ontology show the conditions before implementation of the system. On the other hand, answering knowledge requirements is an indicator after implementation of the system.

Need for ontology did not make much sense to most of the developers. In nine developers only two of them felt this need. However, in eleven end users, five of them felt this requirement before. For the participants in both sides, two of them felt this need.

The awareness of the ontology is another fact that was asked to the group. As it can be seen from Table 33, none of the developers are aware of the existence of an ontology. In the end user side, four of them know the existence and for the remaining, only one participant knows it.

After implementation of the system, the "yes" answers increased. For developers "yes" is six, end users it is five and for the participants in both sides it is four. This result shows that to support system sustainability, maintenance is required.

Currently, in order to see what system is required, first of all, which tasks are required to be implemented in the ontology should be detected.

Between all participants, only three participants have previous experience in a similar system. Debase Graph is given by two of the participants, protégé and IBMProfs are given by two of the participants. In these participants, all three of them have the characteristics of both developer and end-user.

4.3.2 Ontology Tasks (Measurement M2)

Based on the Table 26, Questionnaire and Ontology Task Distribution table, the median points for the ontology tasks distributions were calculated. For M2 calculations, Part II Question results were used. Each question value measures are based on the following values, Table 34.

Table 34 - Part II Question 1 to Question 24, Answers and Scoring

Questions	Answers	Scoring
Part II Q1 to Q24	Strongly Disagree	1
	Disagree	2
	Maybe	3
	Agree	4
	Strongly Agree	5

Six ontology tasks and user inclusions are measured with the questionnaire. All the results were compared between all participants' perspectives, developers' perspectives, end users' perspectives and both developer-end user type perspectives). Based on the calculated scores, the following results are collected;

Table 35 - Ontology Task Median Scores

	OM	OD	OMA	OI	OT	OV	UI
All	3.5	2.75	3.5	3.37	3.33	3.33	3.75
Developer	3.5	3	3.5	3.75	3.33	3.33	3.66
End User	3.5	2.75	3.5	3.25	3.66	3.33	3.83
Both	3.41	2.25	3.25	3.5	3	2.33	3.75
OM: Ontology Mapping, OMA: Ontology Matching and Alignment, OI: Ontology Integration, OT: Ontology Translation, OV: Ontology Versioning, OD: Ontology Debugging							

The questionnaire results shows an existence of ontology tasks implementation from the perspective of three participant groups. The scores are in between 2.25 (both participant group for ontology debugging) to 3.83 range (end user participant group for user inclusion).

For each participant group, values of the ontology tasks could be ordered as follows (highest first);

- Without grouping into the participants, user inclusion is 3.75, ontology matching and alignment and ontology mapping are 3.5, ontology integration is 3.37, ontology translation and ontology versioning are 3.33, ontology debugging is 2.75.

- From the perspective of developer group, ontology integration 3.75, user inclusion is 3.66, ontology matching and alignment, ontology mapping are 3.55, ontology versioning and ontology translation are 3.33 and ontology debugging is 3.

- For the end users, user inclusion is 3.83, ontology translation 3.66, ontology matching and alignment and ontology mapping are 3.5, ontology versioning is 3.33, ontology integration is 3.25 , and ontology debugging is 2.75.

- For "both" participant group, user inclusion is 3.75, ontology integration is 3.5, ontology mapping is 3.41, ontology matching and alignment is 3.25, ontology translation is 3, ontology debugging is 2.25 and ontology versioning is 2.33.

The results are conclusive with the Table 29 to Table 31 results in developers and end users perspectives for the ontology mapping, ontology matching and alignment, and ontology versioning tasks which are also parallel with all participants perspectives. However for the both participant groups, results are not parallel neither for other participants groups nor all participants.

4.3.3 User Expectations (Measurement M3)

For the validation purposes, in Part III, question four answers are collected from all the participants. Based on the following answers, participant answers, their expectations as ontology tasks were collected. In this part, only main ontology tasks were considered without user inclusion.

Each ontology task was coded as given in Table 36;

Table 36 - Ontology Tasks and Given Code

Code	Ontology Task
a	Ontology Matching and Alignment
b	Ontology Mapping
c	Ontology Translation
d	Ontology Integration
e	Ontology Versioning
f	Ontology Debugging

Based on the collected results, from a to e, the tasks were given with other ontology tasks. Based on the users groups, the answers also vary.

For the developers, ontology matching and alignment and ontology debugging task were given by two developers. Ontology matching and alignment, ontology mapping and ontology translation were selected by one developer. Ontology matching and alignment, ontology mapping, ontology translation, ontology integration, ontology versioning and ontology debugging were given by one developer. Ontology matching and alignment, ontology translation, ontology integration, ontology versioning and ontology debugging were given by one developer.

Ontology matching and alignment, ontology integration, ontology versioning were given by another developer. Ontology mapping, ontology translation, ontology versioning and ontology debugging are given together by one developer. And finally ontology translation and ontology debugging were given together by one developer.

End users made the following selections; three end users selected ontology debugging. Two end users selected ontology matching and alignment, ontology translation and ontology debugging together. Ontology matching and alignment, ontology mapping and ontology integration were selected by single end user. Another single user selected ontology matching and alignment and ontology translation together. Ontology mapping and ontology translation were selected by single end user. Ontology translation and ontology integration were selected by one end user. Ontology integration and ontology debugging were selected another user, and finally one another user were selected ontology versioning and ontology debugging together.

All six "both" users selected different choices. Ontology matching and alignment, ontology mapping, ontology translation, ontology integration, ontology versioning and ontology debugging were selected by one, ontology matching and alignment, ontology mapping, ontology translation, ontology versioning and ontology debugging by another one; ontology matching and alignment, ontology integration, ontology versioning and ontology debugging by another one; ontology matching and alignment, ontology versioning and ontology debugging were selected by one both user. Ontology matching and ontology translation were selected by one both user; ontology translation, ontology versioning and ontology debugging were selected by the last "both" user.

As shown in Table 37, in all participant groups, none of the ontology task groups were selected by all participants groups. However for ontology matching and alignment, ontology mapping, ontology translation, ontology integration, ontology versioning and debugging were selected by developer and both groups together. For the end user and both participants groups only ontology mapping and ontology translation groups were selected together.

Table 37 - Ontology Task Grouping

Ontology Task	Code	All (Total)	Developer	End User	Both
OMA	**a**	0			
OMA, OM, OT	**a,b,c**	1	1		
OMA, OM,OT,OI,OV,OD	**a,b,c,d,e,f**	2	1		1
OMA, OM,OT,OV,OD	**a,b,c,e,f**	1			1
OMA, OM,OT,OI,OV	**a,b,c,d,e**	0			
OMA,OM,OI	**a,b,d**	1		1	
OMA, OT	**a,c**	1		1	
OMA,OT,OI,OV,OD	**a,c,d,e,f**	1	1		
OMA, OT, OD	**a,c,f**	2		2	
OMA, OI, OV	**a,d,e**	1	1		
OMA, OI, OV,OD	**a,d,e,f**	1			1
OMA,OV,OD	**a,e,f**	1			1
OMA, OD	**a,f**	2	2		
OM	**b**	0			
OM,OT	**b,c**	2		1	1
OM,OT,OV,OD	**b,c,e,f**	1	1		
OT	**c**	0			
OT,OI	**c,d**	1		1	
OT, OV, OD	**c,e,f**	2	1		1
OT, OD	**c,f**	1	1		
OI	**d**	0			
OI, OD	**d,f**	1		1	
OV	**e**	0			
OV, OD	**e,f**	1		1	
OD	**f**	3		3	
	Total	**26**	**11**	**9**	**6**

4.4 The Follow-Up Study, Interview

To understand the maintenance and ontology task relation, interviews were conducted to the previous questionnaire participants. Especially, participants in the development of the BIHAP project were chosen from the developer and both participant groups. The interview request sent to the seventeen questionnaire participants (eleven developers and six "both"s). Only six of the previous participants agreed for the interview. Face to face interview meetings were arranged with each participant in different time intervals. The results were collected as the expert opinions.

The participants were coded as Participant1, Participant2, Participant3, Participant4, Participant5 and Participant6 base on the order of the interviews.

The interview questions were prepared in order to be able to see ontology tasks and maintenance. The interviews were conducted in Turkish. During the interviews, four open ended questions were asked. (The interview questions are given in Appendix E). These questions were prepared to show participants previous related experience (Question 1), the ontology tasks and maintenance relation from participants point of view (Question 2), the suggestions for the existence ontology tasks (Question 3), and their sustainability expectations from the system with respect to given ontology tasks (Question 4).

Before starting the interviews, each ontology tasks were explained. Also each question was explained to the participants. The given answers are cleaned and translated to English for this study. As addition to the participants' answers, the results indications are also included at the end of the each question. The following results were collected:

Question 1: Before the BIHAP, do you have any professional and academic experience that could relate with the project?

This question was asked to show these participants' competence the concept of ontology development from the perspective of academic and professional perspectives.

Based on the academic degrees hold by the participants, Participant1, Participant5 and Participant6 have PhD degrees and Participant2, Participant3 and Participant4 have MSc Degrees.

The project perspective divided into the two categories, academic project and professional project experiences. From the academic project perspective, Participant1, Participant3, Participant4 and Participant6 have related academic background and study related with ontologies and knowledge management. Participant2, Participant 5 and Participant 6 have related project experiences.

Even Participant1 does not have a related project experience, documents management and knowledge management related experience highlighted as other unrelated project experiences.

Participant2 has an important experience. Participant2 was also a part of PFM project team and contributed the development of PFM ontology in the early stage of the development.

Participant3's has computer programming skills and an academic background. Participant3 had done a research based on with web service compositions via ontologies in the stage of decision of PhD thesis title.

Participant4 does not have a professional ontology based project experience. On the other hand, currently Participant4 studies on ontology learning as a PhD thesis subject.

Participant5 has the highest level of knowledge in academic and professional perspectives. Participant5 combines experiences in different Turkish Government agencies projects as project leader.

Participant6 has direct academic and professional experiences. Participant6 earned PhD degree from the field of Knowledge Management and also received project support from Techo-enterprise program related with knowledge visualization systems from the Turkish Ministry of Industry in 2009.

