An Ontology Model for Medical Tourism Supply Chain Knowledge Representation

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***Abstract*—This study developed an application ontology related to the medical tourism supply chain domain (MTSC). The motivation for developing an ontology is that current MTSC studies use a descriptive approach to provide knowledge, which is difficult to comprehend and apply. The formalization of MTSC knowledge can provide medical tourism stakeholders with a shared understanding of the medical tourism business. As a result, the MTSC domain requires efficient semantic knowledge representation. Ontology is a popular approach for integrating knowledge and comprehension because it presents schema and knowledge base in an accurate and relevant feature. This paper employed the ontology engineering methodology, which included specification, conceptualization, and implementation steps. The conceptual model and facets of the MTSC are proposed. The MTSC objective and scope are tested with semantic competency questions against SPARQL Query formulations. The ontology metrics evaluation was used to verify the ontology quality including the external validation done by the domain experts. The results showed that the MTSC ontology has an appropriate schema design, terminologies, and query results.**

***Keywords*—Medical tourism; application ontology; supply chain; ontology development; knowledge representation**

I. Introduction

The medical tourism (MT) industry is considered a high-value business that can generate a high income for the service providing country [1]. MT is a part of health tourism that focuses on medical intervention to improve or restore an individual's health [2]. MT is a specialized service and differs from general tourism in that medical tourists often have a significant problem and need of medical service, along with the desire to travel as well [3]. The medical tourism supply chain (MTSC) is distinct from both the general and health tourism supply chains. MTSC emphasizes medical and travel intervention, as well as relationships with connected parties who assist the major service providers in both the medical and tourism sectors.

At present, the MT business knowledge tends to relate to the key player side [4]. MT business activities are fragmented between stakeholders [5, 6]. Activities are short-lived interactions between a medical tourist and the providers. As a result, some MT actors are deficient in knowledge of the supply chain (SC). Since the MT business is being challenged by many factors such as the global situation, consumer demand, and business competition [7, 8], a new paradigm for enabling MT success is to integrate intra- and inter-organizational processes [9]. Understanding the MTSC is therefore important.

One method for developing concrete knowledge is to use ontology [10, 11]. Ontology supports aligning the understanding of knowledge by presenting it in an explicit specification and in a meaningful manner [11]. Ontology links the information relationships to a semantic structure. For over a decade now, organizations have used ontologies to build mutual comprehension in the SC [12, 13]. The ontology ideas emphasize making the practitioners understand business logistics, roles, and activities in the SC. We can see studies where ontologies are used for describing SC models, such as [14, 15, 16]. However, an ontology for encouraging MT practitioners to understand the MT business has not been reported. Previous MT studies have emphasized descriptive explanations [4, 6, 17, 18, 19]. At the same time, there is no mention of MT in the SC ontology. Numerous studies have avoided establishing semantic knowledge as a support to MTSC model. Practitioners in MT still lack explicit knowledge that would help them better understand the industry.

Current studies lack a shared understanding of MTSC model between practitioners. Therefore, strengthening business comprehension is of great importance to the business participation and the SC management. This study contributes to the visual linkage of MTSC model.

The paper's key contribution is the MTSC ontology, which was built for the MT domain and enhanced by domain experts. This study developed semantic knowledge utilized in the MT context, to represent MTSC knowledge by using ontology-based tools. The MTSC conceptual model and facets are proposed based on literature extraction and domain expert knowledge. The ontology engineering methodology is presented, adopting ontology engineering methodology of [10, 20]. The instances used for implementation are from Thailand. The evaluation of ontology is performed using the semantic competency questions and the well-known metric-based ontology quality analysis [21, 22]. Domain specialists in the MT industry assisted in the enumeration of terminology and the validation of ontology quality during the development of the ontology.

II. Literature Review

The paper includes MTSC and ontology engineering methodology terms. The literature review discusses the MTSC characteristics and processes followed by a discussion of

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ontology engineering methodology and ontology evaluation. Then the previous ontology works are examined for MTSC ontology development.

A. Medical Tourism Supply Chain

SC is a term used for over a decade. The SC was originally associated with the manufacturing industry, from raw material procurement to manufacture, delivery, and distribution to clients or customers [23]. The system is interconnected and requires performance management [24]. The expected outcome of SC management is improved quality of operations and products that promote profits for the organization [25]. The actors involved in the SC cycle are grouped to suppliers, producers, transporters, distributors, and customers [14]. At each stage of the SC system, products are produced and transmitted depending on business objectives.

Subsequently, the SC system was introduced in the service business. MT industry has been examined using this concept [26]. MTSC is a network of individuals and organizations who handle information, product or service, and financial flows [27]. The objective of MTSC is to manage the healthcare and tourism processes for improving product and service value for all actors and for creating profits to the organization [26]. The two primary industries that MT is associated with are health and tourism [28]. The MTSC involves a process flow from beginning to end that encompasses the transfer of products or services from providers to customers (internal and external) [6, 19].

