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**Analyzing Value Networks for Change Decision Making  
in a Collaborative Environment  
With a Case Study in Healthcare**

By

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*In the name of God*

## ABSTRACT

Management of Collaborative Networked Organizations faces various challenges in terms of decision-making. Particularly, in complex and multi-player environments, like healthcare, it is not easy to find the roots of low performance processes, and unmet goals. This research provides a framework, as well as associated techniques to analyze the value network, identify problematic actors, and consequently, find the best possible solution to change them. The proposed framework consists of two main components: *Analyzing the value network*, and *Multi-Criteria Decision Making*. To analyze the value network of a collaborative environment, in addition to the existing techniques, four complementary components are introduced: *Actors' value interchanges* matrix, *Value Gantt* chart, *Identifying problematic actors* flowchart, and *Actors' ease of substitution* table. Employing these hybrid analyses, decision makers gain a better understanding of the bottlenecks in the value network, current conditions and contributions of the involved actors, and the consequences of considering various alternatives. Then, by applying one of the Multi-Criteria Decision Making methods, and based on pre-defined criteria, possible alternatives are analyzed and outlined. As a proof of concept and validation of the proposed methods, we reviewed a scenario of patient flow and wait times in healthcare. We derive the value network for collaborative processes in a hospital, specify the roles' of actors, identify the bottlenecks, then rank the solutions, and suggest possible changes to improve the performance of the collaborative environment.

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## **Acronyms and Definitions:**

**Table 1-1: Acronyms and Their Definitions**

|                    |  |
|--------------------|--|
| <b><i>CNO</i></b>  | A collaborative network (CN) is a network consisting of a variety of entities (e.g. organizations and people) that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals, but that collaborate to better achieve common or compatible goals, thus jointly generating value, and whose interactions are supported by computer network. Although not all, most forms of collaborative networks imply some kind of organization over the activities of their constituents, identifying roles for the participants, and some governance rules, therefore, can be called collaborative networked organizations (CNOs) (Luis M. Camarinha-Matos, Afsarmanesh, Galeano, & Molina, 2009). |
| <b><i>MCDM</i></b> | Multiple-criteria decision-making is concerned with structuring and solving decision and planning problems involving multiple criteria. The purpose is to support decision makers facing such problems (Zionts, 1979).   |
| <b><i>SLA</i></b>  | Service Level Agreement is developed between service providers and customers to describe the service, document service level targets, and specify the responsibilities of each party (Office of Government Commerce, 2007)   |
| <b><i>SOA</i></b>  | Service Oriented Architecture is an architecture for building business applications as a set of loosely coupled black box components orchestrated to deliver a well-defined level of service by linking together business processes (Hurwitz, 2008)  |
| <b><i>SOVO</i></b> | In a Service Oriented Virtual Organization, different organizations address a business opportunity by composing their services to create a more complex service that provides more value to the customer. Partners can publish their   |

|                             |  |
|-----------------------------|--|
|                             | business processes as services without threatening their privacy or comprising aspects that form their own competitive advantage (Ahmadi Danesh Ashtiani, 2012; S. M. A. Kamali, 2013).  |
| <b><i>Value network</i></b> | A value network is any set of roles and interactions that generates a specific kind of business, economic, or social good (Allee & Schwabe, 2011)  |
| <b><i>VO</i></b>            | Virtual Organization is a dynamic, temporal consortium of autonomous legally independent organizations which cooperate with each other to attend a business opportunity or cope with a specific need, where partners share risks, costs and benefits, and whose operation is achieved by a coordinating sharing of skills, resources and competencies (Karvonen, Salkari, & Ollus, 2005) |

## **CHAPTER ONE: INTRODUCTION**

Inter-organizational collaboration has become inevitable in today's business environments, especially when organizations want to achieve a differentiated competitive advantage, and open new markets (Luis M. Camarinha-Matos et al., 2009). Whether it is a large organization, or Small or Medium size Enterprise (SME), companies are gradually restructuring their business models, and software infrastructures to facilitate dynamic and flexible environments in order to involve in more complex partnerships with more complex value exchanges (L. M. Camarinha-Matos, Afsarmanesh, & Ollus, 2008). This is the reason behind the increasing rate of Collaborative Networked Organizations (CNO) and Virtual Organizations (VO) creation.

Moreover, powered by new collaborative technologies, the game of business is changing from the process-centric view to human-centric view (Allee & Schwabe, 2011). Creation of value networks is dramatically changing work design and management practices. Loosely structured networks, instead of the traditional linear process or hierarchical organization structures, are the main characteristics of the new era, which puts users in control. The freedom to determine with whom, when and how to collaborate, has attracted even the most traditional businesses to the value networks and CNOs.

### **1 Research Motivation**

In the globalization era, characterized by new markets and unlimited competitors, one of the few survival strategies for organizations is to collaborate with each other, and provide value added services to their customers. Participation in sustainable collaborative networks for the formation of dynamic virtual organizations in response to the rapidly changing market conditions, will become an unavoidable approach in the following years (Arana, Rabelo, Gusmeroli, & Nagellen, 2010).

Additionally, Service-Oriented Architecture (SOA), which is one of the most favorable inter-organizational process management solutions, is being widely used across the world (Sholler, 2008), and there is increasing demand for its usage and structure. Among organizations' motivations to adopt SOA, are its dynamic and reusability nature, conformance with Business Process Modeling standards, platform independency, and high worldwide adoption rates (Holley & Arsanjani, 2010).

In dynamic, agile, SOA-based environments, decision-making could be challenging especially in large, multi-player organizations (like hospitals), where identifying problems and making best possible decisions to improve the processes should be done efficiently. In this research, our goal is to efficiently and effectively identify problematic actors in the value networks, compare alternatives, and come up with the most desired solutions.

## 2 Definition of the Research Problem

Conducting studies and literature survey on Collaborative Networked Organizations, value networks, performance measurement, and the importance of decision-making in collaborative environments, the observations and the questions listed in Table 1-1 are attained.

**Table 1-1: Framing research problem**

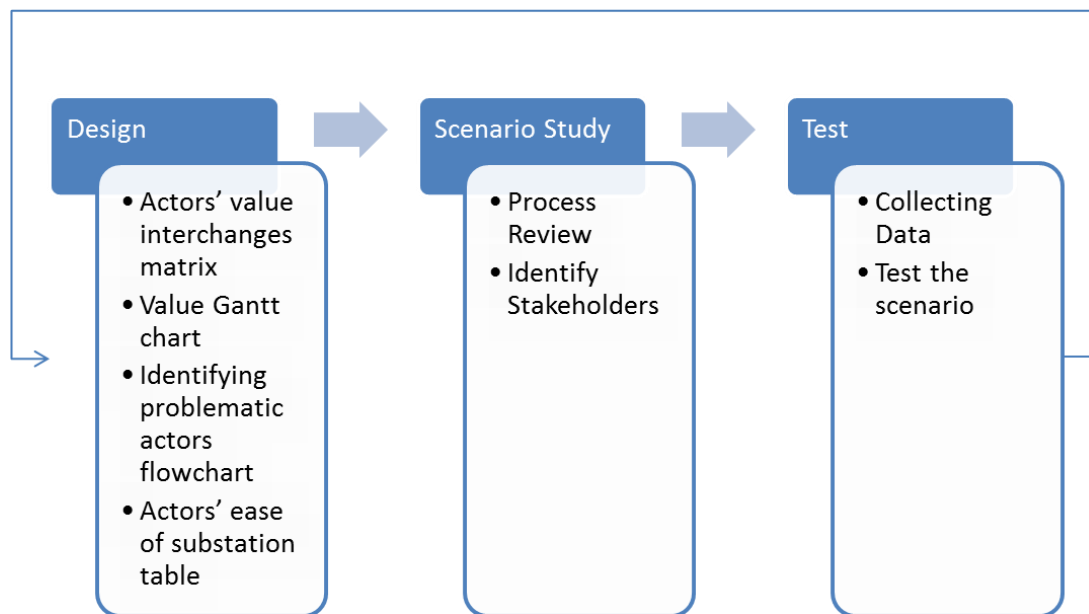
| <b>Steps</b>        | <b>Description</b>   |
|---------------------|--|
| <b>Observations</b> | <ul style="list-style-type: none"> <li>- The number of Collaborative Networked Organizations (CNOs) is increasing, and by 2020 most of organizations will participate in some kind of CNO (Luis M. Camarinha-Matos et al., 2009)</li> <li>- Companies are moving from strict organizational charts to collaborative and role-based value networks (Allee &amp; Schwabe, 2011)</li> </ul> |

