

# Enterprise Ontology Based Knowledge Map for Improving Hospital Services

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**Abstract**— The global healthcare spending has constantly increased in the last decades, and there is data showing inefficiency in resource consumption that is not reflected in healthcare improvement. The need to introduce new ways to do the same at a lower cost is rational. To address this, we propose a method based on Enterprise Ontology and knowledge map to find non value-added transactions that must be redesigned to improve the healthcare management. This methodology was chosen as a basis for our solution because it provides a better understanding of the dynamics of an organization, and allows a good alignment between the enterprise design and operation. Demonstrations were accomplished in University Teknologi Malaysia Healthcare Center, making it possible to find transactions that can be refined or improved. Results prove that the method yields an adequate and clear process view and is reliable when it comes to improving healthcare operational processes.

## I. INTRODUCTION

In a world of growing business dynamics, high rates of organizational changes and technological breakthroughs, most organizations need to be effectively and continuously redesigned and reengineered in order to achieve strategic and operational success. The inefficiency of processes and the lack of innovation are some of the main reasons for strategic failures, entailing serious consequence for business and its competitiveness [1].

These strong external forces and the need for innovation also challenge the healthcare system. Its organizations need to improve treatments, eliminate non value-added activities, reduce waiting time and expenses, treat more patients, and implement new technological services. Besides these challenges, the healthcare system suffers from operational management problems, and its processes are considered inefficient [2].

A frightening factor is that its expenditure accounts for 10% of the Gross Domestic Product (GDP) in developed countries, and there is an increasing trend. Other than that, there is data indicating that service cost and quality are not correlated by showing inefficiency in resource consumption, which is not reflected in improved quality of care. Consequently, quality of life may be affected because of a knock-on effect on the economy, increase in tax rates and insurance contributions, disinvestment in other public services, and increased difficulties to afford healthcare [3], [2]. Hence, this research stems from the assumption that many healthcare processes have become inefficient and unsustainable, which affects the management of the healthcare system.

Although the problem is identified as a need for organization redesign and reengineering, some authors argue that there is not a strong and reliable method to solve this

problem [4]. It is estimated that over 70% of strategic initiatives such as Total Quality Management (TQM), Business Process Reengineering (BPR), and Six Sigma, among others, tend to [5]; [6]. In this context, two main reasons are addressed:

The lack of integration among the various enterprise elements at the design level; and 3) lack of knowledge management technique that will make the knowledge visible within the organization [7].

One of the factors influencing a successful BPR is understanding the environment within which the business process exists. This lack of understanding of the environment suggests the need for the integration of knowledge management models and techniques. One such knowledge management technique that could be relevant is knowledge mapping, as knowledge maps can be used for several purposes, including finding sources of knowledge or opportunities for knowledge creation, identifying expertise and increasing knowledge-sharing, and helping to determine the knowledge competencies that exist within an organization and how they interact.[8]

Following this, our research proposes an approach based on the theories of Enterprise Ontology (EO) and knowledge map. We chose this approach as foundation for our proposal, because it is deemed able to provide a better understanding of an organization's dynamics, has a strong and well-formed theory, allows a good alignment between the enterprise design and operation, and it also enables a unified reengineering strategy [9]. Therefore, our research main objective is to provide a method based on EO and knowledge map to find non value-added transactions, and redesign them to improve the healthcare management.

## II. RELATED WORK

### A. Health care organization

The provision of healthcare services within a regional or national health system can be usefully categorized and analyzed through the classification of three main subsystems or sectors: primary, secondary and tertiary care, as depicted in Figure 4. Each of these sectors can be modeled and analyzed as subsystem of the whole industry, though in many countries boundaries between these sectors are often ambiguous or blurred, and frequently shift as health services provision moves from one to another. A typical patient journey should start with contact with primary care for an initial diagnostic consultation, and might then involve the patient being referred to secondary care for more specialized diseases or treatment, or a tertiary service for even more specialized follow-up.

However, Most of the practices described above are not tied to any methodology, being created and implemented *ad-hoc* for specific problems or tasks. From some perspectives, these practices are important as they come from the accumulated experience, can be implemented during a redesign or reengineering project, and some of them report good results. For example, these practices help to avoid medical errors, increase customer satisfaction, reduce unnecessary work, and consequently, affect positively the quality of life, public health, and operational efficiency [10]).