The MTSC processes commence with the marketing process to attract medical tourists followed by medical tourists' decision-making regarding service, then making the necessary travel arrangements, followed by diagnostic activity and travel to the destination for medical treatment [6]. The subsequent recovery care is the main activity, involving the rechecking of the treatment result and assessing health risks. During the process of medical services in the destination country, medical tourists can participate in tourism activities [6, 18]. At the end of the process, the relevant activities are tourist departure, tracking potential symptoms, and follow-up activities at the country of origin [27, 29]. The actors in MT business are those who participate in the MTSC processes [4, 18]. Actors come from diverse industries and have various business objectives and roles including activities to be carried out inside and outside the organization [12, 15, 28]. The goods or services are produced by actors and delivered to others.

B. Ontology Engineering Methodology

Ontology engineering methodology is a method for aligning understanding of knowledge by presenting it in an explicit specification and in a meaningful manner [11]. Ontology links the information relationships to a semantic structure. Organizations use ontology to build mutual comprehension in the general business and in context-specific domains.

The goal of ontology development is to express knowledge in such a way that both people and computers can comprehend it [22]. Developing an ontology usually begins with recognizing the need for a certain purpose [20]. Then an ontology is created. Many methodologies can be used to develop an ontology. For example, the method of [22] designing and evaluating an ontology combined six steps: scenario motivation, informal competency questions, first-order logic: terminology, formal competency questions, first-order logic: axioms, and completeness theorems; methodology of [20] relating to the knowledge process consisted of five steps: feasibility study, ontology kickoff, refinement, evaluation, and maintenance; the method of [10] consists of seven steps: determining the ontology domain and scope, considering and reusing existing ontologies, enumerating ontology terms, defining the classes and hierarchy, defining class properties, defining the facets, and creating instances; the method of [30] combines development and support processes that can run in parallel with all of the development phases.

We can see that [22] focused on ontology development, whereas [20] detailed all steps in the process of maintaining. Identically [30] enumerated the entire process, but the steps were complex. On the other hand, [10] proposed the clear steps of ontology creation than other studies considered although they did not have much detail relating to the ontology testing process.

Taking into account the ontology development and quality testing objectives, this study employs a hybrid waterfall methodology by combining waterfall methodologies from [10, 20]. The creation of an ontology involves three major steps.

1) Specification The purpose is to gather informal knowledge about the domain. The specification step develops the conceptual taxonomy of MTSC ontology.

2) Conceptualization The purpose is to organize and structure the information into semantic framework. The conceptualization step defines the classes, objects and instances of ontology.

3) Implementation The purpose is to implement, verify and validate the ontology. The implementation step creates a concrete ontology with an ontology implementation tool and validates the ontology quality.

C. Ontology Evaluation

The ontology evaluation indicates the quality of the ontology. This study defines the quality as ontology should be validated by robust approaches in technical aspects and domain experts' involvement. The methodology used in this paper adheres to the semantic competency questions method of [22] and the ontology metrics proposed by [21].

The semantic competency questions technique [22] generates answers to competency questions. The ontology concept is tested against SPARQL Query formulations. Domain experts will involve in the evaluation process by verifying competency questions and answers.

The ontology metrics [21] combine three evaluation aspects.

1) Ontology schema metrics assess ontology design and its capabilities for representing rich knowledge. The proposed metrics are as following:

Relationship richness (RR) relates to an ontology having many interrelated relationships. RR is a percentage representing the number of connections between classes with multiple relationships. If the percentage closes to one, it demonstrates ontology has various connections other than class-subclass. On the other hand, if RR value closes to zero then ontology does not have many relationships.

Attribute richness (AR) relates to an ontology having a sufficient amount of knowledge. AR is a number representing the amount of knowledge that ontology conveyed. The high AR means ontology has a high average attribute or knowledge per class. On the other hand, the lower AR means ontology has less knowledge.

Inheritance richness of schema (IRs) relates to an ontology having a wide knowledge distribution. IRs is a number representing the ontology's ability to arrange knowledge into multiple categories and subcategories. The low IRs means ontology is a very detailed knowledge, while the high IRs reflects a broad spectrum of generic knowledge.

2) Knowledgebase metrics assess the amount of knowledge representation and the design efficacy of the ontology. The proposed metrics include:

Class richness (CR) relates to an ontology having a class with knowledge. CR is a percentage representing the use of class with instances. The high CR indicates ontology has rich knowledge in class. By contrast the low CR reflects low knowledge.

Average population (P) relates to an ontology having described the schema's whole knowledge adequately. P is a number representing the average knowledge per class. The high P shows sufficient knowledge of schema, while the low P means insufficient knowledge representation.

Cohesion (Coh) relates to an ontology having relationships among nodes and edges. Coh is a number representing the isolated components. A high Coh indicates that the ontology knowledgebase has lost its connection. If the Coh value is small, it means that knowledge is connected.

3) Class metrics investigate the knowledge distribution of all ontology classes. The proposed metrics include:

Importance (Imp) concerns the instance distribution in each class. Imp value shows which classes have enough instances and which classes have fewer instances.

Connectivity (Cn) concerns the relationship of the instance in one class over another class. Cn number refers to how well instances are linked together.