|                           |   |
|---------------------------|---|
|                           | - Decision making in multi-player, dynamic and service-oriented environments could be challenging (M. V. Drissen-Silva & Rabelo, 2009)  |
| <b>Thesis</b>             | Proposing a framework to analyze value network of collaborative-networked organizations to identify problematic actors, and find best possible alternative using multi-criteria decision making techniques.   |
| <b>Enthymeme</b>          | A framework for analyzing value network and proposing preferred alternatives for changing actors, based on their performance, is needed.  |
| <b>Problem Statement</b>  | Making the best possible decision to substitute or add actors in a value network is not always easy, especially in complex collaborative environments.  |
| <b>Objective</b>          | Design and test a framework for identifying problematic actors in the collaborative value networks and find preferred solution for changing them.   |
| <b>Research Questions</b> | <ol style="list-style-type: none"> <li>1. Can we identify problematic actors based on the analysis of the value network?</li> <li>2. How can we offer preferred solutions to substitute problematic actors in collaborative environments, leveraging on the Multi-Criteria Decision-Making techniques?</li> </ol> |

### 3 Research Methodology

Figure 1-1 shows the methodology we applied in this research. In the first phase, we study collaborative networks and the framework of the service oriented virtual organization. We then analyze the challenges of decision making for change in collaborative environments. We devise a framework consisting of formal methods and analytical techniques, including *Actors' value interchanges* matrix, *Value Gantt chart*, *Identifying problematic actors* flowchart, *Actors' ease of substitution* table and Multi-

Criteria Decision Making for changing actors in value networks. Then, we gather data for testing our framework. In this phase, we review a process in the healthcare environment and identify stakeholders. We then model the value networks of this process, and test our proposed techniques on the case.



**Figure 1-1: Research Methodology**

**Table 1-2: Research phases and detailed activities**

| No | Phase         | Activities   |
|----|---------------|--|
| 1  | <b>Design</b> | <ul style="list-style-type: none"> <li>• Review VOs and their characteristics and challenges</li> <li>• Research on Value Network and its application in collaborative environments</li> <li>• Review Service Oriented Virtual Organizations (SOVO) process management and performance management frameworks</li> <li>• Review existing value network analysis methods</li> <li>• Investigate decision making challenges in</li> </ul> |

|          |                       |   |
|----------|-----------------------|---|
|          |                       | collaborative environments <ul style="list-style-type: none"> <li>• Identify required analysis</li> <li>• Investigate available techniques (like Gantt chart)</li> <li>• Devise mathematical models and methods:             <ul style="list-style-type: none"> <li>○ Actors' value interchanges matrix</li> <li>○ Value Gantt chart</li> <li>○ Identifying problematic actors flowchart</li> <li>○ Actors' ease of substitution table</li> </ul> </li> </ul> |
| <b>2</b> | <b>Scenario Study</b> | <ul style="list-style-type: none"> <li>• Select a used case</li> <li>• Review the process</li> <li>• Identify involved actors and their roles</li> <li>• Map the value network for the case</li> <li>• Select appropriate MCDM technique</li> </ul>   |
| <b>3</b> | <b>Test</b>           | <ul style="list-style-type: none"> <li>• Collect data for testing</li> <li>• Perform the proposed analysis on the case based on the framework</li> <li>• Apply the selected MCDM method and suggest alternative solutions</li> </ul>  |

#### **4 Contribution of the Thesis**

In this research, we developed a framework and a formal method to analyze value networks, find problematic actors, and accordingly, rank and suggest solutions to change actors in a collaborative environment. In complex and multi-player organizations, this helps managers and decision makers to suggest solutions to improve the performance of the organization, and consequently, increase the level of satisfaction of their customers.

Through the process of developing this framework, we proposed a method to extract actors interchange matrices from the value network to analyze and identify problematic

actors. We described the steps to convert values to tasks, in order to find the critical path and slack time of each value. This feature (similar to the Gantt chart in project management) helps VO managers concentrate on critical values, and let actors know how long they can postpone their tasks without affecting the whole value network.

Moreover, we characterized attributes for decision matrix of actors' substitution. We observed different aspects of an actor in a value network, and how hard it would be to substitute the actors. The *Ease of actors' substitution* table will illustrate challenges, difficulties and consequences of changing actors to the decision makers.

## **5 Structure of the Thesis**

The rest of the thesis is structured as follows: in Chapter 2, we review the literature from different perspectives, related to the objective of the thesis. First, we study the current literature on collaborative-networked organizations, virtual organizations, their characteristics, and challenges of their management. Following that, the concept of value networks in today's business environment is elaborated. Then, we discuss Service Oriented Virtual Organizations (as an advanced form of collaborative environment), their characteristics, and challenges in regard to decision-making.

In Chapter 3, we propose the framework for analyzing value network to identify problematic actors and make the best possible solution to change them. We review SOVO analysis method for value dependencies, based on which, we develop four components and methods for value networks: *Actors' value interchanges* matrix, *Value Gantt* chart, *Identify problematic values* flowchart, and *Actors' ease of substitute* table. Then, we introduced three MCDM techniques that could be useful in VO management.

In Chapter 4, we apply the framework to a healthcare scenario as a proof of concept and validation. We draw its value network map. Then, using the proposed methods, we

analyze the value network to find the bottlenecks and problematic actors. At the end, we apply the Analytic Hierarchy Process (AHP) method as one of the MCDM techniques, and rank and suggest alternative solutions.

Finally in Chapter 5, we conclude the thesis by providing the summary of the research. Following that, we highlight the contributions of the thesis and discussed the research limitations, as well as possible future works.

## CHAPTER TWO: LITERATURE SURVEY

### 1 CNO and VO

Today' world economy with borderless markets demands flexibility and quick adaptation. Players in both manufacturing and service industries require new business models, strategies, processes and technologies to survive in this highly competitive environment. (National Research Council, 1998) discussed what organizations need to do to fill the gap between where they are and where they need to be in 2020. Among the challenges, they mentioned:

- 1- Instantaneously transform information gathered from a vast array of diverse sources into useful knowledge for making effective decisions,
- 2- Reconfigure enterprises rapidly in response to changing needs and opportunities.
- 3- Develop innovative processes and products with a focus on decreasing dimensional scale.

Organizations should address these concerns in different layers of their operations to adapt to the dynamic environment. These requirements are even more challenging for Small and Medium sized Enterprises (SMEs) due to their limited resources, skills and infrastructure. However, collaboration between them, sharing values and ability to form temporary and opportunity-driven associations gives them the capacity to adjust to the needs of the market (L. M. Camarinha-Matos et al., 2008). Therefore, dynamic inter-organizational business models will be an inevitable part of future complicated markets.