From another point of view, the lack of a rigorous methodology makes these practices sometimes decontextualized, as they do not consider an integrated view among the enterprise elements at the design level (referred in the problem definition from Section 1.1), and there is a lack of vision to deal with the enterprise dynamics due to the inexistent enterprise construction models, which is referred also in problem [11].

Emergency Departments (ED) are considered a highly complex system, with numerous managerial challenges, and accounting for the majority of the overall healthcare spending [12]. Moreover, they have some concerns of their own, such as the fact that the cost of treating an episodic illness is higher than outside the ED, some patients cannot wait, several resources must be available for prevention, there is not much time to make decisions, and patients cannot stay in the service taking up space from other acute episodes.

Based on the available literature we can point out some suggestions to *smooth patient flow*. For example, many authors argue that much of the demand is predictable and that flow and process analysis tools used widely in other industries can be brought to improve ED management. There are suggestions about the implementation of forecasting methods to predict future demand, to allocate the available human resources, to speed up patients' discharge thus freeing up resources, to create rapid response teams to act in very urgent situations avoiding mortality, among others [13]. And for this to be achieved there is to explore all the relevant knowledge within the organization that can help speedily the process of patient-Doctor relationship.

#### *B. Organizational knowledge*

Knowing is defined as how knowledge works in a business system and is important in understanding how tacit knowledge is used in the [14]. Research in modelling processes suggests that organizational processes should be modelled based on four perspectives – functional, behavioural, informational and [15].

The functional perspective describes the tasks performed, why (i.e. what goals the tasks are achieving) and the informational objects required. The organizational perspective focuses on and with what resources the tasks are performed). This perspective considers the roles, actors and other resources that are deployed. The behavioural perspective focuses on when tasks are performed and how (e.g. the sequencing of tasks). These four perspectives provide the

who, what, where, why, when and how of the process in an organization.

#### *C. knowledge map*

A map is a drawing that reveals physical and/or abstract relationships for places or objects of interest. Throughout human history, people have been creating physical maps, such as cave paintings, atlases, and more recently satellite scans and three-dimensional computer visualization. Examples of abstract maps include Concept Map for learning objects [16] and Mind Map for improving memorization [17]

A knowledge map is a knowledge representation that reveals the underlying relationships of the knowledge sources, using a map metaphor for spatial display. For example, a knowledge map for news articles could highlight the current major news topics and their relationships by using blocks to represent key concepts and possibly using lines to represent relationships [17]

The individual items of knowledge included in such a map can be text, stories, graphics, models, or numbers. Knowledge mapping is defined as the process of associating items of information or knowledge (preferably visually) in such a way that the mapping itself also creates additional knowledge.“ types of knowledge maps that can be used in a corporate context. To appropriately design good knowledge map ontology is needed to accurately locate relevant knowledge sources and match them with corresponding actors.

#### *D. Enterprise ontology*

The term “Ontology”, dated from 1721, in its abstract philosophical notation can be defined as a branch of metaphysics concerned with the nature and relations of being [18]. Its notion has been used in several disciplines as a form of knowledge representation about the world or some part of it, or a specification of a shared conceptualization. In our thesis context, the purpose of ontology is the specification of a conceptualization for describing and understanding the construction and operation of the enterprise system, inline with previous researches [11].

The Enterprise Ontology (EO), an ontology designed towards organizations, is a collection of terms and definitions relevant to business enterprises modeling and provides a formal way to define a particular domain. It has its roots in the Performance in Social Interaction Theory (PSI-Theory), which provides an explanation of the construction and operation of organizations at the level of human interactions, allowing a better understanding of the operation [19].

### III. METHODOLOGY

This paper used design science approach to develop a methodology that will improve healthcare services in hospital. The method will consider the overall environment and model together with the business process. The researcher will integrate some existing techniques currently used in modeling business process like knowledge map, enterprise ontology and some business process diagrams. The process consist of 5 steps, the details of each steps will be discussed in the following sections.

A. Step1: design organizational knowledge map

The first step in designing the methodology will be developing an organizational knowledge map. The ontology mapping represents the organizational knowledge which provides the means to understand the relationships between organizational goals, sub-goals, business processes, tasks, subtasks, resources and decision makers (e.g. groups, actors). It helps to identify the business processes and the tasks and subtasks required to carry out each of these processes. It can also be used to identify which roles and/or groups are carrying out particular subtasks and the resources that are being produced and consumed during the execution of these subtasks. One important resource that must be considered is knowledge, the ontology shows the knowledge each actor possesses and also the knowledge decision makers should possess. This helps to determine if there is a mis-match between the knowledge needed for a subtask and the knowledge allocated to the subtask (i.e. the actors assigned to a task).