Readability (Rd) concerns whether the ontology contains human-readable descriptions. Rd is calculated from comments, labels, or captions of ontology.

D. Medical Tourism Supply Chain Ontologies

MTSC ontology is categorized as application ontology because the terminology depends on both specific tasks that are MT processes and the domain that encompasses health and tourism [31]. Ontology has been proven to help practitioners clarify SC models including fragmented processes [32]. However, during this research, no ontology for building MTSC comprehension was discovered. Therefore, the common SC ontologies based on SC definition given by [23] and ontologies related to health tourism domain were reviewed.

Üreten and Đlter [14] present SCM ontology derived from the common concept of SC. There are four main classes: Agent, Product, Operations, and Flow. The Agent subclasses include supplier, producer, transporter, distributor, and customer. Agent has data properties that are production activity type, utility created, size, geographic location, service content, and make-buy decisions. The Product is identified to two subclasses: Goods, Services. Goods have data properties: process type, weight, size, resistance, durability, characteristics, and product type; while Service has service content, property, location, and degree of customer contact. The Operation subclasses are Plan, Source, Make, Deliver, and Return. There are sub-activities in a given operation. The Flow has three subclasses: Material, Money, and Information, with flow direction and flow between properties. There are relationships between the common classes. SCM ontology shows that Agent and Product have a link with produces object property. Also, Agent links with Operation by operation performed property and by contrast Operation has an inverse property performed by to Agent.

Ye, Yang, Jiang, & Tong [15] introduce Onto-SCM ontology for sharing the SCM conceptualization. The idea of Onto-SCM is evolved from general SCM. The ontology combines five main classes: SC_Management, SC_Structure, SC_Activity, SC_Resource, and SC_Item. The SC_management implies the management of SC operation in which activities and the important elements are linked from the remaining four main classes. SC_Structure classifies agent classes into five subclasses:Dyadic_Structure,Serial_ Structure,Divergent_Structure,Convergent_Structure,and Network_Structure. The SC_Structure has Strategy that is derived from Goal class and has SC_Process that implies the implementation of SC to achieve the goal. SC_Activity has Activity class. Activity has sub-activity property that is connected under the interval time. SC_Resource presents resources used in SCM. There are four resource classes: Production_Resource, Storage_Resource, Transportation_ Resource, and Human_Resource. Each resource has a role. SC_Item refers to products produced from SC. There are three item classes: Offer, Business_Order, and Plan. Offer has meant the products that are separated to Product or Service. Business_Order means the flow of object that transfers from one activity to other. Onto-SCM can explain the relationship between the activity and goal, the agent who performs activity, and the resource used in SCM at a given activity.

Soares, Azevedo, and Sousa [16] propose an ontology to support the process flow management of semiconductor manufacturing. The ontology helps agents to communicate regarding the requirement of the business’s particular planning and control system. There are three semantic processes: Organizations, Plans Management, and Orders Management. Organizations have VE Unit class that represents the agents involved in the SC process. Plan management has three main classes: Plan presents the semantics of activities; Planning presents the semantics of action to implement Plan; Resource presents the necessary entity that serves a given activity. Resource class has a capacity as a data property, which means the allocation of resources used in each activity. Order management includes the classes of Order and Product. Order has been described by Order Item and its data properties such as quantity, due date, delivery date. Product is produced by supplier that is included in VE Unit.

Vegetti et al. [33] propose ontology for the SC domain. The goals are to demonstrate the SC structure, process, resource, and application evaluation. The structure identifies SC infrastructure, including roles, and combines the following classes: Supply Chain, Organizational Unit, Organizational Unit Role, and Functional Area. The process dimension defines SC's processes and subprocesses, including the execution of a process within a specific timeframe. Process, Process Occurrence, Temporal Relationship, and Utilization are the classes that make up the process. The resource dimension depicts resource utilization and its role in the SC process. The resource combines the classes Resource and Resource Role. Each class has data properties as well as relationships to other classes.

Spoladore et al. [34] propose health tourism ontology. The goal is to connect natural resources with visitor demands. There are six main classes: Destination, Descriptor, Variable, KPI_Families, Optima, and Target_Groups. The Destination explains the tourism inflows, whereas Descriptor focuses on regional services and characteristics. The Variable, KPI_Families, and Optima depict the value that health tourists will receive. Target_Groups has six subclasses that explain different types of health tourists. Chantrapornchai and Choksuchat [35] provide an ontology that collects information on health tourism. Many classes make up the ontology, including Product, Package, Facility, Service, Treatment, and so on. Almost every class has subclasses; for example, the Service class has two subclasses: BeautyService and Massage. Ontology has re-used classes and inferred concepts.

Previous studies [14,15,16,33] created ontologies using the core SC concept. This study may benefit from some structure design. However, there is a difference between the SC and MTSC concepts. For example MTSC agents are grouped based on service provided to medical tourists such as medical providers, medical tourists, tourism providers whereas SC agents are derived from general industry such as suppliers, customers, transporters. The MTSC involves the process of utilizing medical tourists' services until the follow-up process, while SC includes the process of producing items until selling products to customers. The flow of data, money, and product differs between MTSC and general SC. Medical tourists' service requests and consumption of services are the objects exchanged between or within the activity flows of MTSC. On the other hand, SC's flows are concerned with raw materials, physical goods trading, and purchase orders.