By cooperating and outsourcing some of their components and services, organizations have tried to share their resources and skills. Their early attempts were relatively stable, static and roles and responsibilities were strictly defined. However, new complicated and

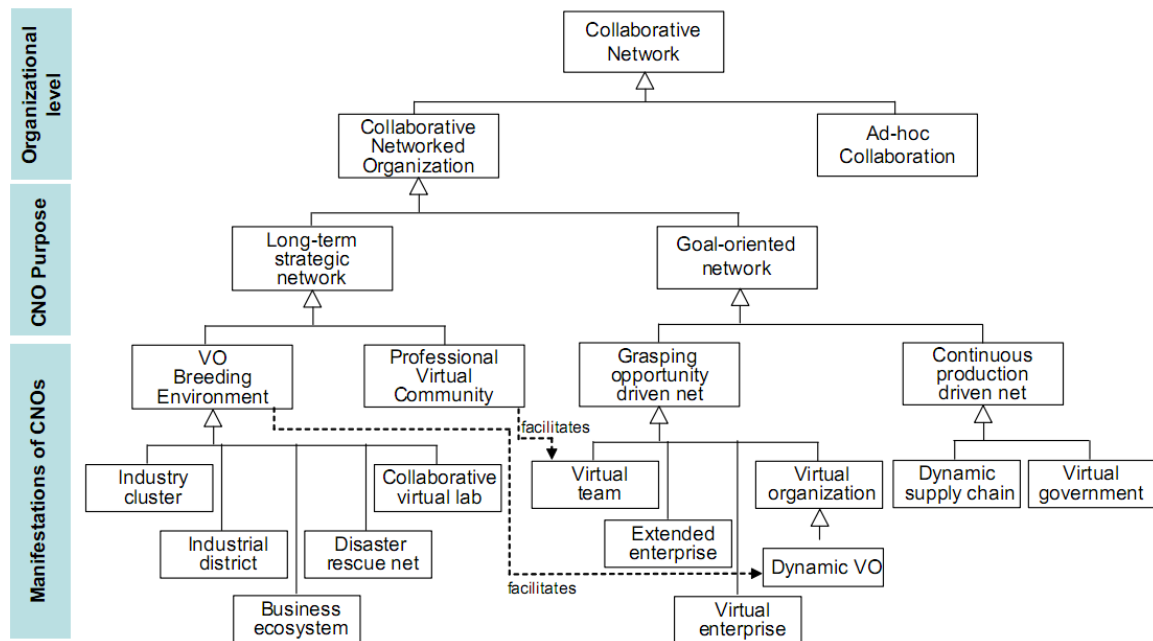
dynamic markets demand new form of collaborations. Compared to traditional data driven networks of business entities, these new initiatives are more knowledge driven networks (Luis M. Camarinha-Matos et al., 2009). A Collaborative Network (CN) is “a network consisting of a variety of entities (e.g. organizations, people, and even machines) that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals, but collaborate to better achieve common or compatible goals, and whose interactions are supported by computer networks” (Luis M. Camarinha-Matos & Afsarmanesh, 2005).

Camarinha and his colleagues have provided a taxonomy classification model for CNs based on their purpose and timeframe (Luis M. Camarinha-Matos et al., 2009). Forms of CNs, in which “entities share information, resources and responsibilities to jointly plan, implement, and evaluate a program of activities to achieve a common goal and therefore jointly generate value” are called Collaborative Networked Organizations (CNOs). These organizations usually apply distributed business process management, integration, and coordination methods. They may either work together in a long-term strategic networks (like VO Breeding Environments), or try to reach a common goal (like opportunity driven networks). Figure 2-1 shows CNs taxonomy classification.

## **2 Virtual Organizations**

As shown in Figure 2-1, a specific type of opportunity driven CN is called a Virtual Organization. By comparing several definitions for VO, (M.H. Danesh, Raahemi, & Kamali, 2011) described it as “a dynamic, temporal consortium of autonomous legally independent organizations which collaborate with each other to attend a business opportunity or cope with a specific need, where partners share risks, costs and benefits, and whose operation is achieved by coordinated sharing of skills, resources and competencies and whose interactions are supported by computer networks”.

Virtual Organizations are one of the most mature Collaborative Networked Organizations. Goals, identities, responsibilities and activities of partners are jointed (Luis M. Camarinha-Matos et al., 2009). Compared to the other CNOs, determination of partner contribution and VO creation process is more complex.



**Figure 2-1: Classification of Collaborative Networks (Camarinha-Matos et al., 2009)**

VOs themselves can be classified based on the partners' interaction topologies. (Karvonen et al., 2005) defined topology here as different structures, in which VO partners interact as nodes of a network (Figure 2-2). These interactions can be exchange of money, information, material, service, control flows, responsibilities, and power relationships. Three identified topologies are supply chain, star and peer-to-peer. In a supply chain topology, each partner interacts with its immediate upper and lower partner. In a star topology, all partners only interact with the central partner. Lastly, in a peer-to-peer topology each partner may or may not interact with other partners.

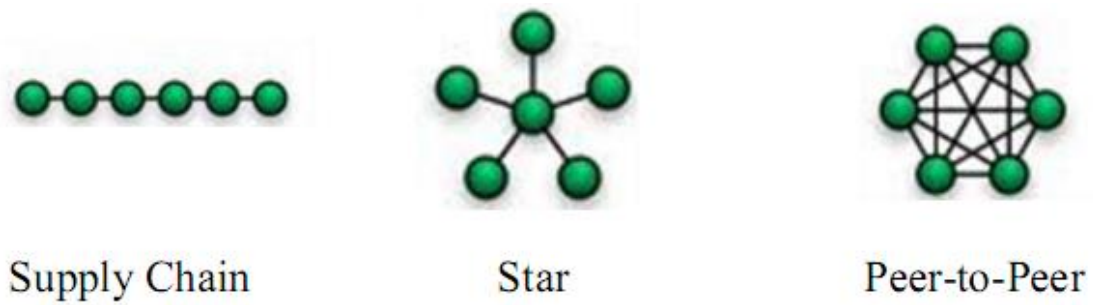


Figure 2-2: VO interaction and management typologies (Karvonen et al., 2005)

### 3 VO Management

Every CNO has four main stages in its lifecycle; Creation, Operation, Evolution and Inheritance (L. Camarinha-Matos & Afsarmanesh, 2007). VO management mostly applies to the operation and evolution stages. VO management means organization, allocation and coordination of resources, along with their inter-organizational dependencies to accomplish mutual objectives within the predefined time, cost and quality requirements (Karvonen et al., 2005). As VOs include several autonomous partners, and run in a highly dynamic and temporal environment, their management is complex and multi-layered. Among VO management challenges there are temporality in its nature, distributed operation between different business partners, adoption to fast changing environment, which may cause restructuring in management approach or even VO configuration. Consequently real-time actions and efficient performance management with reliable indicators are required (Karvonen et al., 2005).

VOs have a wide range of characteristics regarding their structure, time span, lifecycle and behavior. Although it is principally difficult to define a one-size-fits-all model to cover all requirements of VO management, different approaches for VO management are identified. Some perceive VO as a project using the Project Management Body of Knowledge (PMBOK) (Indelicato, 2009) which expresses a project as “a temporary effort to create a unique product or service”. However, there is an argument that VO

management is much more complicated than project management since multiple autonomous organizations are involved. Moreover, since the very initial phase of VO creation, there are continuous negotiations among partners. The second approach to managing VOs is to define and employ decision protocols and mechanisms. Unfortunately, there is a lack of specified guidelines and supporting methodologies for VO management activities. And a last but not least approach is based on collaborative discussions between different VO partners.(M. Drissen-Silva & Rabelo, 2008; Karvonen et al., 2005)

Table 2-1 presents a comparison between a traditional management model and Collaborative Networked Organizations management models (M. Drissen-Silva & Rabelo, 2008).

**Table 2-1: Traditional vs. CNOs management models (Drissen-Silva & Rabelo, 2008)**

| <b>Criteria</b>                          | <b>Traditional Model</b> | <b>CNO/VE</b>            |
|--|--------------------------|--------------------------|
| Decision Scope                           | Intra-organizational     | Inter-organizational     |
| Decision                                 | Typically centralized    | Preferably decentralized |
| Information sharing among partners       | No or eventual           | Yes                      |
| Decision transparency                    | No or Low                | Yes                      |
| Quality decision evaluation              | No or Low                | Yes                      |
| Decision process rigidity                | Inflexible / Workflow    | Flexible / Ad-hoc        |
| Information integration between partners | Low / Medium             | High / Very High         |
| Trust among partners                     | Implicit                 | Explicit                 |
| Decision objective                       | Best local result        | Feasible global result   |
| Mutual help level between partners       | Cooperation              | Collaboration            |

#### **4 Value Network**

Various methods have been published to model and design collaboration between organizations. Traditionally when partners decide to collaborate and produce value added services they started by designing their processes using function or process oriented models. However, when it comes to alignment of overall value co-production of the

virtual organizations, most of them have shortcomings (Wang, Chu, & Xu, 2010). Therefore many recent VO researches have based their business value creation mechanism on value networks.