The answers are given for the first questions indicate; all the participants have some basic knowledge to share ideas about the ontology tasks and maintenance implementation in the BIHAP. There are three PhD graduates and three MSc graduates attended in these interviews. The summary of this part is given in Table 38.

Table 38 - Question1 Participants Answers

Participants	**Academic Background**		**Project Experience**	
Participants	MSc	PhD	Academic	Professional
Participant1		X	X	
Participant2	X			X
Participant3	X		X	
Participant4	X		X	
Participant5		X		X
Participant6		X	X	X

Question 2: In the explained ontology tasks, are there any ontology tasks sufficient enough to support ontology maintenance requirements?

This question was asked to see the current ontology tasks previous implementation in the current system's structure to support ontology maintenance from the perspective of the participants.

Collection of Ministry's Employee's process definitions, job description and 5N1K has provided important knowledge for building basic ontology structure. One part of the maintenance also has been implemented over this structure. From basic document to ontology transformation requires ontology translation for this reason. In this Participant group, Participant1, Participant2, Participant3, Participant5 and Participant6 indicate this transformation as the basic tasks of ontology maintenance for this reason.

Participant1started evaluation based on the future expected maintenance. Based on Participant1's perspective currently ontology matching and alignment, ontology mapping, and ontology versioning have not been implemented yet. However, ontology debugging was implemented by these participant groups for building and maintaining ontology and controlled dictionary structures. When compared with the ontology translation, this task stays a rather manual one. Considering different document formats transformation and integration to the ontology after control meeting of the developed ontology structure, these two activities have brought ontology translation and ontology integration in the ontology maintenance process.

Participant2 indicates that, by including each document to ontology translation in the current ontology structure creates ontology versions. For this reason, this participant indicates ontology versioning as a natural result of the ontology maintenance. Also the manual changes in the ontology defined as the ontology debugging task by this participant.

Participant3 indicates implementation of all these tasks in the maintenance activities except ontology integration. By indicating system interfaces related with each ontology task, this participant highlights the existence of ontology maintenance. One more important point that's required to be mentioned is; based on Participant3's perspective, ontology integration could also be implementable with the integration of the other knowledge bases that belongs to other government agencies.

Participant4 indicates implementation of the ontology matching and alignment and ontology debugging for correcting semantic mistakes in the ontology. Based on Participant4's perspective, these tasks are sufficient to support the future maintenance requirements.

Similar to Participant1, Participant2, Participant3's indications, the Participant5 gave parallel answers the reason of the implementation of the ontology debugging and ontology translation. Also, Participant5 mentioned the system current support of the versioning, however, currently this support have not been used fully. For this reason Participant5 tried not to include ontology versioning in the currently used ontology task for ontology maintenance.

In these six participants, ontology integration was only given as an ontology task for the maintenance by the Participant6. Especially in the integration of collected different departments terms and relations, ontology integration, ontology mapping and ontology alignment and matching implemented together by this participant. Again similar to most of the participants, implementation of ontology debugging and ontology translation is given for the same ontology maintenance reasons.

Second question indicates different results. The given answers are summarized in Table 39.

These results show that, ontology debugging is mentioned by all of the six participants. Ontology translation mentioned by five participants, ontology matching and alignment by three, ontology mapping by two, ontology versioning by two and finally, ontology integration mentioned only by one participant.

Table 39 - Ontology Tasks Pointed out By the Interview Participants

	Ontology Tasks					
Participants	**OMA**	**OM**	**OD**	**OI**	**OV**	**OT**
Participant1			X			X
Participant2			X		X	X
Participant3	X	X	X		X	X
Participant4	X		X			
Participant5			X			X
Participant6	X	X	X	X		X

The grouping of these tasks is different for every participant. Ontology matching and alignment, ontology mapping, ontology debugging and ontology translation are grouped together by two participants. Ontology debugging, ontology versioning and ontology translation are grouped by two participants. However, in generally, ontology debugging and ontology translation tasks were given together by the six of the participants. Ontology matching and alignment, ontology mapping and ontology debugging are grouped by two of the participants. All the other groups are given in Table 39.

Question 3: Are there any other ontology tasks that you can suggest for ontology maintenance?

This question's aim is to collect other potential ontology tasks that could be included in the ontology maintenance. In this question, participants gave other tasks that were not included in the given ontology task list.

Participant1 and Participant6 pointed out user search/browsing related maintenance tasks for increased potential of the ontology. Participant1, for the management of the knowledge in the ontology, gap analysis suggested as another task for future integration of the governmental knowledge structures. This gap analysis also mentioned by the Particiapnt2, Participant5 and Participant6 as feasibility and gap analysis requirement.

Meta transformation of the ontology was suggested as an ontology maintenance by the Participant3. Again for the integration and mapping purposes, this could be easing different ontology structures to align in the BIHAP structure.

To support self-matching and alignment of the entities in the ontology, ontology learning is suggested by the Participant4.

Ontology maintenance quality and measurement are considered as tasks by the Participant5 to standardize the ontology maintenance processes. However, the participant also includes the need for more ontology maintenance considered studies focused on these aspects.

Participant1, Participant5 and Participant6 indicated the need for human aspects of the ontology maintenance. However, they cannot give a specific ontology task to support this suggestion.

The need for knowledge management related tasks reflected by the Participant1, and Participant6 especially from the administrative support and knowledge activities being embedded into the organizational culture.

The collected results could be summarized in Table 40.

Table 40 - Suggested Ontology Tasks for Maintenance

	Ontology Tasks						
Participants	**Ontology Feasibility/Gap Analysis**	**Ontology Search/ Browsing Improvement**	**Human Aspect**	**Knowledge Management, Administrative Support**	**Ontology Meta Transformation**	**Ontology Learning**	**Quality and Standardization**
Participant1	X	X	X	X			
Participant2	X						
Participant3					X		
Participant4						X	
Participant5	X		X				X
Participant6	X	X	X	X			

Question 4: Based on the answers given in question 2 and question 3, do you think ontology that was built for the BIHAP project is a sustainable ontology?

This question's purpose is to directly indicate participants' believe in the sustainability of the system by implementing ontology tasks given in question2 and question3.

Participant1, Participant2, Participant3, Participant4 and Participant6 gave positive answers. However, Participant1, Participant6 mentioned the need for knowledge management and human related aspects again. The other participants believe the possibility of sustainability without implementing the suggested tasks.

Participant5 on the other hand reflected a more pessimistic perspective. Even the ontology tasks that were given in previous questions were implemented for maintenance, so the possibility of this system transformation into a XML or database structure is highly probable.

The results collected from the participants summarized in Table 41;

Table 41 - Participants' Believe in BIHAP Ontology Sustainability

	Believe in Sustainability		Not Believe in Sustainability
Participants	**Without New Tasks**	**With New Tasks**	
Participant1		X	
Participant2	X		
Participant3	X		
Participant4	X		
Participant5			X
Participant6		X	

4.5 Summary of the BIHAP Case

BIHAP case study was started with the pilot implementation of the questionnaire on Yıldırım Beyazıt Universitiy Management Information Systems undergraduate students by looking at the whether the questions are understandable by the students or not. With the collected feedback, before implementation of the final version of the questionnaire, the questions were discussed with the BIHAP project leader.

Under the direct inclusion of Project Leader's supervision, the questionnaires were sent to thirty five people. Twenty six individuals participated in the study. Among these participants, three sub groups are identified as developer, end user and both, the group which has both developer and end user characteristics.

The data collection activities and analysis procedure implemented in between May 2014 to November 2014. The ontology tasks and user inclusion are discussed in the results of the questionnaires. By looking at the whole, these ontology tasks are studied as groups.

Finally for the BIHAP case, as the implementer of ontology tasks, from developer and both groups, series of interviews were implemented to see the real effect of ontology tasks in their maintenance activities. Six participants have volunteered for these interviews.

CHAPTER 5

CONCLUSIONS and DISCUSSIONS

In this final chapter, discussion of the findings, contribution of the study, limitations, implications for practice and future research opportunities are discussed.

The findings are discussed in respect to these main four research questions (RQ);

RQ-1: What are the indicators of ontology maintenance requirement based on ontology tasks?

RQ-2: What is the relation between user inclusion and the ontology maintenance?

RQ-3: How could ontology tasks be implemented for providing a maintenance plan for sustainability of the ontology?

RQ-4: How can the sustainable ontology maintenance be defined and therefore improved?

5.1 Discussions of the Findings

In this part, the results that were obtained from the study are discussed by focusing on literature via looking at related research questions.

RQ-1: What are the indicators of ontology maintenance requirement based on ontology tasks?

Based on the literature review and implemented tasks, the following findings were collected. The position of the ontology in the given maintenance process is one of the indicators of the ontology maintenance requirement. As given in the Standard 14764:2006 (International Organization for Standardization and the International Electrotechnical Commission,2006), the decision of whether the system deserves maintenance or not, is made based on where the ontology is positioned on the maintenance process. This condition was affected directly in the ontology maintenance case selection. In Chapter 2, the main aim was to study three cases that was referenced in the literature review, Semantic Web for Earth and Environment Terminology (SWEET), Transparent Access to Multiple Bioinformatics Information Sources (TAMBIS) and Galen. Tambis and Galen ontologies are retired ontologies that have no more new versions. The Galen ontology was retired after completion of its services. All the documentation and ontology code were reachable (Galen,2013). On the other hand, as indicated in the last image of Tambis (Transparent Access to Multiple Bioinformatics Information Sources, 2013), the project was cancelled due to financial problems. Because of this condition, instead of Tambis ontology, Public Finance Management was found and was studied over the existed codes and documentations. The codes and documents were not reachable. However, SWEET is different. SWEET was developed by NASA's expert. Although it does not have a new version since 2011, it has not been shut down yet. PFM is also important, because it is similar to BIHAP based on these aspects;

- Both have been developed for the Turkish Ministries;
- Both have been constructed over Turkish terms and relations.