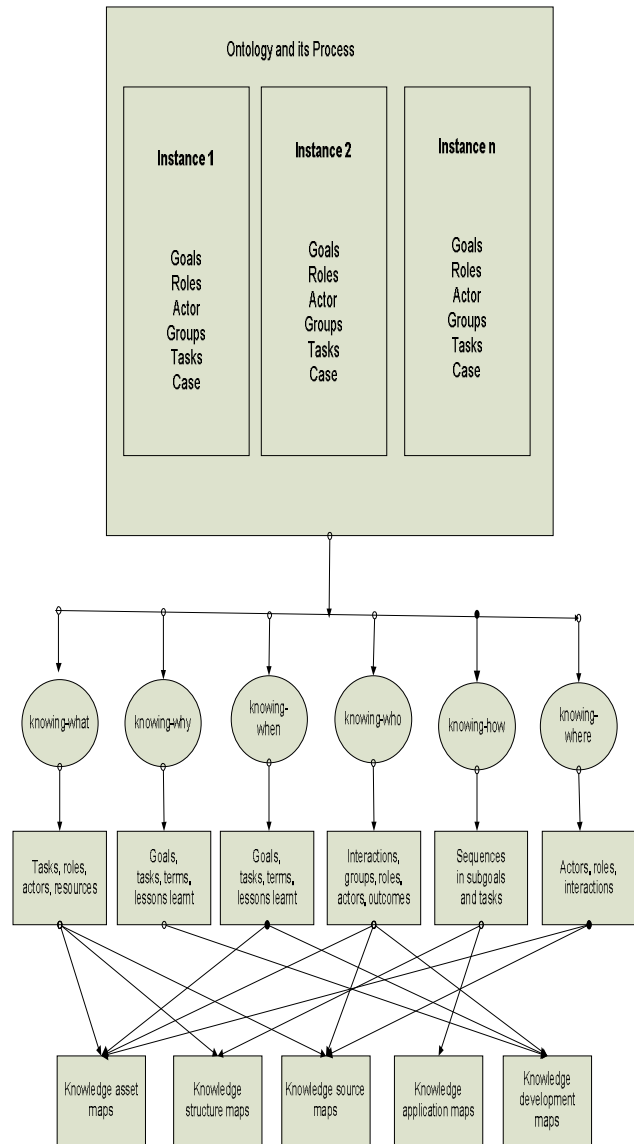


Fig. 1 organizational knowledge map

The figure 1 above describes details on the mapping process in the organization where task, role, actors and resources are related to one another. For example the know-what is describing how to access the knowledge asset map through the actors, roles, and resources.

B. Step 2: use the knowledge map to create organizational ontology

For this demonstration we applied the method to the internal operation of an Emergency Department(ED) Unit of Universiti Teknologi Malaysia Healthcare Center with more than 1,000 admissions per year. To conduct the demonstration, we interviewed 5 patients and 10 practitioners (the ED director, physicians, nurses, and health services researchers). The following sections describe the details of the methodology, giving more emphasis to the organizational

ontology, on how to apply EO to an organization, to the Construction and Process Models, and finally on how can a costing model help to quantify the improvements.

Organizational ontology is proposed for representing ‘who does what’ and ‘who knows what’ in an organization. The ontology provides a knowledge perspective of an organization, as it helps in representing knowledge that is embedded in the actual practices (i.e. the cases) of an organization. Using the knowledge map already created, the next step is to develop organizational ontology. The ontology represents the relationships between organizational goals, business processes, tasks, subtasks, resources and decision makers (i.e. groups, actors). The organizational ontology can as well be adopted if it is appropriate for that case below was adapted from a previous study that describes an approach to the development, representation and evaluation of formal ontologies. This multi-step approach includes the development knowledge maps is dependent on developing an ontology of the domain knowledge.