Value Network is “a set of roles and interactions that generates a specific business, economic, or social good” (Allee & Schwabe, 2011). It shows the ways in which organizations interact and share values to form complex chains of multiple providers and administrators. The ultimate goal of each value network is to create value for the client (Ul-Haq & Schikuta, 2010).

Modeling value networks is the starting point to design collaborative business processes. It helps VO managers identify participants, their value expectations and value exchanges. Based on value inter-dependencies in the value network, we can analyze the collaboration among partners and track information, services and money flow (A. Kamali, Richards, Danesh, & Raahemi, 2012; Wang et al., 2010; Wieringa & Gordijn, 2005).

## **5 Service Oriented Virtual Organizations**

### **5.1 Service Oriented Architecture**

One of the most suitable implementation approaches to manage VOs is Service Oriented Architecture (SOA) because of its key benefits of flexibility and reusability (Holley & Arsanjani, 2010). SOA responds faster and more efficiently to today’s market calls for agile enterprises, which can shift requirement, regulations and customer needs quickly. Tight competition is forcing businesses to provide a palette of atomic or composite services that can be easily and dynamically assembled into business processes (Fiammante, 2009).

SOA is “an architecture for building business applications as a set of loosely coupled black-box components orchestrated to deliver well defined services by linking together

business processes” (Hurwitz, 2008). However, it can be defined from different aspects; from managers’ point of view, SOA is “a journey that promises to reduce lifetime cost of the application portfolio, maximize Return on Investment (ROI) in both application and technology resources, and reduce lead times in delivering solutions to the business”, where from business executives’ point of view SOA is “a set of services that can be exposed to their customers, partners and different parts of the organization”, and last but not least, from information systems architects’ point of view, SOA is “a mean to create dynamic, highly configurable and collaborative applications built for change which reduces IT complexity and rigidity” (Holley & Arsanjani, 2010).

In the past years, many attempts have been made to combine SOA and Business Process Management (BPM) to come up with appropriate approach to facilitate IT and business alignment. Not all of them were successful (Fiammante, 2009). To address dynamic BPM, SOA principles and best practices should be followed in all three layers of service design. The top layer is collaborative services, which include high-level inter-organization business processes. The second layer is public services, which are intra-organizational services between different business components. Finally, the third layer is private services, which are internal business activities within a business component (Fiammante, 2009).

SOA-based solutions facilitate technology co-existence through support of standards-based design, development, and implementation have three main characteristics: support of standard-based interoperability (WS-Standards), dynamic composition via service discovery, and dynamic governance and orchestration (Tsai, Fan, Chen, Paul, & Chung, 2006)

## **5.2 SOVO process management**

The dynamic, collaborative and temporal nature of VOs has left no choice for them except adopting computer systems and networks. Applying shared infrastructure and interoperable information structures have become crucial strategies of all CNOs (Karvonen et al., 2005). Due to aforementioned characteristics of VOs, managing them requires well-defined practices. Also, in VOs management should focus on value offering instead of long-term business goals and strategies. To address collaborative business processes, synchronize and integrate VO's partner processes and resources, Danesh et al. (2011) proposed a process management framework for Service Oriented Virtual Organizations (SOVO).

SOVO accomplishes two main goals: 1) allow organizations to share their designated services with other partners while keeping their core competencies private, 2) facilitate virtual workflows without the need for a central authority. To reach these objectives, Danesh et. al. (2011) relied on reference architectures and best practices like Open-EDI, S3 Service Oriented Architecture, ITIL V3 and PMBOK.

The framework assumes two layers of business processes for VO. The higher layer is Collaborative Business Processes, which are VOs processes orchestrated by and composed from partner processes acting at the lower level. (A. Kamali et al., 2012) provided a link between the first and the second layer of the framework; a formal method to extract service choreographies from the value networks. In this paper, we used this formal method and modified it to analyze the roles of actors in value network (see Chapter Three: The Proposed Framework).

Figure 2-3 shows the SOVO Process Management framework and its components in six layers (M.H. Danesh et al., 2011). The main boxes represent the layers and the small inner boxes indicate components of each layer.

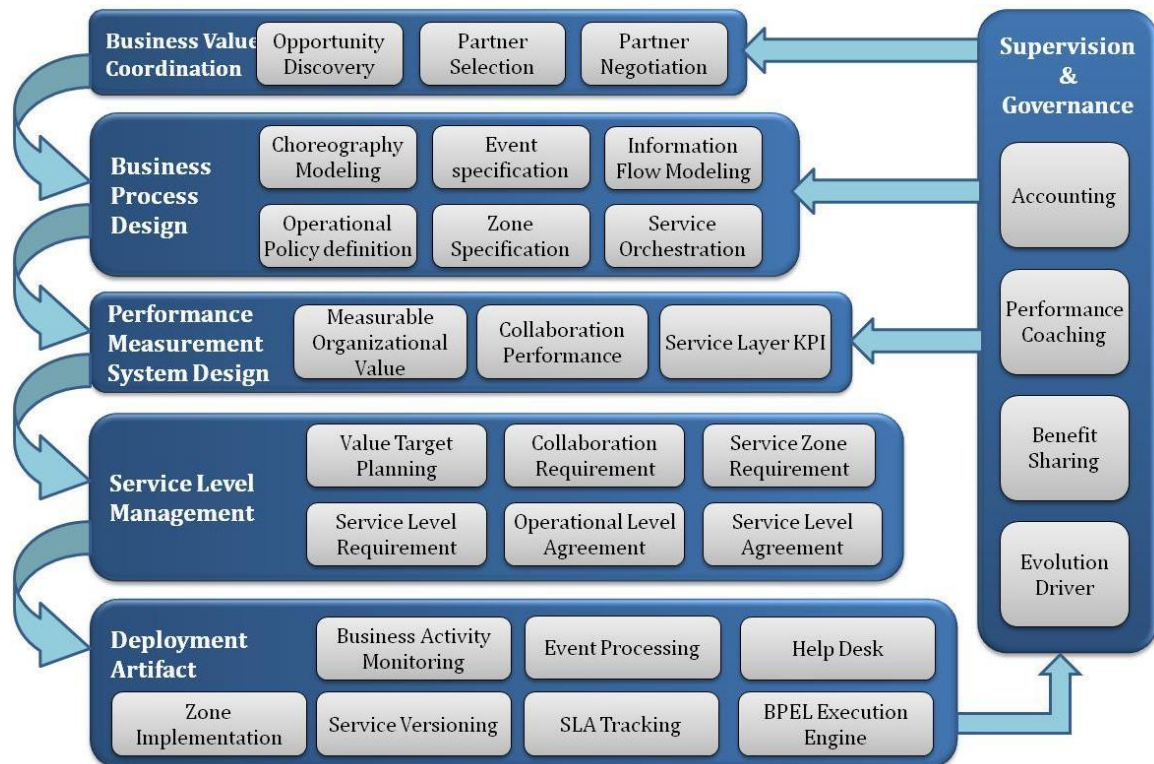
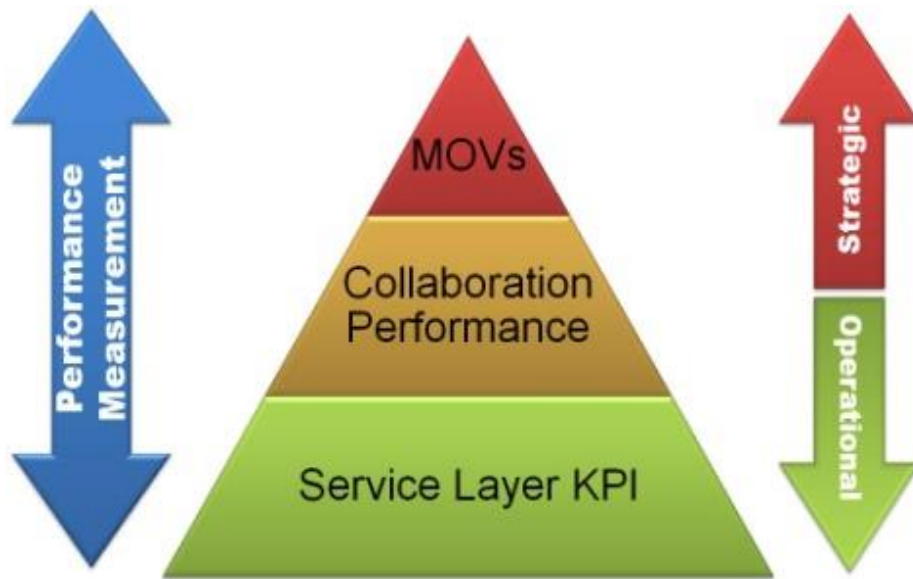