The maintenance processes still works on SWEET and PFM. For this reason, they are still in maintenance processes, which means that maintenance will be implemented on all ontology tasks in the future. Moreover, all of the ontology tasks are still implementable into the SWEET and PFM. However, for Tambis and Galen, there are still possible implementation opportunities. They would be re-implemented in other projects for migration purposes. In this case, especially to support migration, ontology mapping, ontology matching and alignment could be implemented.

Another indicator is the size of the ontology. In these ontologies, with over 200 sub-ontologies, SWEET is the largest. Galen is the second, and PFM is the smallest. In 2010 and 2011 SWEET reached its highest volume. In these years, totally 21 ontology tasks were implemented. In 2008, SWEET's size was close to the Galen's final size with nearly 50 sub ontologies. In 2005, SWEET's size was close to the PFM's current size with nearly 10 sub ontologies. In 2004, in SWEET 6 ontology tasks were implemented for maintenance purposes. In PFM, this was 5 for reaching to the current version. In 2008, in SWEET, 7 ontology tasks were implemented. In Galen, for reaching the final version, that was 4. This shows that, by increasing the size, the ontology tasks implementation for the maintenance purposes also increases.

In BIHAP, because of the lack of number of ontology maintenance activities, ontology tasks were taken as the indicators of the ontology maintenance. By asking developers and end users of the BIHAP system, ontology tasks requirements were collected. Based on the collected results, the likert scale implemented for the ontology tasks evaluation, based on median values. The results show that, from all participants' view, ontology mapping and ontology matching and alignment focused maintenance related answer has the highest value of 3.5. From the developer perspective, ontology integration takes the lead with 3.75. End users' perspective is parallel with all participants' perspective. For the "both" participant group, this value is 3.5 in ontology integration. "Both" participant groups ontology maintenance is in ontology integration with the participant group developers. As indicated by the results, based on the participant groups, maintenance requirement changes depending on the ontology tasks.

RQ-2: What is the relation between user inclusion and the ontology maintenance?

In the first three cases, SWEET, Galen and PFM, the main approach was to study the available code and documentation. There was not any chance to contact with the developer and end user groups because of the lack of communication points. BIHAP gave this opportunity to include user perspectives in the ontology maintenance. For this reason, with BIHAP, ontology maintenance requirement and ontology tasks relation levered into the human level. User inclusion was defined to include end users, developers and "both" group into maintenance decision.

In the questionnaire, Part II questions from 7 to 24 mainly aim to show ontology tasks implementations. Part II first six questions aim to indicate user inclusion from the perspective ontology tasks from system functionalities. By including ontology tasks and user inclusions, the median values were calculated, please see Table 35. In all participant group, user inclusion median value is 3.75 which is higher than all other ontology tasks values. In developer participant group this value is 3.66, which is lower than ontology integration value (3.75). End users are also in favour of user inclusion with the value of 3.83. "Both" group is also in the favour of user inclusion with the value of 3.75. As seen from the results, only developers were fully concerned with ontology tasks. The other participant groups which are basically include end users mostly concerned with the user inclusion related ontology maintenance.

After implementation of maintenance, the interview results show a shift into the ontology debugging and ontology translation as the maintenance requirement. In six participants, all participants gave ontology translation and five participants gave ontology translation, please see Table 39. The question 3 of the interview was asked to include potential ontology tasks. However, given results mostly stay in the user inclusion definition because of the definition of system functionalities over ontology tasks. The ontology feasibility/gap analysis which was given by Participant1, Participant2, Participant5 and Participant6 is achievable by implementation of ontology mapping. Ontology search and browsing improvements which were indicated by Particapnt1 and Participant6 could be implemented through ontology translation. Ontology meta translation which was indicated by Participant3 could be implemented by ontology debugging and ontology translation. Ontology learning, which was indicated by Participant4, would require combination of all ontology tasks. For the human aspect (indicated by Participant1, Participant5 and Participant6), knowledge management administrative support (indicated by Participant1 and Participant6) and quality and standardization of the ontology maintenance (Indicated by Participant5), could be taken as supportive ontology task that comes with the user inclusion which could be included under the user inclusion.

As shown by the results, user inclusion requirements could be satisfied by the ontology tasks oriented ontology maintenance. However, this condition is not correct for some specific requirements. Users could indicate some requirement which could not be solved by these ontology tasks solely.

RQ-3: How could ontology tasks be implemented for providing a maintenance plan for sustainability of the ontology?

In SWEET, Galen and PFM ontologies, all these ontologies are built in different domains and with different purposes by different developer teams. To maintain these ontologies, combination of ontology tasks could be implemented. In all the ontology tasks nearly all of them are implemented except ontology versioning. In SWEET and PFM all tasks were implemented however, for Galen, ontology versioning implementation was not required. For BIHAP, in order to specify which ontology tasks are required to be implement in ontology maintenance questionnaire, Part III Question 3 results were taken into the account, please see Table 37. In these results two groupings have significance. One grouping that was made with all ontology tasks has existed in one developer and one "both". Only ontology debugging was selected solely by three end users. These different grouping was possibly created by the need for implementation of correction and enhancement related maintenance requirement.

To validate these findings and to demonstrate which ontology task should be considered for the up-coming ontology maintenance, interview Question 3 was asked two the participants. Based on the results were given in Table 39, each participant's grouping is different. In these results, there were not any common ontology task groups identified by all participants. However there is a significant result that requires concentration; ontology matching and alignment, ontology mapping, ontology translation and ontology integration were not expected to be implemented solely. However, from three end users perspective, three participants reflect the individual ontology debugging implementation needs that requires consideration.

The interviews also show that these tasks and implementation reasons, the maintenance mostly implemented for correction and enhancement reasons. Correction reason indicates corrective maintenance and enhancement reason indicates perfective maintenance. This is related with the age of the ontology. As the system gets older, it could be expected to shift towards correction maintenance.

Again from the interviews, Question 4 was asked for naming other ontology task requirements. The suggested ontology tasks vary in participants. In here, user inclusion tasks such as browsing/searching and versioning is given as answers. This could indicate more functional browsing and searching mechanism and creation and management of different versions. BIHAP has potential to become upper level ontology. However manual implementation of these will be problem with inclusion of different knowledge structures of different organizations. This requirement was also sensed by the participants. These participants gave the feasibility/gap analysis before inclusions of different knowledge organizations; and meta-transformation of the ontology for implementing ministry to organizations and organizations to ministry implementations. Also, rather than implementation of manual system based tasks implementations, ontology learning is given for automated or semi-automated task suggestion.

Based on these results, ontology maintenance is implemented especially to satisfy debugging requirements. Ontology debugging was identified in 17 of the 26 different groupings. In the interviews, debugging was indicated by all the participants. Ontology translation indicated in the 15 ontology groups. In the interview results, 5 of the participants indicated ontology translation.

The interview participants grouping and comparison with questionnaire results are given as follows; Participant6 grouping that indicated all tasks except ontology versioning was not existed in the grouping results of the interview. Participant3 has indicated all tasks except ontology integration indicated by 1 "both" participant. Participant2's grouping of ontology debugging, ontology versioning and ontology translation was indicated by one developer and one "both" participant. Particiant5 and Participant1's ontology debugging and ontology translation group was indicated by one developer; Participant4's ontology mapping and alignment and ontology debugging grouping indicated by two developers. All groups except Participant6's is exist in the interview groups. This result was created because of the maintenance on the ontology. Some versioning related functions were exist in previous versions during the questionnaires.(individual end user version creation). However that function was removed after the maintenance. For this reason this answer could not be found in the interviews.

By grouping these ontology tasks, a maintenance plan could be created for the next phases of the ontology maintenance.

RQ-4: How can the sustainable ontology maintenance be defined and therefore improved?

For the sustainability of the BIHAP system, ontology has an important role. All the knowledge visualization functions of the BIHAP are working over the ontology. For this reason, sustainability of the BIHAP is dependent on its ontology's sustainability. During the interviews, most of the participants gave positive answers except Participant5. Participant5 has the highest level of project experience and academic background. This condition gave a significant technical perspective and administrative perspective to this participant. For this reason in Question3, this participant indicates quality and standardization, human aspects and feasibility and analysis issues together. Currently because of lack of implementation of these tasks, Participant5 could not believe the sustainability of the system.

On the other hand, for Participant2, Participant3 and Participant4 the current ontology tasks are sufficient to support sustainability. For Participant1 and Participant6, new tasks could be included.

The suggested tasks are important to support further improvements. Especially the highlighted end users' transactions were identified under user inclusion because they require high graphical user interface implementation. During the interviews, the given ontology tasks suggestions, ontology search/browse, more complicated versioning, ontology meta transformation and ontology learning included in the user inclusion. However ontology gap/feasibility analysis and human dynamics related parts could be taken as the tasks over there ontology tasks. These separations will be helpful for proper ontology maintenance structure.

Moreover, to support user needs, a limitation could be sensed in the implementation of the ontology based system. As pointed out by the Participant6, technologically, database system and XML structures work faster for the implementation of the knowledge visualization and mapping. The ontology structure could be improved or not. In the condition of not to improve, for the sustainability purposes, the ontology could be translated into a database or a XML structure.

5.1.1 Internal, External and Construct Validity

Internal validity of this study was established with the detailed literature review under the title of ontology maintenance. The existence ontology tasks (ontology mapping, ontology matching and alignment, ontology integration, ontology translation, ontology debugging and ontology versioning) and the ontology cases (SWEET and Galen) were identified as results of this literature review. With inclusion of PFM ontology, this gives the credibility of the ontology tasks concepts in the applicability of ontology maintenance. By looking at the BIHAP, transferability and generalizability of the concept was studied in the internal framework of the study. The validation of the results collected from the questionnaire was satisfied with the face to face implementation of the interviews with the ontology developers. All these concepts maintained internal validity of this study.

External validity of this study was established with different perspectives. Based on ontology task implementation, a knowledge management process model was suggested by the researcher as a part of BIHAP System Sustainability Report, 2014. This brings the applicability of the ontology tasks in the knowledge management area for the public management domain. Over software maintenance model standard base (International Organization for Standardization and the International Electrotechnical Commission,2006), implementation of ontology maintenance was discussed in Medeni et al., 2014a. For transformation of the upper level ontologies, BIHAP and future BIHAP was debated in a special session and the model of ontology task oriented knowledge management process model proposed for implementation (Medeni et al.,2014b). By looking at the homogenous participants of end user, developers and “both” groups, the ontology tasks implementability for the maintenance of sustainable ontologies, the generalizability of the study was established with the support of applicability for the all participant groups.