Taking into account the health tourism ontologies [34, 35], the earlier designs focused on gathering and formalizing information for tourist decision-making. The MTSC domain cannot be represented by previous ontology structures. Some health tourism terms, on the other hand, can be reused. The considerations for the reuse of ontologies are discussed in the following section. Table I compares previous studies that were unable to provide semantic knowledge about MTSC.

TABLE I. COMPARISON OF PREVIOUS ONTOLOGIES WITH THE PRESENT WORK

Aspects	Domain	Target user	Source of knowledge	MTSC related
[14]	General industry	Practitioners	International standard	No
[15]	General industry	Practitioners	Previous work, case study	No
[16]	Semiconductor industry	Practitioners	Previous work, case study	No
[33]	Food industry	Practitioners	Previous work, case study	No
[34]	Health tourism	Tourists, government	Case study	No
[35]	Health tourism	Tourists	Case study	No
This Work	Medical Tourism	Practitioners	Previous work, case study	Yes

III. BUILDING A MEDICAL TOURISM SUPPLY CHAIN ONTOLOGY

The goal of ontology development is to express knowledge in such a way that both people and computers can comprehend it [22]. Developing an ontology usually begins with recognizing the need for a certain purpose [20]. This study used a hybrid waterfall methodology with three key steps in the formation of the MTSC ontology adapted from [10, 20].

A. Specification

1) Determination of ontology domain and scope: The MTSC ontology focuses on the MT domain. This ontology represents the domain knowledge model that captures information of the MT attributes based on MTSC concept. The competency questions were created and measured the degree to which the ontology nailed its purpose and scope [22]. As a basis, the ontology should answer general questions, for example:

- How many actors are featured in the MTSC?
- What is the actor's primary role in the MTSC?
- What is the main process chain of MTSC?
- What are the activities in a given MTSC process?
- What is the core product produced in MTSC and by whom?
- How many flows do appear in the MTSC?

For complex knowledge representation, the ontology should answer further questions, for example:

- Which actors are involved in a given MTSC process?
- What is the actor's role when involving a given MTSC activity?

- What are the flows that are activated in a given MTSC activity?
- What are the inputs and outputs that relate to a given MTSC activity?
- What is the direction of the MTSC flow in each activity and between whom?

2) Consideration of the existing ontology: The literature demonstrates the use of ontology to explain the SC semantically. Although the existing ontologies did not pertain to the MTSC domain, there is some idea that can be reused. Previous ontology for sharing SC information at the top-level [14] has been considered as a starting point for the MTSC ontology model and the idea of the class (actor, action, product, and flow) is re-used. Some terminology from [35] is taken into account in the MTSC ontology. However, there is no ontology in the MTSC domain that represents enough terminologies. As a result, the next step involves the enumeration of terminology.

3) Enumeration of important terms in the ontology: Because terms constitute the foundation of an ontology, it's critical to be precise and unambiguous about the main terms and their associated attributes. The motivation of the ontology representation is derived from [14]. Fig. 1 shows an ontology model. The model is composed of seven main concepts: MT actors, MT processes, MT activities, MT roles, MT products, MT flows, and MT flow between.

MT actors represent the semantic knowledge of who is involved in the MTSC. MT actors can be organization units, companies who participate in MTSC system, or even individuals. MT actors have a role in MTSC. The MT actor and MT role conceptual model are derived from the stakeholder investigations [36, 4, 37, 18].

MT processes and MT activities represent the semantic knowledge of operations performed in the MTSC. The process description visualizes the logistics and flow of information and includes many activities. MT processes have been activated by MT actors. The actions of MT actors cause the forwarding of MT products and MT flows. The MT process and MT activity conceptual model is suggested by [6, 29, 27, 18].

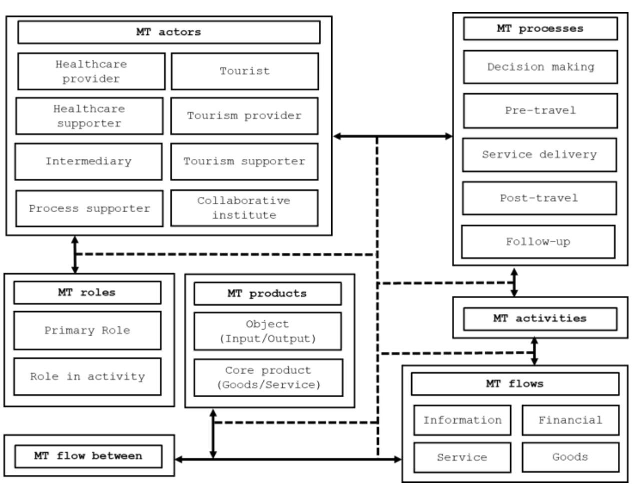


Fig. 1. MTSC Ontology Representation Adopted from [14].