Figure 2-3: The SOVO Process Management framework (M.H. Danesh et al., 2011)

Business Value Coordination layer focuses on the business values and motivations of VO formation. It illustrates the business opportunity and demonstrates the values, which VO partners gain from it. When general business model is defined, partner discovery and selection is performed. In an ideal service oriented environment, a semantic service-matching agent will do this using the service registry (via the Universal Description, Discovery and Integration standard or more advanced protocols). Final part of this phase is partner negotiation and contracting. Here, each partner's offering, competencies and their contribution in VO value creation will be elaborated and modeled. The output of this layer is a network of collaborative value creation in form of value network (which is discussed in Chapter Two: 4).

Business Process Design layer focuses on business process flows and explains conditions and dependencies between processes. The choreography modulation defines partner collaboration and service interactions, and specifies each partner's roles and activities, and the sequences of service invocation (Mohamed, Galal-Edeen, & El-Zoghbi, 2010). Also, VO event specification is defined and modeled using Business Process Model and Notation (BPMN). Moreover, BPMN is used to model information flow between different services in a process and specifies what information should be delivered to whom at what time. Policy definition happens in two aspects; service policy definitions which express anything a service wants to know, and process policies which indicate the collaborative process rules. In the zone specification, each partner's configuration of its gateway to VO is done. Finally, the service orchestration illustrates service sequences. In this layer, BPMN is used to model the final process, and derive the corresponding BPEL (Business Process Execution Language) according to the partner zone specifications (Allweyer, 2010)

In the Performance Measurement System Design layer there are three categories of Key Performance Indicators (KPIs); 1) Service Layer, 2) Services Collaboration, and 3) Organizational Values. Figure 2-4 shows different layers of a SOVO performance pyramid. The bottom-level performance indicators are mainly at the operational level and will be used to assess the performance of services provided by a specific partner in the collaborative process. The mid-level performance indicators are used to measure the effectiveness and efficiency of collaboration between the partners. The top-level KPIs are employed to measure the effectiveness of managerial approaches, strategies and decision-makings. Using the language of IT project management, (M.H. Danesh et al., 2011) named this level Measurable Organizational Values (MOVs). More details of performance management in SOVO will be discussed in Chapter Two: 5.3.



**Figure 2-4: The SOVO Performance Indicators pyramid (M.H. Danesh et al., 2011)**

The Service Level Management layer is responsible for defining and negotiating service level targets, objectives and agreement. It guarantees service consistency and continual improvement and facilitates better monitoring and quality assurance based on ITIL V3 service level management principles. By mapping the previously modeled processes and performance system design to traceable services, this layer generates management Service Level Agreements (SLAs). Based on measurable organizational values, the value target planning focuses on overall service level target. The service collaboration requirement specifies service interdependencies and their quantitative performance measurements. The service zone requirements clarifies each partner's gateway characteristics and acts as an SLA for the overall policies and rules of specific partner's services. The service level requirement (SLR) is a set of specifications and requirements for a service, based on the business objectives. Operational level agreements (OLA) is an agreement on operational support between service provider and its users. The main expected functionalities from a service are described in SLR and OLA. The output of this layer and the result of all these negotiations and agreements are projected in a single

Service Level Agreement (SLA) document which will be used for monitoring service (Ahmadi Danesh Ashtiani, 2012).

Deployment Artifact layer contains a set of components and implementation principles for SOVO process deployment and monitoring. These guidelines and implementation tips are mostly from ITIL. In an ideal solution these components will run on a distributed infrastructure. The Business Activity Monitoring (BAM) and SLA tracking modules track the stats of VO activities and possesses through a set of dashboards and reports. The KPIs mentioned in the third layer of the framework are projected in these components. The event-processing module handles events in collaborative processes and analyzes these events. The service versioning module is a set of documents which track services and their changes over time. The zone implementation module provides authenticated access and The BPEL execution engine is responsible for executing the orchestrated collaborative processes (Ahmadi Danesh Ashtiani, 2012).

The last but definitely not the least layer is Supervision and Governance. Based on performance measurement, this layer ensures that VO moves toward the right direction. By forecasting, planning and design future trends of the VO, continual improvement and change management will be achieved. Accounting talks about financial issues of shared activities. Performance coaching seeks improvement via performance evaluation and partners' feedback. The benefit-sharing component aligns VO partners benefits based on the value constellation and value creation. It assesses rewards and shares benefits to partners by appraisal of their performance. Finally, the evolution driver triggers appropriate changes in the VO based on performance criteria. In this environment, there are three types of change; 1) within a partner's services which only triggers performance indicators; 2) change in VO service choreographies which affects higher levels in VO;

and 3) VO value creation changes which result in renegotiation or even resolution (M. Drissen-Silva & Rabelo, 2008).

SOVO process management framework supports various VO topologies such as supply chain, star and peer-to-peer. Based on its interaction topology, SOVO can design collaborative business processes and efficiently responds to changes due to its loosely coupled components (Mohammad. H Danesh, Raahemi, Kamali, & Richards, 2012).

Danesh and his colleagues implemented their architecture based on a service zone interaction model which allows organizations to share their business processes as services under specific rules and policies defined by the VO business processes and service choreographies. Service zones are considered as the gateways to the virtual organization's shared resource pool and enable the VO to manage and orchestrate its services as if it were the actual owner. Implementation of the service zone interaction model is based on federated SOA infrastructures. At the heart of such federated infrastructure, resides an Enterprise Service Bus (ESB) that integrates services and facilitates policy enforcement (Ahmadi Danesh Ashtiani, 2012). The strength of this architecture is that it provides business partners complete control and autonomy to manage or change their services within the boundary of the agreed collaborative policies and zone specifications.

### **5.3 SOVO performance management**

Traditional definition of Performance Measurement is “the systematic approach to planning and conducting the collection of data regarding the accomplishment of tasks and the corresponding objectives...”(L. M. Camarinha-Matos et al., 2008). However, in collaborative environment between organizations, new ways of measuring and managing performance is required (Busi & Bititci, 2006).

There are two main characteristics of VO which make performance measurement challenging; temporary nature and inter-organizational complexities (Graser, Westphal, & Eschenbaecher, 2005). Typically short life cycle and impermanence of the VOs indicates that typical strategic objectives would not be useful, because they are meant to measure long-term performance of organizations. Moreover, on top of each VO's own performance measurement framework, its performance should be comparable to other VOs through standard measures.

In order to come up with a successful performance measurement solution, alignment of the partners' goals and objectives in a way that satisfies the VO's purposes should be considered. Also, such a solution must respect the fact that partners are concerned about their data privacy concerns and they want to keep internal to their own companies.

Kamali et. al. (2012) proposed a performance management framework based on unique characteristics of SOVO. The framework is consisted of two components; structural and procedural. As we discussed in previous section, the structural framework defines different layers of performance indicators and their relationships. However, it cannot guarantee the success of a performance measurement system. The VO needs procedures to design, implement, and improve its performance structure of performance indicators. Figure 2-5 shows the SOVO performance management procedural framework, designed in five phases, by adapting aforementioned specifications of the SOVO environment (S. M. A. Kamali, 2013).