Finding the evidence of ontology tasks implementation for the ontology maintenance in SWEET, Galen and PFM cases and also the ability of collecting ontology task and ontology maintenance related results from the BIHAP case supports the construct validity of this research.

5.2 Implication for Findings

The current research is a first step to achieve sustainability of the ontologies by implementing ontology tasks oriented maintenance.

- Based on the collected results from the questionnaires and interviews, it could be implied that, the system still needs to be improved in order to support future expansion of the ontology. Knowledge sharing culture must be supported by the Ministry administration. Starting from the Ministry itself, all the employees encourage sharing their knowledge to include as a part of the ontology. This will help to close the gap of explicit and tacit knowledge of the organizational knowledge.

- Technical procedures based on the standards and measurements need to be prepared for the ontology maintenance especially integration of the other organizations into the BIHAP ontology. Currently this may not be the case because BIHAP is still in the internal system architecture; however this will not be case in the near future. Feasibility and gap analysis should be made for every potential organization's knowledge bases. To do that meta-transformation of the knowledge exporter organizations' knowledge bases should be done for full integration to the BIHAP ontology.

- Semi or full automated learning ontology should be included especially on ontology mapping, ontology matching and alignment and ontology integration. After some point, these tasks cannot be done manually by the Ministry's experts.

- Ontology versioning will be used in highly because different knowledge semantic structure would be required for different organizations and their sub-hierarchical structures, such as departments, teams and even individual levels. To keep update the semantic entities and relations of all different ontology versions, these ontology versions should be managed very professionally and carefully.

- Ontology maintenance is not only a system related issue. Experts should be trained to be able to implement all these implications. As a part of ontology maintenance, their training will need to be maintained. From this perspective, this is also a maintenance requirement.

- Not directly as a part of this study, for the management of the BIHAP, in the BIHAP project documentation, in the knowledge management handbook (BIHAP, 2014) a dynamic model that combines knowledge management processes with software corrective and perfective maintenance together with the ontology tasks were suggested base on the this study. This suggested model was presented in ICKM 2014

- By using the study's findings in the Ministry of Development, the PFM ontology also will continue to evolve in the Ministry of Finance. As a part of a San-Tez project, a new version of PFM will be developed.

5.3 Further Research

Based on the literature research results, there were not any previous studies reported in the studied scientific fields under the same conditions at this research.

- This study was conducted in three ontology based project cases (Semantic Web for Earth and Environmental Terminology (SWEET), Galen and Public Finance Management (PFM) ontologies) and a single organization's ontology (Ministry of Development's BIHAP project's ontology).

- The implemented questionnaires and interviews should be re-conducted after one year to define ontology maintenance requirements and implement ontology tasks accordingly.

- Knowledge management perspective could increase the management of BIHAP's knowledge base with reflecting changing trends and requirements. For this reason this ontology should be taken as a part of a knowledge base system.

- By looking at ontology tasks, a knowledge management model by concentrating on processes and relations between ontology tasks is required. For the future researchers, this could be given as an important aspect which is open for further study opportunities.

- Moreover, the maintenance is not only dependent on questionnaires as a tool for implementation. However, an intelligent tool could be developed for answering requirements of the different systems. Based on interview participants' perspectives, this ontology tool must support meta-transformation and self-learning capabilities of the ontologies that were built over the given ontology tasks.

- Also, a study focused on ontology maintenance standards could be required for standardization of implementation of these tasks under proper condition. Measurement will be the next title after structuring of these standards.

- Human perspective of the maintenance is another open field for future researches, especially focusing on knowledge management. Training of ontology maintainers than maintenance of the content of these trainings will be other open aspect for the future studies.

- Other ontologies could be research based on given further research lists. Especially in Turkey, most of the project management still prefer not to implement ontologies in most of their knowledge projects. With changes in the knowledge perspectives of the organizations, it could be expected to implemented more ontology related approaches, for this reason, ontology maintenance still a virgin field that expects more researchers.

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APPENDICES

Appendix A Pilot Questionnaire

Questionnaire Version 1—Pilot

Sayın değerlendirici, öncelikli olarak vaktinizi ayırıp bu anketi doldurmaya karar verdiğiniz için teşekkür ederiz. Bu anketin amacı, kullanmakta olduğunuz sistemin sizin gözlemlediğiniz hususlar doğrultusunda, gerekli görülmesi halinde yenilenip sürekliliğinin sağlanmasıdır.

Temel Değerlendirici Karakteristikleri

1) Cinsiyetiniz
E K
2) Yaşınız
a) 25 ten küçük b)25-35 arası c)35-45 arası d)45 ten büyük

3) Ne kadar zamandır bilgisayar kullanmaktasınız

a) 5 yıldan az b)5-10 yıl arası c)10 yıldan fazla

4) Ne kadar zamandır internet ve/veya intranet tabanlı yazılımlar kullanmaktasınız

a)5 yıldan az b)5-10 yıl arası c)10 yıldan fazla

5) Ontology deyince neyi anlıyorsunuz?

a) Felsefi bir kavram b) Dini bir kavram c)Teknolojik bir kavram d)Hiç biri

6) Bilgi ihtiyacı olarak ne anlamaktasınız?

a) Veriler b)İlişkiler c)İstatistik d)Kavramlar e)Hepsi

Sistem Kullanımı

1) Daha önceden kullanmakta olduğunuz sisteme benzeri bir sistem kullanmış mıydınız?

i)Hayır   ii)Evet, Lütfen belirtiniz__________________

2) Bu sistemin daha önceki sürümlerini deneyimlediniz mi?
i)Evet   ii)Hayır

3) Şu ana kadar sistemi kullanmaktan ne kadar memnun kaldınız
a) Çok Memnunum   b)Memnunum   c)Memnun Sayılırım   d)Hiç memnun değilim

4) İş arkadaşlarınıza sistemi kullanmayı tavsiye eder misiniz?

a)Kesinlikle Evet   b)Evet   c)Belki   d)Hayır   e)Kesinlikle Hayır

5) Sistemini birkaç kelime ile tasvir etmek isteseniz hangi kelimeyi seçerdiniz?
a) Huzur   b)Sadece ekran ve Klavye c)Stress d)Keşke elektrikler kesilse

6) Sistem sizce bilgi ihtiyacı karşılamaya yeterli midir?

a) Kesinlikle Evet   b)Evet   c) Belki   d)Hayır   e)Kesinlikle hayır

Lütfen aşağıdaki boşlukları [1 ile 5] arasındaki değerlerle doldurunuz.(1 en düşük 5 en yüksek)

7) Sistemde gözüken kavramlar ve de kavramlar arası ilişkiler tutarlıdır.

8) İhtiyacım olan görevleri hızlı bir şekilde yapılmasını sağlamaktadır.

9) Sistemi kullanarak iş performansım artmaktadır.

10) İşteki etkinliğim sistemi kullanarak gelişmektedir.

11) İşimi kolaylaştırmaktadır.

12) Sistemin kullanımı kolaydır.

13) Kavramlar ve de ilişkileri görmek kolaydır.

14) Sistemde gözüken kavramlar ve de kavramlar arası ilişkiler doğrudur.

15) Sistemle açık ve de anlaşılırdır.

16) Aradığım bilginin nerede olduğunu rahatça görebilmekteyim.

17) Aradığım kavramın hangi kavramlarla ilişkili olduğunu rahatça bulabilmekteyim.

Sistemden Beklentiler

1)Sistem kullanımı sırasında gösterilen kavramlar ve de kavramlar arasındaki ilişkileri doğru buluyor musunuz?

a)Evet b)Hayır

2)Sistem kullanımı sırasında gösterilen kavramlar ve de kavramlar arasındaki ilişkileri yeterli buluyor musunuz?

a)Evet b)Hayır

3) Sistemi bu haliyle yeterli buluyor musunuz?

a)Evet b)Hayır

4)Sistemde sizi en rahatsız eden şey nedir?

5)Sistemde kesinlikle olmasını beklediğiniz özellik nedir?

6)Sistemin bir özelliğini değiştirmek isteseydiniz hangi özelliğini değiştirirdiniz

7)Sizce bu sistem bırakılıp başka bir sisteme mi geçilmelidir?

Appendix B: Questionnaire Version 2

BİHAP Sistem Sürdürülebilirliği Anketi

Sayın katılımcı, öncelikli olarak vaktinizi ayırıp bu anketi doldurmaya karar verdiğiniz için teşekkür ederiz. Bu anketin amacı, kullanmakta olduğunuz sistemin sizin deneyimleriniz doğrultusunda, gerekli görülmesi halinde yenilenip sürekliliğinin sağlanmasıdır. Bu amaçla bu anket üç bölüm olarak düzenlenmiştir. İlk bölüm, sizlerin temel sistem anlayışını göstermeyi, ikinci bölüm, sistem kullanımından edindiğiniz deneyimleri ölçülmeyi ve son bölüm ise, sistem kullanımından edindiğiniz genel görüşleri toplanmayı amaçlamaktadır.

Bölüm I

1) Ontoloji denilince ne anlıyorsunuz?

a) Felsefi bir kavram　　b) Dini bir kavram　　c)Bilgi Görüntüleme/Haritalama Aracı

d)Teknolojik bir araç　　e)Hiçbiri

2) Bilgi ihtiyacı denilince ne anlıyorsunuz? (Birden fazla seçenek işaretleyebilirsiniz)

a)Veriler　　b)Belgeler ve Dokümanlar　　c)İstatistik

d)Kavramlar ve ilişkiler　　e)İnsanlar ve çevresindeki insanlar

3) Daha önceden kullanmakta olduğunuz sisteme benzeri bir sistem kullanmış mıydınız?

i) Evet, Lütfen belirtiniz___________________　　ii) Hayır

Bölüm II

Lütfen aşağıdaki soruları ilgili cevabınızı X ile işaretleyerek doldurunuz.