MT products represent the semantic knowledge of objects produced from MT actors including objects required to perform activity. MT product conceptual model is captured from [14, 18, 35].

MT flows represent the semantic knowledge of object movement from a process starting point to the end of MTSC system. Flow is a thing with distinct and independent existence and involves the transfer of an object between respective activities and actors. The MT flow and MT flow between conceptual model is extracted from [14, 6, 29, 18].

This study focuses on the trustworthiness and practical benefits of ontology. Interviews with MT experts were used to build and verify the ontology structure and terminologies. Sixteen domain experts who have experience in MT business from Thailand, took part in the face-to-face interviews. The interviewing techniques begin by presenting the ontology design and components. Second, interviewers were requested to corroborate the ontology conceptualization and share MT knowledge. The final stage is to summarize the understanding and double-check the accuracy of the interview results with the interviewers right away. Table II lists the brief profiles of the MT experts who assisted with the interview parts.

TABLE II. NUMBER OF MT EXPERTS IN THE INTERVIEW SECTIONS

MT Domain Group	Number of MT experts	Approximate experience in MT
Health provider (Hospital, Dental clinic)	4	10-20 years
Tourism provider (Hotel, Tour operator)	3	15-20 years
Collaborative institute (University)	2	12-25 years
Health and tourism supporter (Interpreter, Insurance, Shop, Restaurant)	7	5-21 years

As a result of sharing knowledge with domain experts, terms such as important MT actor terms, process and activity names, and linkages among terms were discussed according to actual usage. The initiated terms can be used to advance the construction of ontologies. The obvious benefit of bringing in a diverse group of experts is that they can share their knowledge and illustrate relationship design approaches.

B. Conceptualization

1) Definition of the classes and the class hierarchy: The class hierarchy is designed using the top-down approach [10]. Classes and subclasses are categorized based on MTSC ontology model designed with the terms mentioned earlier. The ontology classes are as follows:

MT_Actor: refers to the stakeholders involved in the business and has eight subclasses.

MT_Product: refers to the objects produced by actors including input/output used in activities and has two subclasses.

MT_Process: refers to the processes in MTSC.

MT_Activity: refers to the activities that are part of the process.

MT_Flow: refers to an entity that transfers objects within an activity or from one activity to another activity and has four subclasses.

MT_FlowBetween: refers to the interaction of the actors in any flow.

MT_Role: refers to the responsibility/task of actors in MTSC and has two subclasses.

2) Definition of classes-slot properties: The data properties were defined as the qualification for each particular class. Table III identifies data property, representation, and domain usage of ontology creation in this study.

TABLE III. DATA PROPERTIES OF MTSC ONTOLOGY CLASSES

Data property(Domain usage)	**Representation**
hasActorName(MT_Actor)	Name of actor
hasActorDesc(MT_Actor)	Description of actor
hasPrimaryRoleDesc(PrimaryRole)	Description of primary role
hasRoleInActivityDesc(RoleInActivity)	Description of role in activity
hasProductDesc(MT_Product)	Description of product
hasProductType(MT_Product)	Type of product: *goods, services, input, output*
hasProcessDesc(MT_Process)	Description of process
hasActivityDesc(MT_Activity)	Description of activity
hasFlowDesc(MT_Flow)	Description of flow
hasFlowDirection(MT_Flow)	Direction of flow: *one-way, two-way*

Object properties are defined to link the relationship between two instances. Table IV shows the object properties with the boundaries of their inferences between domains and ranges.

3) Creation of instances: This step provides values to the defined classes and properties. For the instances of MTSC ontology, they are derived mainly from academic literature and a case study for credibility and practicality. The case study is from the document of experienced private hospital agency in Thailand that provides medical tourism services to foreign patients. The knowledge obtained from the experiences correlates with academic education. The knowledge agents presented in MTSC are reliable and can be used to explain MTSC.

For example, Hospital/Clinic is an instance of the MT_Actor class and the HealthProvider subclass. Its data property is hasActorName and the attributions of the property are “Hospital, Clinic, Health Institution, Health Center, Medical Center”. This implies that the *hospital/clinic* has multiple names used in the MT business. We present an excerpt of the instances of the MTSC ontology in the implementation section.

TABLE IV. OBJECT PROPERTIES OF ONTOLOGY CLASSES FOR ROLE-BASED RECOMMENDATION

Object property(Domain > Range)	**Inference**	**Cardinality**
hasPrimaryRole(MT_Actor > PrimaryRole)	An actor has primary role	1,1
hasRoleInActivity(MT_Actor > RoleInActivity)	An actor has role in activity	1,N
makeProduct(MT_Actor > MT_CoreProduct)	An actor makes core product	1,1
performActivity(MT_Actor > MT_Activity)	An actor performs activity	1,N
consistOfActivity(MT_Process > MT_Activity)	A process consists of activity	1,N
activateFlow(MT_Activity > MT_Flow)	An activity activates flow	1,N
isPerformedBy(MT_Activity > MT_Actor)	An activity is performed by actor	1,N
relateToProcess(MT_Activity > MT_Process)	An activity relates to process	1,1
getInput(MT_Flow > MT_Object)	A flow gets input to perform activity	1,N
returnOutput(MT_Flow > MT_Object)	A flow returns output after performing activity	1,N
isFlowBetween(MT_Flow > MT_FlowBetween)	A flow is action between actors	1,N

C. Implementation

1) MTSC ontology with protégé 5.0: This study implemented an ontology by using Protégé 5.0 software with OWL language. The tool can present knowledge and collaborate with other tools and is available as software implementation [38]. The OWL is a markup language focusing on semantic web representation and mostly manipulates XML language expressions. The MTSC ontology taxonomy is presented using OntoGraf (Protégé-OWL plugin). Fig. 2 shows the MTSC hierarchy and relationships in the top-level design.