The Design phase includes identification of stakeholders' needs, coordination of partners' value propositions, designing the structure of performance indicators, setting the targets, setting the frequency of measurement, setting the responsibility zone for each partner, and designing the configuration of the distributed dashboards.

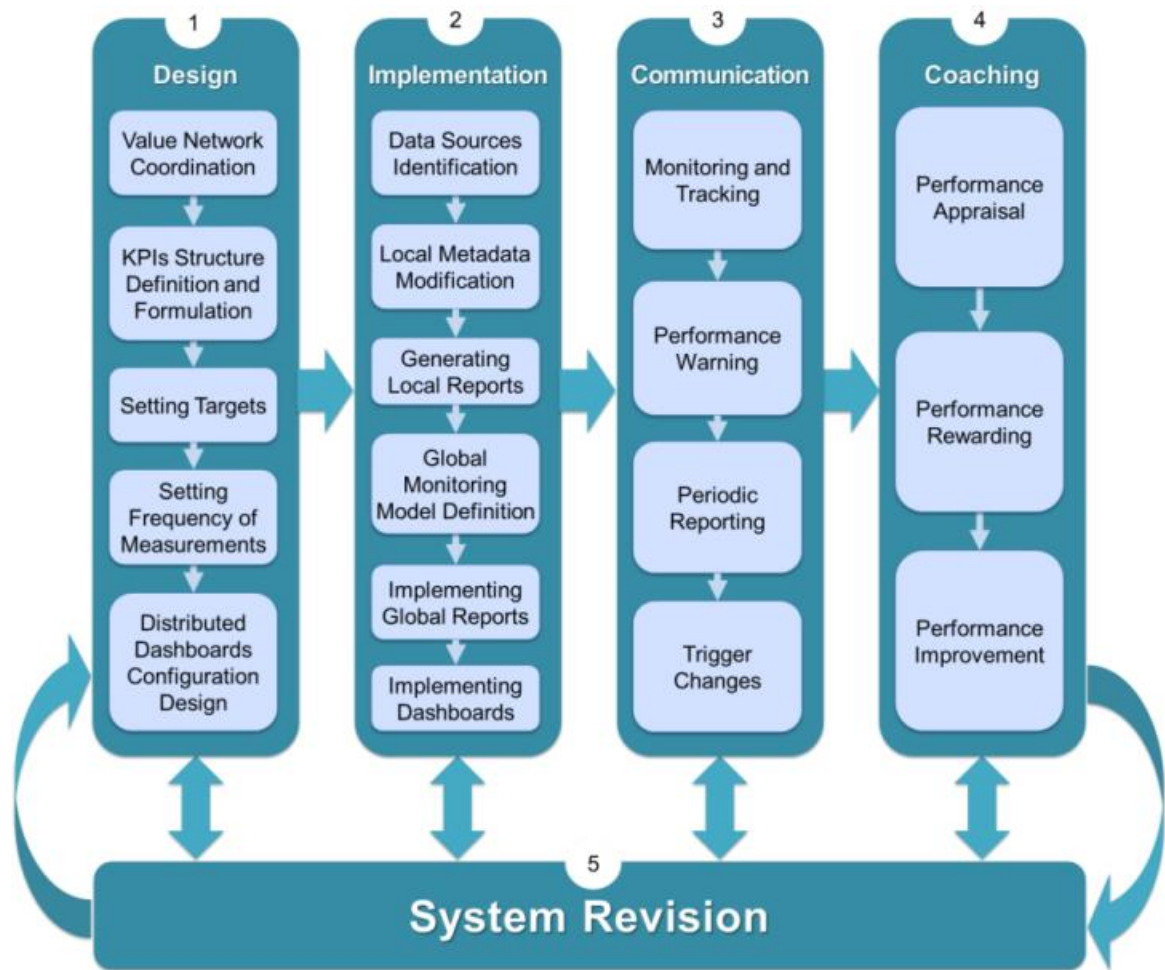


Figure 2-5: SOVO PM Procedural framework (S. M. A. Kamali, 2013)

In the Implementation phase, data from distributed sources is captured, and integrated. This is done by establishing links between the data sources and performance indicators. Also, the local metadata must be modified to become consistent with VO performance measurement requirements. Therefore, the resulting local reports will have consistent namespaces. Then based on the modified local metadata, the global monitoring model can be defined. The last step of the implementation phase is Physical implementation of dashboards.

The third phase is Communication where encompassing the processes of information provision, interpretation, and communication happens. The module contains monitoring and tracking, setting performance alerts, providing periodic reports, and triggering

changes. It is important that both proactive and reactive commitment of the partners have to be supported by communication of performance information. Proactive monitoring can happen by monitoring and tracking of performance indicators in a relatively real-time manner and providing periodic reports. On the other hand, alerts (specific reports of events or out of control performance levels) assist reactive monitoring.

Coaching, the fourth phase of this framework includes evaluating performance, supporting relevant improvements in operations and collaborations of the partner organizations, and establishing incentives. Conducting performance assessments and taking steps towards improvement ensure this. The agreed-upon levels of performance in the most abstract layer (the value network), and aggregated operational performance of VO partners can be used as a basis to manage incentives. The incentive structure would have been stated in the SLA. As the result, all the needed information to enable partners to compare performance against expectations and trigger appropriate incentives within their own organizations would be accessible to them.

The Revision phase takes account of different review procedures over time to improve the performance management system. By providing feedback loops, these procedures facilitate revision and improvement of the system. Also, this phase enables inter-organizational learning. It is worth mentioning that there is a difference between system revision and performance coaching; in performance coaching the target is the processes of the partners, while the goal of system revision is to improve the performance management system itself, including the structure of performance indicators and the procedures required to implement, measure, monitor, and improve them.

## 6 SOVO Challenges for Change Decision Making

(M. Drissen-Silva & Rabelo, 2008) compared traditional management and VO management models and demonstrated some of the differences in terms of decision-making. They claimed in traditional organizations, where decisions are intra-organizational, top-to-down and made by central authority, usually evaluation and transparency of decisions are neglected. In contrast, based on their nature, CNOs and VOs management, and their process of decision-making should be handled in more flexible, decentralized and global manner. Table 1-1 summarizes decision-making characteristics in these different environments.

**Table 2-2: Decisions in traditional organizations vs. VO (Drissen-Silva & Rabelo, 2008)**

| <i>Criteria</i>             | <i>Traditional Organizations</i> | <i>CNO/VO</i>            |
|-----------------------------|----------------------------------|--------------------------|
| Decision Scope              | Intra-Organizational             | Inter-Organizational     |
| Decision Making             | Typically Centralized            | Preferably decentralized |
| Decision Transparency       | No or Low                        | Yes                      |
| Quality Decision Evaluation | No or Low                        | Yes                      |
| Decision Process Rigidity   | Inflexible / Workflow            | Flexible / Ad-hoc        |
| Decision Objective          | Best Local Result                | Feasible Global Result   |

On the other hand, due to the involvement of multiple organizationals, a complicated long preparation process for VO creation, and the collaborative nature which requires continuous negotiation, decision making should be taken collaboratively not in form of central authority (M. V. Drissen-Silva & Rabelo, 2009). All the affected partners should be consulted, regarding their rights and autonomy.

## CHAPTER THREE: THE PROPOSED FRAMEWORK

In this chapter, we propose a framework for decision support in Service Oriented Virtual Organizations (SOVOs) to identify issues with service delivery and quality of services, and facilitate decision making for change of actors in the SOVO environment. It aims at assisting VO managers to analyze roots of problems, improve the VO, and consequently, improve service quality. This framework takes inputs from different sources, including the value network map. Then, through its two main components, *Analyzing value network*, and *Multi-Criteria Decision-Making*, it comes up with preferred solution for changing actors. Figure 3-1 presents this framework. Further details are presented in the following sections.