	Kesinlikle Katılıyorum	Katılıyorum	Belki	Katılmıyorum	Kesinlikle Katılmıyorum
1) Kullanmakta olduğum sistem bilgi ihtiyacımı karşılamak için yeterlidir.					
2) Sorgulamanın sonucu çıkan şekiller bilgileri ve ilişkileri göstermek için yeterlidir.					
3) Sistem bilgiye erişimimi kolaylaştırmaktadır.					
4) Bilgiler ve ilişkileri anlamak kolaydır.					
5) Aradığım bilgiye rahatça ulaşabilmekteyim.					
6) Sistemi yardım almadan kullanmayı öğrenebildim.					
7) Aradığım bilginin nerede olduğunu rahatça görebilmekteyim.					
8) Aynı anlamda kullanılan farklı bilgiler sistem tarafından görüntülenmektedir.					
9) Aradığım bilgi benim uzmanlık alanım dışındaki bilgilerle ilişkili gözükmektedir.					
10) Aradığım bilgi birden fazla yerde farklı bilgi ve ilişkilerle geçmektedir.					
11) Farklı birimler benimle aynı bilgileri kullanmaktadır.					
12) Farklı birimler benim ilgili olabileceğim bilgileri değişik ilişkiler içinde kullanmaktadır.					
13) Aradığım bilgiyi beklemediğim ilişkiler içinde bulabilmekteyim.					
14) Sistem farklı arama metotlarıyla sorgulama yapabilmemi desteklemektedir.					
15) Farklı sorgulama metotları daha özel bilgi ve ilişkiler getirmektedir.					
16) Uzmanı olduğum konularla ilgili görünen bilgiler ve					

	Kesinlikle Katılıyorum	Katılıyorum	Belki	Katılmıyorum	Kesinlikle Katılmıyorum
ilişkilerde tutarsızlıklar görmekteyim.					
17)Uzmanı olduğum konularla ilgili gözüken bilgiler ve ilişkilerin tutarsızlıkları sisteme olan güvenimi azaltmaktadır.					
18)Sistem yakaladığım tutarsızlıkları bildirmeme izin vermektedir.					
19) Sistem de yakaladığım tutarsızlıkları düzeltmeme izin vermektedir.					
20)Bilgi haritasının daha önceki versiyonlarına farklı sorgulama metotları erişebilmekteyim.					
21) Sistem kendi birimim dışındaki birimlere özel bilgilerde sorgulama yapabilmeme izin vermektedir.					
22) Sistemde ilişkisiz, tek başına kalan bilgi(ler) bulunmamaktadır.					
23)Sistemde uzmanı olduğum bilgiler üzerinde yapılan değişikleri ve eski ilişki durumlarını görebilmekteyim					
24)İhtiyacım olan bilgileri bir araya getirip kendime özgü bilgi(ler) ve ilişkiler üretebilmekteyim.					

Bölüm III

1)Bu sistemi kullanmaya başlamadan önce burada verilen hizmetin gerekliliğini hissettiniz mi?

a)Evet b)Hayır

2) Bu sistemi kullanmaya başlamanızla beraber bilgi haritalaması üzerine bir farkındalığınızın oluştuğuna inanmakta mısınız?

a)Evet b)Hayır

3) Sistem bu haliyle bilgi ihtiyacından beklentilerinizi karşılamaya yeterli midir?

a)Evet b)Hayır

4)Sistem sizce hangi yönlerden geliştirilmeye ihtiyaç duymaktadır.(Birden fazla seçeneği işaretleyebilirsiniz)

a) Bilgi ve Kavram İlişkilendirme	b) Bilgi ve İlişki Gösterimi	c)Sorgulama metotları
d)Sorgulama sonuçlarının getirilmesi	e)Kullanıcı Geçmişi	f)Bilgi ve İlişki Tanımlaması, Güncellemesi

Ayırdığınız değerli zamanınız için teşekkür ederiz.

Appendix C: The PFM Ontology

Table 42 - Version 4 Categories, Terms and Relations

Categories	Number of Terms (in English)	Relations (in Turkish)	Number of Relations
Org Std	12		
Planning	9	Tanımlar/Dayalıdır	5
		Sahiptir/Oluşturur	1
Budgeting	46		
Accounting	78		
Cost	10	Tanımlar/Dayalıdır	2
		Kapsar/Alt Kümesidir	9
		Gerçekleştirir/ Gerçekleştirilir	1
Asset	16		
Process, Project, Service	18	Tanımlar	2
		Yönetilir	1
		Sahiptir	6
		Kullanır	4
		Dayalıdır	2
		Üretir	3
		Kapsar	1
		Desteklenir	1
Risk, Control	26		
Audit	5		
Results	26		
Method	21		
Economy	26		

Table 43 - Version 5 Categories, Terms, Relations

Categories	Number of Terms (in English)	Relations (in Turkish)	Number of Relations
Org Std	12		
Planning	9	Tanımlar	5
		Sahiptir	1
Budgeting	46		
Cost	11	Dayalıdır	2
		Kapsar	9
		Gerçekleştirir	1
Asset	16		
Has	8		
Process, Project, Service	18	İçerir	1
		Tanımlar	2
		Yönetilir	1
		Sahiptir	6
		Kullanır	3
		Dayalıdır	3
		Üretir	3
		Kapsar	1
		Desteklenir	1
Risk, Control	26		
Audit	5		
Results	26		
Method	21		
Economy	26		

Table 44 - Version 6 Categories, Terms and Relations

Categories	Number of Terms	Relations	Number of Relations
Accounting 1	32		
		Super, sub, is-a	12
		has	6
		uses	10
		Manages	1
Accounting 2	38	Super,sub,is-a	10
		Has	9
		Uses	2
Accounting 3	26	Super,is-a,sub	18
		Has	2
		Results in	1
		implies	1
		Is related	1
Process	18	Super,sub,is-a	5
		Has	7
		Consists of	6
		Is controlled by	1

Table 45 - Version 7 Relations

Relations	Number of Relations
Has	97
Super,is-a,sub	100
Defines	4
Enforces	2
Consists of	24
Guides	9
Results in	4
Equals	5
Uses	23
Relations	**Number of Relations**
Is represented by	9
Controls	3

Table 46 - Version 8 Ontologies, Terms, Relations

Ontologies	Number of Terms	Relations	Number of Relations
Audit	11	Super, is-a, sub	9
		Control	1
Accounting	110	has	16
		Uses	14
		equals	3
		Consists of	4
		Is represented by	7
		Results in	1
		Super,is-a,sub	64
Cost	52	Has	24
		Results in	3
		Equals	1
		Consists of	7
		Super,is-a, sub	16
		Uses	1
Control	33	Super,is-a,sub	5
		Has	23
		Controls	1
Performance	28	Has	6
		Uses	3
		Is represented by	1
		Consist of	3
		Controls	2
Planning	29	Has	16
		Uses	1
		Defines	4
		Consist of	7
		Guides	9
		Enforces	2
		Is-a,super, sub	2
Process	19	has	9
		equals	1
		Consist of	3
		Is-a,super,sub	6
Risk	19	Has	11
		Equals	2
		Uses	1
		Super,is-a,sub	5

Appendix D: Measurements

1 User Characteristics

1.1 Participant Measure

Table 47 - User Characteristics, Participant

Name	Participant Knowledge Visualization and Ontology Knowledge
Code	M1a
Purpose of the Measure	Measure the awareness of the participant in knowledge visualization
Detail	Compute the points in the related questions. Compare the total points with the other participants. These questions are in the first part of the Questionnaire. 1) What you understand from the term ontology? a) Philosophical term (3) b) Religious term (2) c)Knowledge visualization/Mapping Tool (5) d)A technological tool (4) e)None of above (1) 2) What you understand from the knowledge need? (You may mark more than one choice) a)Data(1) b)Documents(1) c)Statistics(1) d)Terms and relations(1) e)People and related people in the environment(1) 3) Have you ever used a similar system? a)Yes__________ b)No
Inputs	Questionnaire, Part I
Measurement Formula	Question1+Question2+Question3
Interpretation of Measured Value	The value in between 10 and 15 shows reliable knowledge of participant. The value in between 5 to 9 shows moderate knowledge level. The values less then 4 shows unreliable awareness to the system
Used For	User Characteristics

1.2 General

Table 48 - User Characteristics, General Participants

Name	All Participants Knowledge Visualization and Ontology Knowledge
Code	M1b
Purpose of the Measure	Measure the awareness of the all participant in knowledge visualization and ontology
Detail	Compute the points in the related questions for all participants and calculate based on number of participants. These questions are in the first part of the Questionnaire. 1) What you understand from the term ontology? a) Philosophical term (3) b) Religious term (2) c)Knowledge visualization/Mapping Tool (5) d)A technological tool (4) e)None of above (1) 2) What you understand from the knowledge need? (You may mark more than one choice) a)Data(1) b)Documents(1) c)Statistics(1) d)Terms and relations(1) e)People and related people in the environment(1)
Inputs	Questionnaire
Measurement Formula	Sum of(Question1+Question2+Question3)/Number of Participants
Used For	User Characteristics

2 Task Characteristics

2.1 Mapping

2.1.1 Participant

Table 49 - Task Characteristics, Ontology Mapping, Participant

<table>
<tr><td>Name</td><td>Ontology Mapping Requirement from The Participant Point of View</td></tr>
<tr><td>Code</td><td>M2.1.a</td></tr>
<tr><td>Purpose of the Measure</td><td>To see the need of ontology maintenance focused on ontology mapping from each individual perspective.</td></tr>
<tr><td>Detail</td><td>Compute the total points obtained from the Questionnaire based on single participant. Questions are taken from the part II of the questionnaire;
<table>
<tr><th></th><th>Strongly Agree</th><th>Agree</th><th>Maybe</th><th>Do not Agree</th><th>Strongly Do not Agree</th></tr>
<tr><td>7) I can easily see the knowledge I request.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>8) The system shows different knowledge titles with the same meaning.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>10) The knowledge I require listed with other knowledge and relations.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>11) Other directories use the same knowledge that I use.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>13) I can find the knowledge in the unexpected places and relations.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>24) I can map other relations to create specific knowledge and related relations.</td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Inputs</td><td>Questionnaire</td></tr>
<tr><td>Measurement Formula</td><td>Average(Question7+Question8+Question10+ Question11+Question13+Question24)</td></tr>
<tr><td>Used For</td><td>Ontology Mapping Measurement</td></tr>
</table>