Fig. 3 and 4 present an excerpt of the instances of the MTSC ontology.

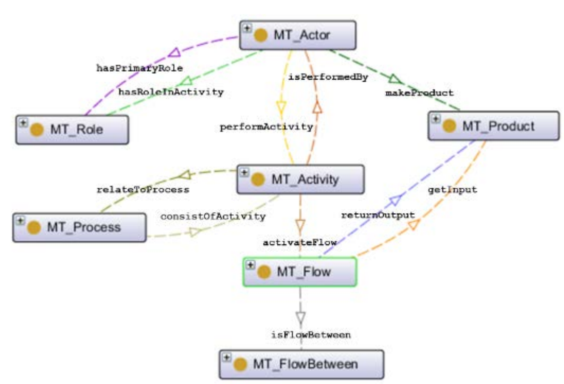


Fig. 2. A Top-level Hierarchy of MTSC Ontology.

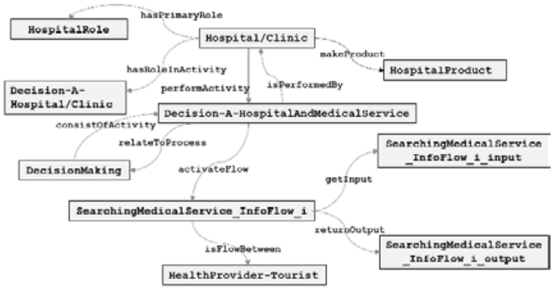


Fig. 3. An Excerpt of Health Provider Instance of MTSC Ontology.

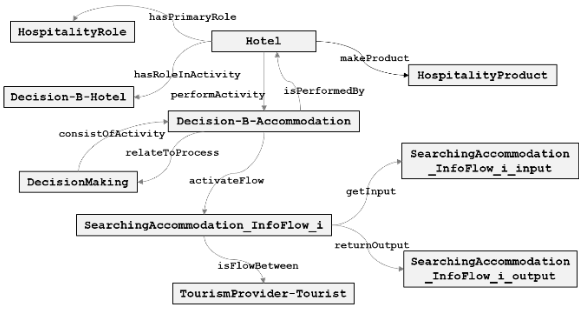


Fig. 4. An Excerpt of Tourism Provider Instance of MTSC Ontology.

2) Ontology evaluation: The MTSC ontology is assessed by competency questions and ontology metrics. The MTSC objective and scope are tested against SPARQL Query formulations. The query results were supposed to address competency questions. Some sample questions as SPARQL queries are as follows:

CQ: How many actors are featured in the MTSC?

SELECT ?Actor ?ActorName ?ActorDesc

WHERE {?Actor p:hasActorName ?ActorName.

?Actor p:hasActorDesc ?ActorDesc.}

The sample answer:

Actor	ActorName	ActorDesc
Bank/ForeignExchang	"Bank, Financial compa	"A financial institution that is legally responsible for deposits and withdrawals, currency exchange , and other financial tra
FoodSupplier	"Food supplier, Food m	"A producer who produces food products and distributes them to individuals or organizations that have purchased the p
GovernmentAgency	"Accreditation body, Ed	"A government agency that has established and controlled policies, functions, and measures for stakeholders manageme
HealthCareMarketer	"Healthcare marketer, "	"A marketing public relation operator who promotes medical services to be known"^^<http://www.w3.org/2001/XMLSc
Hospital/Clinic	"Hospital, Clinic, Health	"A health care provider who offers medical services to medical tourists"^^<http://www.w3.org/2001/XMLSchema#string
Hotel	"Hotel, Accommodatio	"A hospitality provider who offers accommodation and facilitation for tourists based on their intended purpose"^^<http
InsuranceCompany	"Insurance company, In	"An insurance company that is legally licensed to operate the insurance business, has a duty to pay compensation to the
InternationalTransport	"Airplane, Bus, Boat"^^	"An international transporter who offers international travel in various forms such as planes, boats, cars, trains."^^<http:
InterpreterProvider	"Interpreter, Translator"	"A communication mediator who helps bridge understanding between the speaker and the audience"^^<http://www.w
LocalTransporter	"Local transporter, Bus,	"A local transport provider who services at destination country such as train, subway, taxi, minibus, domestic airplane."^
MedicalSupplier	"Medical supplier, Medi	"A medical device manufacturer, modern medicine provider, including traditional medicine provider who produces and
MedicalTourist	"Medical Tourist, Touris	"A foreign tourist who intends to use medical tourism services"^^<http://www.w3.org/2001/XMLSchema#string>

CQ: What is the actor's primary role in the MTSC?