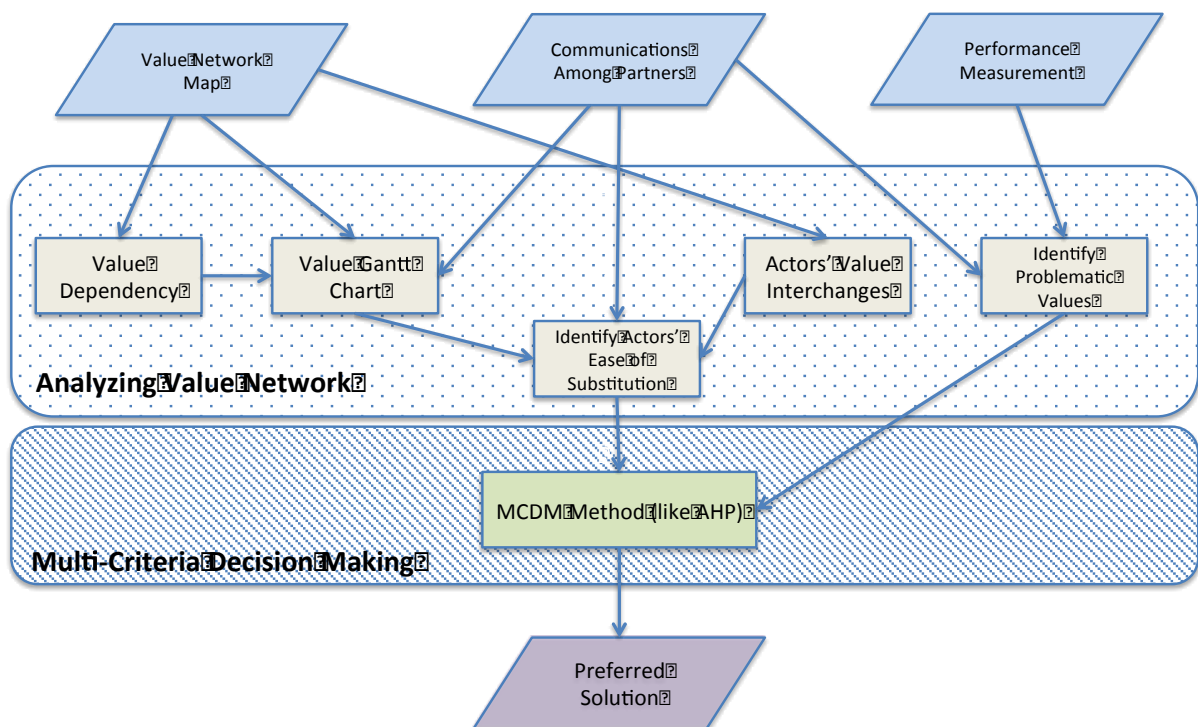


Figure 3-1: Proposed framework for change actors' decision-making

### 1 Inputs

In order to have a better understanding of the current situation of the SOVO during operation and evolution stages, raw information should be gathered from different

sources. These sources can be put in three categories; *Communications among partners*, *Value network map* and *Performance dashboards*.

### **1.1 Communications among partners**

Due to the collaborative nature of the SOVO environment, information exchange among partners is crucial to reach problem resolution. Getting feedback from different perspectives makes it possible to identify problems, evaluate alternatives and come up with proper solutions. Through online discussions participants can point out their opinions about current situation and suggest alternatives.

Partners not only can interact with each other, but also are able to rapidly coordinate their discussions about each identified problem. These discussions can be done about one or more specific subjects through various Web 2.0 services such as instant messaging, mailing, discussion forum, calendar, wiki, content management system, and news (M. V. Drissen-Silva & Rabelo, 2009).

### **1.2 Value network map**

A value network map is a way to visualize the value creation dynamics in any organization, including Collaborative Networked Organizations (Allee & Schwabe, 2011). It helps VO management to identify participants, their value exchanges and expectations. By identifying key roles, transactions, and deliverables for an activity, it helps us to have a better understanding of the VO and do further analyses.

Value network of a specific activity with defined scope and boundaries, can be modeled using three elements: Roles, Transactions and Deliverables. Figure 3-2 shows Value network map of a hypothetical online application store. Nodes represent roles and real people or groups of people who play them. These roles can be in the form of generating transactions, sending deliverables and messages, engaging in interactions, adding value,

and making decisions. Directional arrows show transactions between one role and another. The transactions may end with tangible or intangible deliverables.

(Allee & Schwabe, 2011) suggested four steps to develop the value network Map:

1. Define the scope, boundaries, context, and purpose of the activity.
2. Determine the roles and actors.
3. Identify the transactions and deliverables; both tangibles and intangibles ones.
4. Validate it by sequencing the transactions.

It is worth mentioning that roles are persistent and endure over time regardless of which actor might step in at any particular moment to play them. For example, in Figure 3-2, many companies (actors) could fill the role of "Developers". On the other hand, each actor may play different roles in a value network.

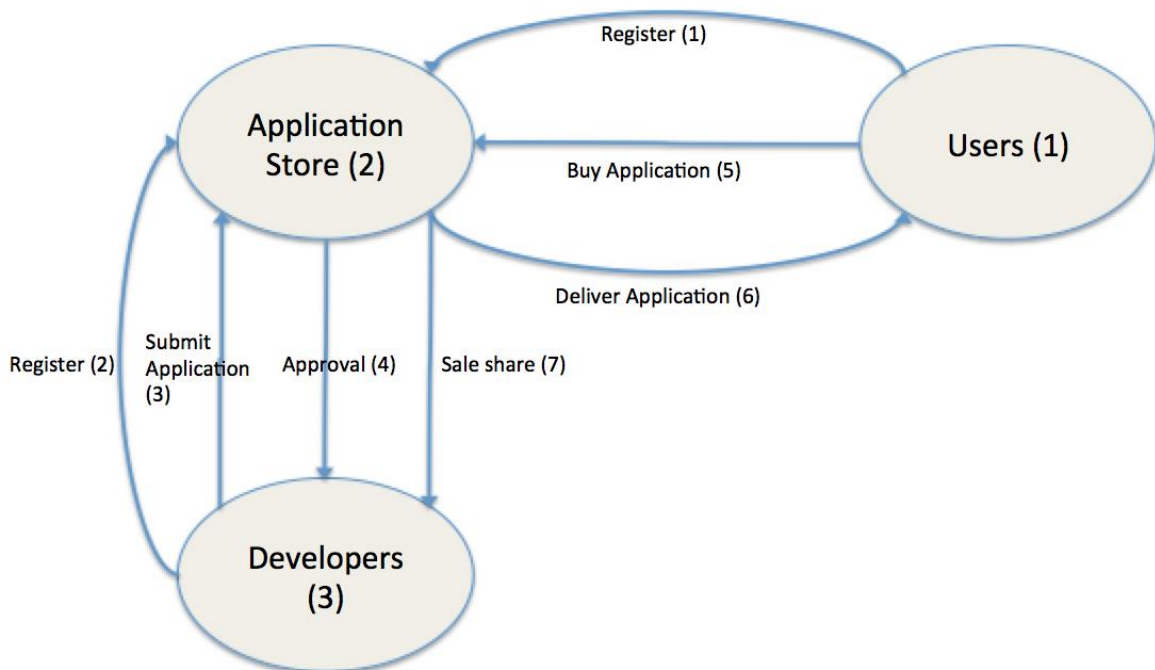


Figure 3-2: Hypothetical value network map of an online application store

### **1.3 SOVO performance dashboards**

Performance dashboards represent the current situation of the SOVO by measuring and monitoring Key Performance Indicators (KPIs). These KPIs could be related to time, money, quality or other agreements in the SLAs. Partners can monitor dashboards and see their own and others' performance, then realize what is going wrong and what should be done better.

The SOVO performance measurement architecture (S. M. A. Kamali, 2013) collects data from different data sources, re-structures the metadata, integrates the performance data, publishes the resulting information, and therefore enables collaborative performance monitoring. All pre-defined KPIs and SLAs in three performance levels of Value network, Collaborations and Services, are measured and the result is available to VO management in the form of charts, reports or dashboards.