2.1.2 General

Table 50 - Task Characteristics, Ontology Mapping, General Participants

Name	Ontology Mapping Requirement from The All Participants Point of View
Code	M2.1.b
Purpose of the Measure	To see the need of ontology maintenance focused on ontology mapping from all participant perspective.
Detail	Compute the total points obtained from the Questionnaire based on all participants, developers, end users and users with the both characteristics.
Inputs	M2.1.a measurement values
Measurement Formula	Median(M2.1.a Measurement Values)
Used For	Ontology Mapping Measurement

2.2 Matching and Alignment

2.2.1 Participant

Table 51 - Task Characteristics, Matching and Alignment, Participant

<table>
<tr><td>Name</td><td>Ontology Matching and Alignment Requirement from the Single Participant Point of View</td></tr>
<tr><td>Code</td><td>M2.2.a</td></tr>
<tr><td>Purpose of the Measure</td><td>To see the need of ontology maintenance focused on ontology matching and alignment from each individual perspective.</td></tr>
<tr><td>Detail</td><td>Compute the total points obtained from the Questionnaire based on single participant. Questions are taken from the part II of the questionnaire;
<table>
<tr><td></td><td>Strongly Agree</td><td>Agree</td><td>Maybe</td><td>Do not Agree</td><td>Strongly Do not Agree</td></tr>
<tr><td>9) The knowledge that I request seems related with the domains that are not in my expertise area.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>10) The knowledge I require listed with other knowledge and relations.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>12) Other directories uses knowledge, that may related with my area of expertise, in different relations.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>13) I can find the knowledge in the unexpected places and relations.</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>Inputs</td><td>Questionnaire</td></tr>
<tr><td>Measurement Formula</td><td>Average (Question9+Question10+Question12+ Question13)</td></tr>
<tr><td>Used For</td><td>Ontology Matching and Alignment Measurement</td></tr>
</table>

2.2.2 General

Table 52 - Task Characteristics, Matching and Alignment, General Participants

Name	Ontology Matching and Alignment Requirement from All Participants Point of View
Code	M2.2.b
Purpose of the Measure	To see the need of ontology maintenance focused on ontology matching and alignment from all participant perspective.
Detail	Compute the total points obtained from the Questionnaire based on all participants, developers, end users and users with the both characteristics.
Inputs	M2.2.a Measurement Values
Measurement Formula	Median(M2.2.a Measurement Values)
Used For	Ontology Matching and Alignment Measurement

2.3 Integration
2.3.1 Participant

Table 53 - Task Characteristics, Ontology Integration, Participant

<table>
<tr><td>Name</td><td>Ontology Integration from the Single Participant Point of View</td></tr>
<tr><td>Code</td><td>M2.3.a</td></tr>
<tr><td>Purpose of the Measure</td><td>To see the need of ontology maintenance focused on ontology integration from each individual perspective.</td></tr>
<tr><td>Detail</td><td>Compute the total points obtained from the Questionnaire based on single participant. Questions are taken from the part II of the questionnaire;
<table>
<tr><th></th><th>Strongly Agree</th><th>Agree</th><th>Maybe</th><th>Do not Agree</th><th>Strongly Do not Agree</th></tr>
<tr><td>13) I can find the knowledge in the unexpected places and relations.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>21) System authorize users to search in other directories specific knowledge</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>22) In the system there are some unrelated solo knowledge</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>24) I can map other relations to create specific knowledge and related relations.</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>Inputs</td><td>Questionnaire</td></tr>
<tr><td>Measurement Formula</td><td>Average (Question13+Question21+Question22+ Question24)</td></tr>
<tr><td>Used For</td><td>Ontology Integration Measurement</td></tr>
</table>

2.3.2 General

Table 54 - Task Characteristics, Ontology Integration, General Participant

Name	Ontology Integration from All Participants Point of View
Code	M2.3.b
Purpose of the Measure	To see the need of ontology maintenance focused on ontology integration from all participant perspective.
Detail	Compute the total points obtained from the Questionnaire based on all participants, developers, end users and users with the both characteristics.
Inputs	M2.3a measurement values
Measurement Formula	Median(M2.3a Measurement Value)
Used For	Ontology Integration Measurement

2.4 Translation

2.4.1 Participant

Table 55 - Task Characteristics, Ontology Translation, General Participant

<table>
<tr><td>Name</td><td>Ontology Translation from a Single Participant Point of View</td></tr>
<tr><td>Code</td><td>M2.4a</td></tr>
<tr><td>Purpose of the Measure</td><td>To see the need of ontology maintenance focused on ontology translation from each individual perspective.</td></tr>
<tr><td>Detail</td><td>Compute the total points obtained from the Questionnaire based on a single participant. Questions are taken from the part II of the questionnaire;
<table>
<tr><td></td><td>Strongly Agree</td><td>Agree</td><td>Maybe</td><td>Do not Agree</td><td>Strongly Do not Agree</td></tr>
<tr><td>14) System support different searching methods.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>15) Different search methods could bring special knowledge and relations.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>20) I can access previous versions of knowledge map with different searching methods.</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>Inputs</td><td>Questionnaire</td></tr>
<tr><td>Measurement Formula</td><td>Average(Question14+Question15+Question20)</td></tr>
<tr><td>Used For</td><td>Ontology Translation Measurement</td></tr>
</table>

2.4.2 General

Table 56 - Task Characteristics, Ontology Integration, General Participant

Name	Ontology Translation from all Participants Point of View
Code	M2.4b
Purpose of the Measure	To see the need of ontology maintenance focused on ontology translation from all participant perspective.
Detail	Compute the total points obtained from the Questionnaire based on all participants, developers, end users and users with the both characteristics.
Inputs	M2.4a measurement values
Measurement Formula	Median(M2.4a Measurement Values)
Used For	Ontology Translation Measurement

2.5 Versioning

2.5.1 Participant

Table 57 - Task Characteristics, Ontology Versioning, Participant

<table>
<tr><td>Name</td><td>Ontology Versioning from a Single Participants Point of View</td></tr>
<tr><td>Code</td><td>M2.5a</td></tr>
<tr><td>Purpose of the Measure</td><td>To see the need of ontology maintenance focused on ontology versioning from each individual perspective.</td></tr>
<tr><td>Detail</td><td>Compute the total points obtained from the Questionnaire based on a single participant. Questions are taken from the part II of the questionnaire;
<table>
<tr><th></th><th>Strongly Agree</th><th>Agree</th><th>Maybe</th><th>Do not Agree</th><th>Strongly Do not Agree</th></tr>
<tr><td>15) Different search methods could bring special knowledge and relations.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>20) I can access previous versions of knowledge map with different searching methods.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>23) I can see changes and previous relation status of the knowledge in my domain</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>Inputs</td><td>Questionnaire</td></tr>
<tr><td>Measurement Formula</td><td>Average(Question15+Question20+Question23)</td></tr>
<tr><td>Used For</td><td>Ontology Versioning Measurement</td></tr>
</table>

2.5.2 General

Table 58 - Task Characteristics, Ontology Versioning, General Participant

Name	Ontology Versioning from all Participants Point of View
Code	M2.5b
Purpose of the Measure	To see the need of ontology maintenance focused on ontology versioning from all participant perspective.
Detail	Compute the total points obtained from the Questionnaire based on all participants, developers, end users and users with the both characteristics.
Inputs	M2.5b Measurement Values
Measurement Formula	Median(M2.1.a Measurement Values)
Used For	Ontology Versioning Measurement

2.6 Debugging

2.6.1 Participant

Table 59 - Task Characteristics, Ontology Debugging, Participant

<table>
<tr><td>Name</td><td>Ontology Debugging from a Single Participants Point of View</td></tr>
<tr><td>Code</td><td>M2.6a</td></tr>
<tr><td>Purpose of the Measure</td><td>To see the need of ontology maintenance focused on ontology debugging from each individual perspective.</td></tr>
<tr><td>Detail</td><td>Compute the total points obtained from the Questionnaire based on a single participant. Questions are taken from the part II of the questionnaire;
<table>
<tr><th></th><th>Strongly Agree</th><th>Agree</th><th>Maybe</th><th>Do not Agree</th><th>Strongly Do not Agree</th></tr>
<tr><td>16) I can see inconsistencies about the subject of knowledge and relations.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>17) The inconsistencies related with the subject in my expert area harm to the trust of the system.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>18) System let me send feedbacks related with the inconsistencies.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>19) System let me fix the inconsistencies that I aware of.</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>Inputs</td><td>Questionnaire</td></tr>
<tr><td>Measurement Formula</td><td>Average(Question16+Question17+Question18+ Question19)</td></tr>
<tr><td>Used For</td><td>Ontology Debugging Measurement</td></tr>
</table>

2.6.2 General

Table 60 - Task Characteristics, Ontology Debugging, Participant

Name	Ontology Debugging from All Participants Point of View
Code	M2.6b
Purpose of the Measure	To see the need of ontology maintenance focused on ontology debugging from all participant perspective.
Detail	Compute the total points obtained from the Questionnaire based on all participants, developers, end users and users with the both characteristics.
Inputs	M2.6a Measurement Values
Measurement Formula	Median(M2.6a Measurement Values)
Used For	Ontology Debugging Measurement