SELECT ?Actor ?PrimaryRole ?PrimaryRoleDesc

WHERE {?Actor p:hasPrimaryRole ?PrimaryRole.

?PrimaryRole p:hasPrimaryRoleDesc ?PrimaryRoleDesc.}

The sample answer:

Actor	PrimaryRole	PrimaryRoleDesc
Bank/ForeignExchangeProvider	FinancialRole	"Provides deposit and withdrawal services including currency exchange and other financial transactions"^^<http:
FoodSupplier	FoodSupplierRole	"Produces food products and sells them to individuals or organizations that have purchased the products"^^<http
GovernmentAgency	GovernmentAgencyRole	"Issues policy, functions, and measures for industry direction and coordination between stakeholders"^^<http://w
HealthCareMarketer	HealthCareMarketerRole	"Promotes medical services and medical tourism industry to be known"^^<http://www.w3.org/2001/XMLSchema
Hospital/Clinic	HospitalRole	"Offers and serves medical services to medical tourist"^^<http://www.w3.org/2001/XMLSchema#string>
Hotel	HospitalityRole	"Offers and serves accommodation and facilitation for tourists"^^<http://www.w3.org/2001/XMLSchema#string>
InsuranceCompany	InsurerRole	"operates the insurance business and has a duty to pay compensation to the insured from the events that occur ur
InternationalTransporter	InterTransporterRole	"Provides international travel in various forms such as planes, boats, cars, trains to medical tourists"^^<http://ww
InterpreterProvider	InterpreterRole	"Communicates between the doctor and the patient using the patient's preferred language"^^<http://www.w3.or
LocalTransporter	LocalTransporterRole	"Services local travel such as trains, subways, taxis, minibusses, domestic airplanes"^^<http://www.w3.org/2001/
MedicalSupplier	MedicalSupplierRole	"Manufacturers medical devices, modern medicines, traditional medicine, and medical-related goods that used m
MedicalTourist	MedicalTouristRole	"Obtains medical tourism services"^^<http://www.w3.org/2001/XMLSchema#string>
[illegible]	[illegible]	[illegible]

CQ: Which actors are involved in a given process of MTSC?

SELECT ?Actor ?Process ?Activity

WHERE {?Actor p:performActivity ?Activity.

?Process p:consistOfActivity ?Activity.}

The sample answer:

Actor	Process	
HealthCareMarketer	DecisionMaking	Decision-A-HospitalAndMedicalService
HealthCareMarketer	DecisionMaking	Decision-D-Intermediary
Hospital/Clinic	DecisionMaking	Decision-A-HospitalAndMedicalService
Hospital/Clinic	FollowUp	Follow-A-TrackSymptom
Hospital/Clinic	PostTravel	Post-B-ShareExperience
Hospital/Clinic	PreTravel	PreTravel-A-ReserveHospitalAndService
Hospital/Clinic	ServiceDelivery	Service-C-ReceiveMedicalService
Hospital/Clinic	ServiceDelivery	Service-D-DischargePayment
Hospital/Clinic	ServiceDelivery	Service-F-PostOperativeCare
Hotel	DecisionMaking	Decision-B-Accommodation
Hotel	PostTravel	Post-B-ShareExperience
Hotel	PreTravel	PreTravel-B-BookAccommodation

Table V summarizes the result of ontology metrics.

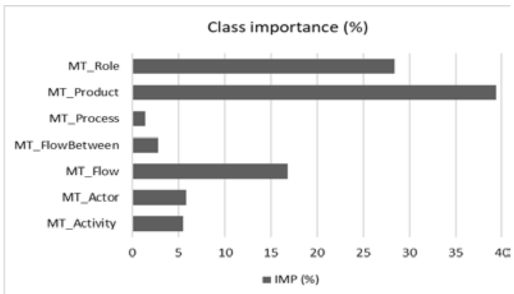
TABLE V. THE ONTOLOGY SCHEMA AND KNOWLEDGEBASE METRICS ASSESSMENT RESULT

Metrics	Ontology schema metrics			Knowledgebase metrics		
	RR	**AR**	**IRs**	**CR**	**P**	**Coh**
MTSC ontology	50%	4.70	0.70	100%	15.78	0

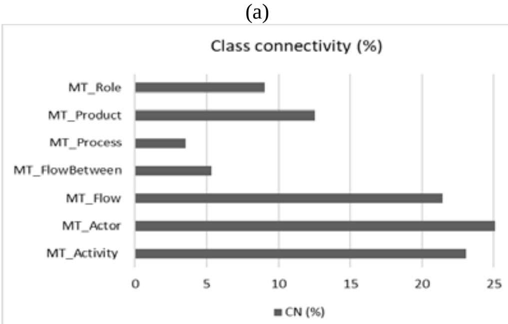
The ontology schema metrics reflect the quality of ontology structure for representing knowledge. The RR result (50%) indicates that MTSC ontology has many connections other than class-subclass, such as object property relationships. The AR result (4.70) indicates that the ontology has a good average of attributes per class. There are many types of knowledge presented. The IRs result (0.7) indicates that the ontology has a general distribution of subclasses and is not considered detailed knowledge. Overall, the MTSC schema metrics indicate good quality of structure design.