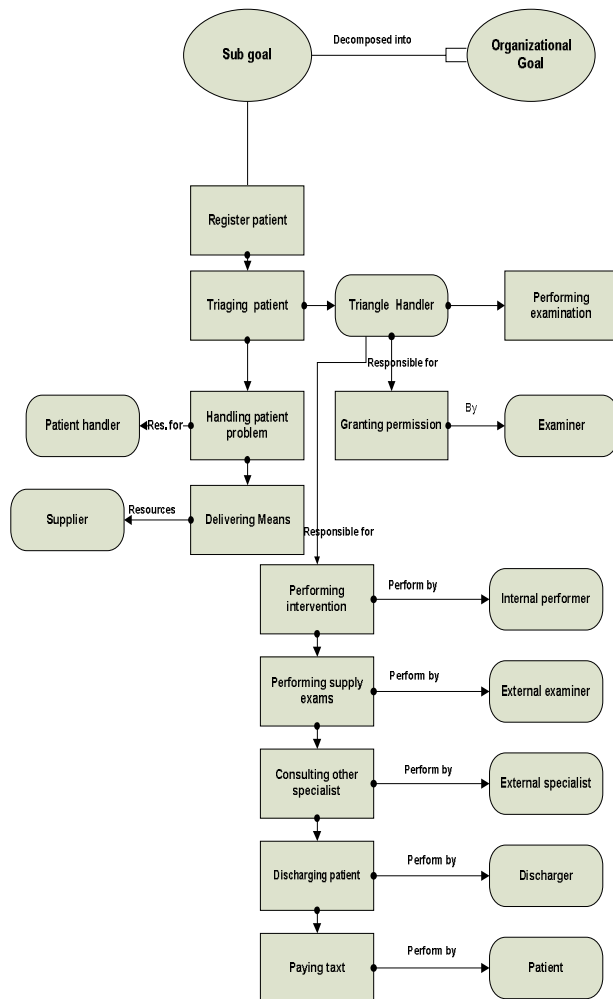


Fig. 2 organizational ontology

In the figure above when patient arrive at the ED he/she must be registered by a secretary, being requested to give some personal information. The secretary writes the data in a registration form and provides an identifier to the patients. After that, they go to a triage room where a nurse triages them, assigns a priority level, and defines patients routing, giving them a printed wristband. Then, the patients must wait for their turn according their urgency level.

Once called, the patients go to a treatment room where a doctor handles their problem. If necessary, this is followed by a diagnostic phase carried out by some internal examiner, or an intervention phase carried out by some specialist or caregiver.

The intervention depends on the patients’ problems. It could be some therapeutic prescription, a chirurgery or other kinds of treatments. At any stage, patients may need to grant permission to continue the process. In complex situations, this permission must be written. To handle the patients’ problems, the physician may also ask for special examinations such as radiology or lab tests. Some of these exams can be administrated indoor, such as electrocardiograms. Others have to be done outdoors, filling in forms that are sent electronically. Some interventions may require other internal specialists, such as minor surgery or orthopedics. These therapies and also the examinations may require external stock supply like medicines or other materials.

Finally, the patients are discharged by a nurse or a social assistant] with their problems solved, or they may need follow-up in another specialty outside the ED, with an after-care or specialty consultation that can be transmitted directly by the caregiver handling the patient. At that time or during the registration the patients may need to pay some taxes, depending on the healthcare system or the owned insurance.

C. Step3: Identify the business process that need to be improve

In the event of emergency department trying to improve some business process, they will normally identify the section of the business that is inefficient. This is normally done by interviewing various stakeholders of that organization. For example in a unit, the doctors, nurses, health assistants, clerks, and the patients can be survey and interview on their opinion with respect to that inefficiencies identify in the process of reengineering. The stakeholders in the organization can be found by querying the ontology for the decision makers and checking the ontology map to find the particular actors playing the role of decision makers.

As depicted in figure 2 above, new patients are registered to the hospital; then they go through a triage process; after that, patients’ problems are handled; and finally, they are discharged. These four transactions are initiated by an external actor, the patient. They are respectively requested to the registrar, triage handler, patient problem handler, and patient discharger that execute them. The handling of the patients’ problems may lead to the following actions: performing some urgent internal examinations; performing medical interventions; performing supplementary examinations; and consulting another external specialty. Since these tasks have

different responsibilities, four different actors are discerned: examiner, intervention performer, external examiner, and external service or specialist.

The first two are internal actors, used for urgent examinations and interventions (i.e. specific interventions may need specialists, such as a surgery or a psychiatry episode). The last two are used for non-urgent situations, such as some extended interventions or supplementary examinations. In addition, there are two transactions concerning the delivery of means, a transaction concerning the patients' permission, a transaction concerning the management of the ED, and finally the payment transaction.