2.7 User Inclusion

2.7.1 Participant

Table 61 - Task Characteristics, User Inclusion, Participant

<table>
<tr><td>Name</td><td>User Inclusion from a Single Participant Point of View</td></tr>
<tr><td>Code</td><td>M2.7a</td></tr>
<tr><td>Purpose of the Measure</td><td>To see the need of ontology maintenance focused on user inclusion from each individual perspective.</td></tr>
<tr><td>Detail</td><td>Compute the total points obtained from the Questionnaire based on a single participant. Questions are taken from the part II of the questionnaire;
<table>
<tr><th></th><th>Strongly Agree</th><th>Agree</th><th>Maybe</th><th>Do not Agree</th><th>Strongly Do not Agree</th></tr>
<tr><td>1) The system is satisfactory to satisfy my knowledge needs.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2) The result figures of a search is enough to show knowledge and it's relations.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3) The system make it easy to reach knowledge.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4) It is easy to understand knowledge and relations.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5) I can easily reach the knowledge that I requested.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6) I learned how to use the system without taking any help.</td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Inputs</td><td>Questionnaire</td></tr>
<tr><td>Measurement Formula</td><td>Average(Question1+Question2+Question3+ Question4+Question5+Question6)</td></tr>
<tr><td>Used For</td><td>User Inclusion Measurement</td></tr>
</table>

2.7.2 General

Table 62 - Task Characteristics, User Inclusion, General Participant

Name	User Inclusion from all Participants Point of View
Code	M2.7b
Purpose of the Measure	To see the need of ontology maintenance focused on user inclusion from all participant perspective.
Detail	Compute the total points obtained from the Questionnaire based on all participants, developers, end users and users with the both characteristics.
Inputs	M2.7a measurement values
Measurement Formula	Median(M2.7a measurement values)
Used For	User Inclusion Measurement

3 Maintenance Expectation Measurement

3.1 User Awareness

3.1.1 Participant

Table 63 - Maintenance Expectation, User Awareness, Participant

Name	Single User Expectation Awareness Characteristics
Code	M3.1a
Purpose of the Measure	To measure "what will be expected after usage of the system" from the perspective of single user
Detail	Questionnaire's Part III's first three questions are implemented to achieve this purpose. The questions are; 1) Have you ever urge the need of using a system similar to this one? a)Yes(1) b)No(0) 2) Do you believe start of awareness to the knowledge mapping after using this system? a)Yes(1) b)No(0) 3) Is this system enough to support your knowledge requirements? a)Yes(1) b)No(0)
Inputs	Questionnaire, Part III
Measurement Formula	Question1+Question2+Question3
Used For	User Awareness Measurement

3.1.2 General

Table 64 - Maintenance Expectation, User Awareness, General Participant

Name	All Users Expectation Awareness Characteristics
Code	M3.1b
Purpose of the Measure	To measure "what will be expected after usage of the system" from the perspective of all participants
Detail	
Inputs	Questionnaire, Part III
Measurement Formula	Total (Question1+Question2+Question3)/Number of Participants
Used For	User Awareness Measurement

3.2 Future Expectations and Awareness After

3.2.1 Participant's After Awareness

3.2.1.1 Participant

Table 65 - Maintenance Expectation, Ontology Task, Participant

Name	Single User Expectation on Ontology Task Characteristics
Code	M3.2a
Purpose of the Measure	To measure "what will be expected from ontology tasks after usage of the system" from the perspective of a single user
Detail	Questionnaire's Part III's fourth question is implemented to achieve this purpose. The question is; 4) In what parts system is required to improve. (You can mark more than one answer) a) Relating Knowledge and Terms; b) Knowledge and Relation Visualization; c)Question methods d) Returning search results; e) User history; f)Updating and Defining Knowledge and Relation
Inputs	Questionnaire, Part III and Evaluation Matrix Measurement Values
Measurement Formula	Question4
Used For	User Awareness Measurement

3.2.1.2 General

Table 66 - Maintenance Expectation, Ontology Task, General Participant

Name	All Users Expectation on Ontology Task Characteristics
Code	M3.2b
Purpose of the Measure	To measure "what will be expected from ontology tasks after usage of the system" from the perspective of all users.
Detail	Compute the total points obtained from the Questionnaire based on all participants, developers, end users and users with the both characteristics.
Inputs	Questionnaire, Part III Question 4 Evaluation Matrix
Measurement Formula	Total(Question4)/Number of Participants
Used For	For comparing the values of M2, M3 and M4 for validation of the questionnaire

Appendix E: Interview Questions

BIHAP Sürdürülebilir Ontoloji Mülakatı

Sayın Katılımcı, bu mülakat daha önce doldurmuş olduğunuz "BİHAP Sistem Sürdürülebilirliği Anketi"ni tamamlamaya yönelik hazırlanmıştır. Bu mülakata vereceğiniz cevaplar, BİHAP sisteminin idamesi ve de Ontoloji İdamesi konusunda bilimsel nitelikli çalışmalar için yararlanılacaktır.

1. BİHAP öncesinden, akademik ya da proje odaklı benzer deneyimleriniz bulunmakta mıdır? Lütfen açıklayınız.
2. Size açıklanmış olan ontoloji görevleri sizin proje için uyguladığınız idame/bakım ihtiyaçlarını karşılamak için yeterli midir?
3. Sistemin idamesi/bakımı için önerebileceğiniz ya da ekleyebileceğiniz başka görevler var mıdır?
4. İkici ve üçüncü sorularda verdiğiniz cevaplar dikkate alındığında sizce BİHAP projesi için ortaya çıkan ontoloji sürdürülebilir bir ontoloji midir?

Appendix F: Questionnaire Raw Results

Part I

Participants	Q1	Q2	Q3
P1	5	3	1
P2	5	5	2,Debate Graph
P3	1	1	1
P4	5	1	2,Protégé
P5	3	1	1
P6	4	3	1
P7	5	5	2,Debate Graph, Protégé
P8	5	2	1
P9	3	2	1
P10	5	1	1
P11	3	1	2,IBMProfs
P12	5	1	2,Protégé
P13	5	1	1
P14	5	2	1
P15	5	3	1
P16	3	2	1
P17	5	1	1
P18	5	3	1
P19	4	4	1
P20	3	2	1
P21	3	4	1
P22	5	3	2
P23	4	2	1
P24	5	2	1
P25	5	4	1
P26	5	5	1

Part II

Participants	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
P1	3	4	4	4	4	5	5	3	3	4	3	3
P2	4	4	4	5	4	5	4	2	3	3	4	4
P3	4	4	4	4	4	4	4	3	3	3	3	3
P4	4	4	5	4	4	4	3	4	4	4	3	3
P5	2	3	4	4	4	4	3	4	4	4	3	4
P6	4	4	5	4	4	5	3	2	3	4	4	4
P7	3	3	3	3	4	5	4	2	3	3	3	3
P8	4	4	4	4	4	3	4	5	4	4	3	4
P9	2	2	4	4	3	4	3	3	4	4	4	4
P10	3	4	3	4	0	4	2	4	4	4	3	3
P11	2	2	4	4	3	4	4	4	4	4	4	4
P12	3	2	4	4	4	4	4	4	4	4	3	3
P13	4	2	4	4	4	4	4	4	2	4	4	4
P14	1	4	2	1	1	1	1	1	1	4	1	1
P15	4	4	4	4	3	4	3	3	4	4	4	4
P16	4	4	5	4	5	5	5	4	3	4	3	3
P17	4	3	4	4	3	5	4	2	4	5	5	5
P18	4	4	5	4	2	3	3	3	4	4	4	3
P19	3	2	2	4	4	3	3	4	3	4	2	4
P20	4	4	5	4	3	5	4	5	3	2	3	4
P21	3	4	5	3	4	4	4	3	3	3	3	4
P22	2	2	2	3	3	2	3	2	3	2	2	2
P23	3	3	4	3	2	3	3	3	2	4	4	4
P24	5	5	5	4	4	1	4	4	4	4	4	4
P25	2	3	3	3	3	2	2	4	3	4	4	3
P26	4	4	5	4	4	5	4	4	4	4	3	3

Part II

Participants	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24
P1	3	5	2	2	2	2	2	3	3	3	1	3
P2	4	2	2	3	4	1	1	1	3	4	3	2
P3	3	4	4	2	2	3	3	3	3	3	3	3
P4	4	4	4	3	3	2	4	2	3	2	3	4
P5	4	4	4	3	4	2	2	2	4	4	4	3
P6	3	3	3	3	3	2	2	2	3	3	2	2
P7	3	1	1	3	4	1	1	1	2	3	1	1
P8	5	5	4	4	3	3	3	4	4	4	4	4
P9	4	4	4	3	2	4	4	3	4	4	3	3
P10	3	4	4	3	3	4	4	3	4	4	4	4
P11	4	4	4	3	3	4	4	3	4	3	3	4
P12	3	3	3	3	3	3	3	3	4	4	4	4
P13	3	4	4	2	2	2	2	2	4	3	4	4
P14	3	1	1	1	1	1	1	3	3	1	1	3
P15	4	5	5	2	2	1	1	1	3	3	3	2
P16	4	5	4	2	4	2	4	4	3	2	4	4
P17	5	5	5	3	4	2	1	1	5	2	1	3
P18	4	4	4	4	2	4	4	4	4	3	4	4
P19	2	4	1	1	2	2	5	0	5	5	3	3
P20	4	4	3	2	2	2	3	3	4	3	4	4
P21	4	5	5	2	2	3	4	3	3	2	3	4
P22	2	3	3	5	5	2	2	2	3	3	2	2
P23	3	2	4	4	3	3	4	4	3	3	4	4
P24	5	5	5	5	1	3	4	3	3	3	4	5
P25	3	4	3	4	4	2	1	1	5	4	4	3
P26	4	2	4	2	2	1	1	2	4	4	4	3

Part III

Participants				
P1	1	1	2	c,e,f
P2	2	2	1	a,e,f
P3	2	2	2	a,f
P4	2	2	1	c,f
P5	2	2	1	a,b,c,d,e,f
P6	2	2	1	a,f
P7	2	2	1	a,b,c,d,e,f
P8	1	2	2	c,e,f
P9	2	2	1	a,c
P10	1	2	1	a,d,e
P11	2	2	1	a,c,d,e,f
P12	2	2	1	b,c,e,f
P13	2	2	2	a,b,c
P14	1	2	1	a,c,f
P15	2	2	1	d,f
P16	2	2	2	c,d
P17	1	2	1	f
P18	2	2	1	a,c,f
P19	1	1.5	1	f
P20	2	2	2	b,c
P21	2	1	2	e,f
P22	2	1	1	a,b,c,e,f
P23	1	1	2	b,c
P24	2	2	2	f
P25	1	2	1	a,d,e,f
P26	1	2	2	a,b,d