The results of knowledgebase metrics show that all ontology classes are implemented to deliver knowledge by the CR result of 100%. The P result (15.78) indicates that this ontology has a not too small knowledge in schema. The Coh result (0) indicates that all components in the ontology are used to describe MTSC. Overall, the knowledgebase metrics have appropriate values. The MTSC ontology has enough knowledge representation.

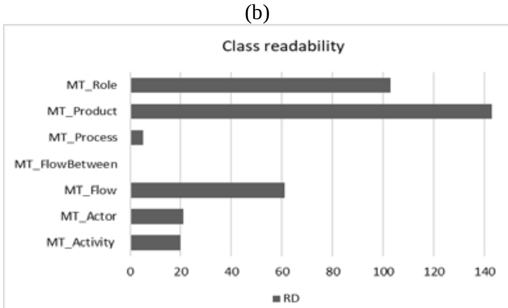
Fig. 5 presents the class metric results. The class metrics results indicate that the most important classes are MT_Product, MT_Role, and MT_Flow. The Imp result makes logical because these three classes store detailed knowledge. The central connectivity is MT_Actor followed by MT_Activity and MT_Flow. The Cn result reflects that the MTSC can explain knowledge using actors and activities as the center linked with other knowledge classes. Rd reflects that almost all of the classes provide descriptions for the users to understand. Overall, the class metrics have appropriate values.



(a)



(b)



(c)

Fig. 5. Class Metric Results in Values of (a) Imp, (b) Cn, and (c) Rd.

The MTSC ontology has a good knowledge distribution. This study was carried out with the collaboration of domain experts. The answers to SPARQL Queries and the ontology metrics values were verified by experts. The findings are adequate to clarify the study's goal and scope. The same group of 16 experts approved the MTSC ontology. Ontology structure and terminologies have quality.

IV. DISCUSSION

This study presented the development of an application ontology for representing MTSC knowledge. The ontology engineering methodology consisted of specification, conceptualization, and implementation steps. The steps are enriched with knowledge engineering techniques and present a practical conceptual design. The key views of MT were verified. The MTSC ontology combines seven main classes namely 'MT_Actor', 'MT_Role','MT_Process', 'MT_Activity', 'MT_Flow', 'MT_FlowBetween', and 'MT_Product'; and has sixteen subclasses. The class conceptualizations can describe MTSC structurally. The concepts are in line with general SC presented by [14].

This MTSC ontology provides instances of 21 actors, 21 primary roles, 5 processes, 20 activities, 21 core products, 122 objects, 82 roles in activity, and 61 flows. The MTSC logistics has two main routes: medical services or tourism services. The MTSC process is divided into five stages. The actor involved in all processes is a medical tourist. The players on the service side who are involved in all processes of the medical side and tourism side are the health provider and tourism provider, respectively, including many supporters. MTSC ontology offers four types of knowledge flows as in [14]. Flow provides insights into how activities contribute to the flow and who is involved in that activity and flow in MT context. MTSC logistics are different from general SC logistics [23]. The MTSC activities are different from general SC which involves stakeholders. The short flows do not pass data to the next step like a production line, such as flow of providing an interpreter during treatment, or flow of selling souvenirs. However, the knowledge flow representation is consistent with MTSC process of [6] and [18]. Core products in MTSC ontology are mostly classified as services that are different from general SC where the products are usually tangible [16].

The ontology evaluation employed competency questions and ontology metrics. Domain experts had verified the quality of structure, design, and usefulness. According to SPARQL Query results, the MTSC ontology can answer semantic questions given in the Specification section. It denotes that the ontology is trustworthy in terms of objective and scope. The ontology metric results reflect the suitability of ontology structure and design. The body of knowledge generated is sufficient to describe the MTSC. Knowledge is distributed in an acceptable manner.

V. CONCLUSION

MTSC ontology generates a clear business understanding for stakeholders in the MT domain. The ontology construction demonstrated a high-quality development approach that can be replicated. The ontology development incorporated academic material and case studies into the acquisition process. The collaboration of domain experts in many activities makes ontology more dependable and efficient. The proposed ontology comprises concepts relevant to the MT domain. The ontology can describe the supply chain of the medical tourism domain: it can tell who is involved in which processes, what roles they play, and what flows are taking place. Based on the evaluation results, the ontology design and knowledge representation are of a quality.

We plan to apply the ontology in our next work a role-based recommendation system. Stakeholders can use the system to learn about MTSC and the ontological relationship that exists in the MT domain. The expertise used in this paper, however, came from a case study. The limitation of this study is that some aspects of the overall challenges may have been overlooked as a result of the different perspectives. Those who will use this work context must examine how well it fits within the framework of the business area.

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