*D. Step 4: Update the organizational ontology to reflect the improvement done*

From the improvement Phase, one must identify process improvements by analyzing the obtained diagrams. After some analysis from the step 3 above, it is possible to conclude that transaction(Registering patient) can be removed as the patient can register during the triage in transaction (Triageing patient), or at least it is possible to automate pertinent registering using a computer terminal with a standardized electronic form. These are in line with the carried interviews and some previous researches. In other words, a common and shared registration is viewed as being vital to both individual and population health, and nowadays there is no need sign papers every time. This strategy is claimed to mainly improve waiting time and resource expenditure.

With the process improvement, one can conclude that it is not efficient having to go through several iterations and actors to be forwarded to another external service, such as a specialist or examiner in transaction. For example, regarding a low-acute episode, instead of being forwarded immediately after triage, patients need to be admitted, triaged, and seen by a physician to be then forwarded to another specialty outside the ED (e.g. specialized consultation, pharmacy or PHC). This leads to unnecessary consumption of resources, higher waste of time, and the patient leaves without being treated in the ED. As presented in the related work, *Provided Directed Queuing and Fast-Tracking System* can anticipate the resolution of some patients' problems. These strategies are claimed to improve waiting time, customer satisfactions, length of stay, and resource expenditure [20]

So virtually, we are left with only 4 major task in the ontology diagram above which are: registering patient, triaging patient, handling patient and consulting other specialty. All other task can be eliminated as discussed above. Therefore the new organizational ontology is now as shown below:

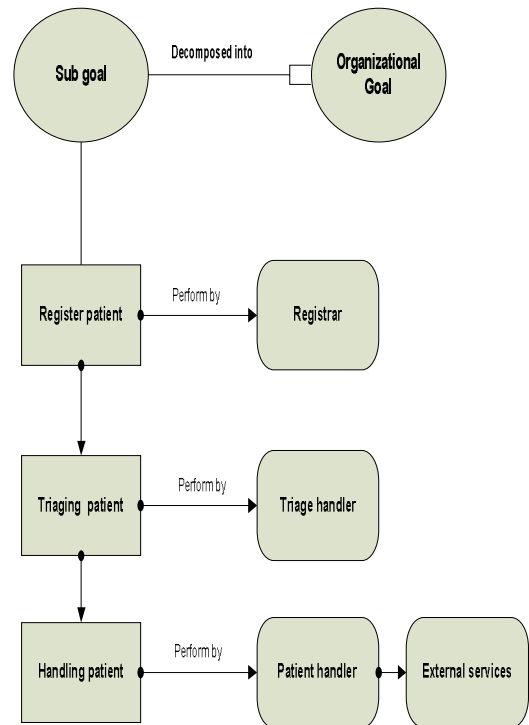


Fig. 3 improved organizational ontology

IV. DISCUSSION AND FUTURE WORK

This paper addresses healthcare management problems, in which its processes have become inefficient and unsustainable. Following this, some concerns are raised in the literature, such as the high failure rate of the traditional organizational sciences to implement management strategies effectively, the growing business dynamics that force organizations to evolve, the inability to deal with these dynamics at the operational level due to weak enterprise construction models, and the consequent lack of organizational self-awareness. To overcome these problems, this research proposes a method based on EO to find non value-added transactions, and redesign them to improve the healthcare management. Therefore, the artifact method relies on a structured set of steps that include the development of enterprise models, their analysis in order to understand the essence of the organization and to find inefficiencies in transactions, the elicitation of possible improvements, their prioritization in terms of feasibility and impact, and finally the redesign of the organization.

We chose the EO as foundation for our proposal as it is deemed able to provide a better understanding of the dynamics of an organization, allows a good alignment between the enterprise design and operation, and enables a structured reengineering strategy. Furthermore, since its models are regarded coherent, comprehensive, consistent, concise and essential, it gives strength to the obtained models. Some of the main contributions of this research are: The proposal to

improve the healthcare management, which differs from the current state-of-the-art approaches; its attempt to solve the problem statement by relating different topics, such as Healthcare Management, BPR, EO, and Its practical demonstrations using organizations as case studies.

As for the future work further research need to be performed to better quantify the impact and feasibility of the proposed improvements during the demonstration, namely by including costing models to the obtained diagrams. This can be a step towards the implementation of innovations in the healthcare system, the understanding of its costs, and also an asset to the EO by adding support for costing models. Furthermore, the Proposal should be expanded to consider the remaining application of other sectors like education and disaster management control.

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