Appendix G: Measurement Results, M1 and M2

Normal Text, Developers
Gray Text 1, End Users
Gray Text 2, Both
M1

Participant	Question1	Question2	M.1.a
P1	5	3	8
P2	5	5	15
P3	1	1	2
P4	5	1	11
P5	3	1	4
P6	4	3	7
P7	5	5	15
P8	5	2	7
P9	3	2	5
P10	5	1	6
P11	3	1	9
P12	5	1	11
P13	5	1	6
P14	5	2	7
P15	5	3	8
P16	3	2	5
P17	5	1	6
P18	5	3	8
P19	4	4	8
P20	3	2	5
P21	3	4	7
P22	5	3	8
P23	4	2	6
P24	5	2	7
P25	5	4	9
P26	5	5	10
		M.1.b	**7.69**

M2

M2.1

Participant	Q7	Q8	Q10	Q11	Q13	Q24	M2.1a
P1	5	3	4	3	3	3	3.50
P2	4	2	3	4	4	2	3.17
P3	4	3	3	3	3	3	3.17
P4	3	4	4	3	4	4	3.67
P5	3	4	4	3	4	3	3.50
P6	3	2	4	4	3	2	3.00
P7	4	2	3	3	3	1	2.67
P8	4	5	4	3	5	4	4.17
P9	3	3	4	4	4	3	3.50
P10	2	4	4	3	3	4	3.33
P11	4	4	4	4	4	4	4.00
P12	4	4	4	3	3	4	3.67
P13	4	4	4	4	3	4	3.83
P14	1	1	4	1	3	3	2.17
P15	3	3	4	4	4	2	3.33
P16	5	4	4	3	4	4	4.00
P17	4	2	5	5	5	3	4.00
P18	3	3	4	4	4	4	3.67
P19	3	4	4	2	2	3	3.00
P20	4	5	2	3	4	4	3.67
P21	4	3	3	3	4	4	3.50
P22	3	2	2	2	2	2	2.17
P23	3	3	4	4	3	4	3.50
P24	4	4	4	4	5	5	4.33
P25	2	2	3	4	3	4	3.00
P26	4	4	4	3	4	3	3.67
				M2.1b	**All Participant**		**3.50**
					Developer		3.50
					End User		3.50
					Both		3.41

M2.2

Participant	Q9	Q10	Q12	Q13	M2.2a
P1	3	4	3	3	3.25
P2	3	3	4	4	3.5
P3	3	3	3	3	3
P4	4	4	3	4	3.75
P5	4	4	4	4	4
P6	3	4	4	3	3.5
P7	3	3	3	3	3
P8	4	4	4	5	4.25
P9	4	4	4	4	4
P10	4	4	3	3	3.5
P11	4	4	4	4	4
P12	4	4	3	3	3.5
P13	2	4	4	3	3.25
P14	1	4	1	3	2.25
P15	4	4	4	4	4
P16	3	4	3	4	3.5
P17	4	5	5	5	4.75
P18	4	4	3	4	3.75
P19	3	4	4	2	3.25
P20	3	2	4	4	3.25
P21	3	3	4	4	3.5
P22	3	2	2	2	2.25
P23	2	4	4	3	3.25
P24	4	4	4	5	4.25
P25	4	3	4	3	3.5
P26	4	4	3	4	3.75
		M2.2b	**All Participant**		**3.50**
			Developer		3.50
			End User		3.50
			Both		3.25

M23

Participant	Q13	Q21	Q22	Q24	M23a
P1	3	3	3	3	3
P2	4	3	4	2	3.25
P3	3	3	3	3	3
P4	4	3	2	4	3.25
P5	4	4	4	3	3.75
P6	3	3	3	2	2.75
P7	3	2	3	1	2.25
P8	5	4	4	4	4.25
P9	4	4	4	3	3.75
P10	3	4	4	4	3.75
P11	4	4	3	4	3.75
P12	3	4	4	4	3.75
P13	3	4	3	4	3.5
P14	3	3	1	3	2.5
P15	4	3	3	2	3
P16	4	3	2	4	3.25
P17	5	5	2	3	3.75
P18	4	4	3	4	3.75
P19	2	5	5	3	3.75
P20	4	4	3	4	3.75
P21	4	3	2	4	3.25
P22	2	3	3	2	2.5
P23	3	3	3	4	3.25
P24	5	3	3	5	4
P25	3	1	5	4	3.25
P26	4	4	4	3	3.75
		M2.3b	**All Participant**		**3.375**
			Developer		3.75
			End User		3.25
			Both		3.5

M24

Participant	Q14	Q15	Q20	M2.4a
P1	5	2	3	3.33
P2	2	2	1	1.67
P3	4	4	3	3.67
P4	4	4	2	3.33
P5	4	4	2	3.33
P6	3	3	2	2.67
P7	1	1	1	1.00
P8	5	4	4	4.33
P9	4	4	3	3.67
P10	4	4	3	3.67
P11	4	4	3	3.67
P12	3	3	3	3.00
P13	4	4	2	3.33
P14	1	1	3	1.67
P15	5	5	1	3.67
P16	5	4	4	4.33
P17	5	5	1	3.67
P18	4	4	4	4.00
P19	4	1	0	1.67
P20	4	3	3	3.33
P21	5	5	3	4.33
P22	3	3	2	2.67
P23	2	4	4	3.33
P24	5	5	3	4.33
P25	3	4	1	2.67
P26	2	4	2	2.67
	M2.4b		**All Participant**	**3.33**
			Developer	3.33
			End User	3.66
			Both	3

M25

Participant	Q15	Q20	Q23	M2.5a
P1	2	3	1	2.00
P2	2	1	3	2.00
P3	4	3	3	3.33
P4	4	2	3	3.00
P5	4	2	4	3.33
P6	3	2	2	2.33
P7	1	1	1	1.00
P8	4	4	4	4.00
P9	4	3	3	3.33
P10	4	3	4	3.67
P11	4	3	3	3.33
P12	3	3	4	3.33
P13	4	2	4	3.33
P14	1	3	1	1.67
P15	5	1	3	3.00
P16	4	4	4	4.00
P17	5	1	1	2.33
P18	4	4	4	4.00
P19	1	0	3	1.33
P20	3	3	4	3.33
P21	5	3	3	3.67
P22	3	2	2	2.33
P23	4	4	4	4.00
P24	5	3	4	4.00
P25	4	1	4	3.00
P26	4	2	4	3.33
	M2.5b		**All Participant**	**3.33**
			Developer	3.33
			End User	3.33
			Both	2.33

M26

Participant	Q16	Q17	Q18	Q19	M2.6a
P1	2	2	2	2	2
P2	3	4	1	1	2.25
P3	2	2	3	3	2.5
P4	3	3	2	4	3
P5	3	4	2	2	2.75
P6	3	3	2	2	2.5
P7	3	4	1	1	2.25
P8	4	3	3	3	3.25
P9	3	2	4	4	3.25
P10	3	3	4	4	3.5
P11	3	3	4	4	3.5
P12	3	3	3	3	3
P13	2	2	2	2	2
P14	1	1	1	1	1
P15	2	2	1	1	1.5
P16	2	4	2	4	3
P17	3	4	2	1	2.5
P18	4	2	4	4	3.5
P19	1	2	2	5	2.5
P20	2	2	2	3	2.25
P21	2	2	3	4	2.75
P22	5	5	2	2	3.5
P23	4	3	3	4	3.5
P24	5	1	3	4	3.25
P25	3	4	4	2	3.25
P26	2	2	1	1	1.5
		M2.6b		**All Participant**	**2.75**
				Developer	3
				End User	2.75
				Both	2.25

M27

Participant	Q1	Q2	Q3	Q4	Q5	Q6	M2.7a
P1	3	4	4	4	4	5	4.00
P2	4	4	4	5	4	5	4.33
P3	4	4	4	4	4	4	4.00
P4	4	4	5	4	4	4	4.17
P5	2	3	4	4	4	4	3.50
P6	4	4	5	4	4	5	4.33
P7	3	3	3	3	4	5	3.50
P8	4	4	4	4	4	3	3.83
P9	2	2	4	4	3	4	3.17
P10	3	4	3	4	0	4	3.00
P11	2	2	4	4	3	4	3.17
P12	3	2	4	4	4	4	3.50
P13	4	2	4	4	4	4	3.67
P14	1	4	2	1	1	1	1.67
P15	4	4	4	4	3	4	3.83
P16	4	4	5	4	5	5	4.50
P17	4	3	4	4	3	5	3.83
P18	4	4	5	4	2	3	3.67
P19	3	2	2	4	4	3	3.00
P20	4	4	5	4	3	5	4.17
P21	3	4	5	3	4	4	3.83
P22	2	2	2	3	3	2	2.33
P23	3	3	4	3	2	3	3.00
P24	5	5	5	4	4	1	4.00
P25	2	3	3	3	3	2	2.67
P26	4	4	5	4	4	5	4.33
				M2.7b		**All Participant**	**3.75**
						Developer	3.66
						End User	3.83
						Both	3.75

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YAZARIN

Soyadı : MEDENİ
Adı : İHSAN TOLGA
Bölümü : BİLİŞİM SİSTEMLERİ

TEZİN ADI (İngilizce) MAINTENANCE FOR SUSTAINABLE ONTOLOGIES

TEZİN TÜRÜ : Yüksek Lisans ☐ Doktora ☒

1. Tezimin tamamı dünya çapında erişime açılsın ve kaynak gösterilmek şartıyla tezimin bir kısmı veya tamamının fotokopisi alınsın. ☐

2. Tezimin tamamı yalnızca Orta Doğu Teknik Üniversitesi kullanıcılarının erişimine açılsın. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) ☐

3. Tezimden bir (1) yıl süreyle fotokopi alınamaz. (Bu seçenekle tezimizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) ☒

Yazarın imzası .... Tarih ....