## **2 Analyzing Value Network**

In order to have a better understanding of the current situation of SOVO, and accordingly, make a valid decision for a change, some analytics should be done on the value network. In (A. Kamali et al., 2012), the authors introduced the Value dependency graph and matrix derived from the value network. In this research, we propose four additional complementary components, namely, *Actors' value interchanges* matrix, *Value Gantt chart*, *Identify problematic actors* flowchart, and *Actors ease of substitution* table. These new components are explained in details in the following sub-sections.

### **2.1 Value dependency**

In (A. Kamali et al., 2012), the authors modeled inter-dependencies among values in the value network of a SOVO. Unlike previous attempts (Wang et al., 2010; Wieringa & Gordijn, 2005), they did not decouple value chains. As the result, their method works for

all kind of topologies -including peer-to-peer, and was a proper solution to extract service choreographies from value networks. Their proposed method includes the following steps:

1. Break information and service values in the value network down to the smallest unit possible. For example, if a finance company facilitates financial services (the value that the finance partner brings to the VO as its main contribution), specify lower level services as loan acquisition, financial transaction, plan provisioning and receipt provisioning. Then, assign an ID to each value in the network.
2. Define a set of values as  $V = \{v_1, v_2, \dots, v_n\}$ .
3. Form  $M$ , the value dependency matrix, where  $v_i$  and  $v_j$  are values of the set  $V$ .  $p_{ij}$  is 1 if  $v_j$  has a dependency on  $v_i$ , in a sense that  $v_j$  cannot perform as it should unless  $v_i$  is performed, otherwise  $p_{ij}$  is 0. Note that this dependency is direct, so if  $p_{ij} = 1$  and  $p_{jk} = 1$  and there is no direct relation between  $v_i$  and  $v_k$ , then  $p_{ik} = 0$ .

$$M = \begin{matrix} & \begin{matrix} v_1 & v_2 & \dots & v_n \end{matrix} \\ \begin{matrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{matrix} & \begin{bmatrix} 0 & p_{12} & \dots & p_{1n} \\ p_{21} & 0 & \dots & p_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ p_{n1} & p_{n2} & \dots & 0 \end{bmatrix} \end{matrix}$$

4. Then, to achieve value dependency graph, count successive values ( $SV_i$ ) for each value in  $V$ :

$$SV_i = \sum_{k=1}^n p_{ik}$$

5. Calculate depth of influence ( $DF_i$ ) of each value in  $V$ :

$$DF_i = \left\{ SV_i + \sum_{j=0}^n DF_j \mid \text{where } p_{ij} \text{ in matrix } M \text{ is equal to } 1 \right\}$$

Where  $SV_i = 0$ ,  $DF_i = 0$ . So, the best way to calculate this formula is to start from the values with  $SV_i = 0$ )

6. In the value dependency graph, nodes are representing values in set V and the numbers on top of each node are depicting values depth of influence. Arrows demonstrate dependencies; the node at the end of an arrow is dependent on the node at the bottom of that arrow.

For example, value dependency matrix of the previously mentioned hypothetical online applications store is:

|       | $V_1$ | $V_2$ | $V_3$ | $V_4$ | $V_5$ | $V_6$ | $V_7$ |
|-------|-------|-------|-------|-------|-------|-------|-------|
| $V_1$ | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| $V_2$ | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| $V_3$ | 0     | 1     | 0     | 0     | 0     | 0     | 0     |
| $V_4$ | 0     | 0     | 1     | 0     | 0     | 0     | 0     |
| $V_5$ | 1     | 0     | 0     | 1     | 0     | 0     | 0     |
| $V_6$ | 0     | 0     | 0     | 0     | 1     | 0     | 0     |
| $V_7$ | 0     | 0     | 0     | 1     | 0     | 1     | 0     |

Figure 3-3 shows value dependency graph of the hypothetical value network.

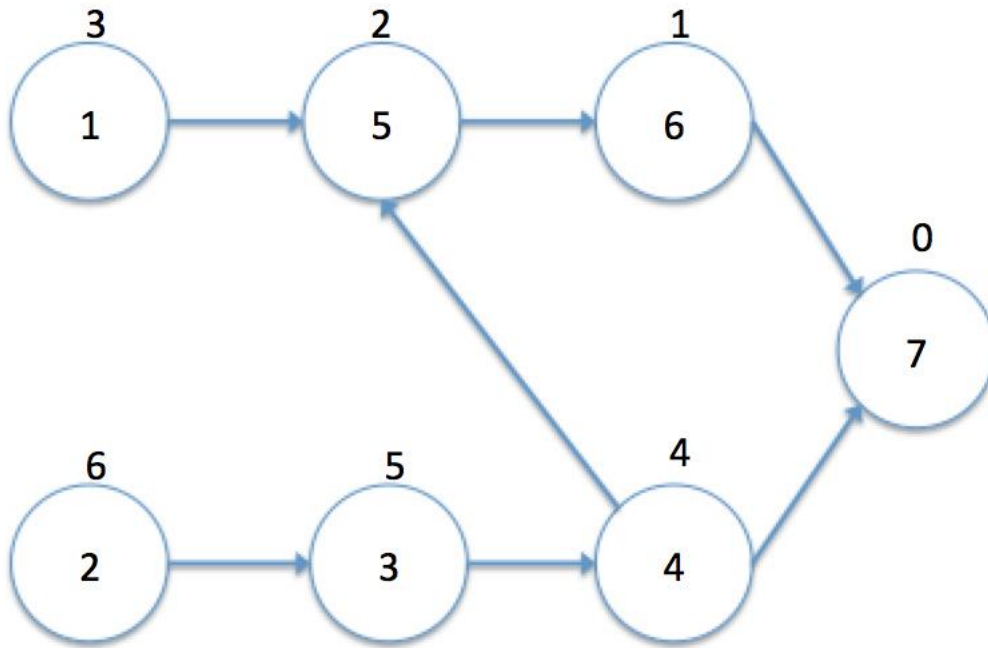


Figure 3-3: Hypothetical value dependency graph of an online application Store

## 2.2 Actors value interchanges

To illustrate value interchanges between different actors/roles in the value network, we suggest forming the *Actors' value Interchanges* matrix by following these steps:

1. Define a set of actors as  $A = \{a_1, a_2, \dots, a_n\}$ .
2. Form  $N$ , the *actors' value interchanges* matrix, where  $a_i$  and  $a_j$  are actors of the set  $A$ , and  $q_{ij}$  is a set of values that  $a_i$  gives to  $a_j$ :

$$N = \begin{matrix} & a_1 & a_2 & \dots & a_n \\ \begin{matrix} a_1 \\ a_2 \\ \vdots \\ a_n \end{matrix} & \begin{bmatrix} - & q_{12} & \dots & q_{1n} \\ q_{21} & - & \dots & q_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ q_{n1} & q_{n2} & \dots & - \end{bmatrix} \end{matrix}$$

For example, *actors' value interchanges* matrix of the hypothetical online applications store is:

$$\begin{array}{c}
 A_1 \quad A_2 \quad A_3 \\
 A_1 \begin{bmatrix} - & 1,5 & - \\ 6 & - & 4,7 \\ - & 2,3 & - \end{bmatrix} \\
 A_2 \\
 A_3
 \end{array}$$

### 2.3 Value Gantt chart

Henry Gantt developed a type of bar chart to illustrate a project's schedule (Gantt, 1910). It demonstrates the start and finish dates of the project's broken-down tasks. Some Gantt charts also indicate the precedence relationships between tasks within a network. This technique has become common among project managers around the world, and there are numerous computer software to facilitate the technique.

There are four general steps to create a Gantt chart:

1. List your tasks: make a list of everything that you plan to do in the project.
2. Estimate the time required: for each item on your list, estimate how long it will take you to do that task.
3. Put tasks in order: based on dependencies (i.e. situations where you can't do one task until another is started or finished), put everything in order.
4. Draw the chart: you can use project management software (like Microsoft Project), spreadsheet software (like Microsoft Excel) or even hand-write it.

To benefit from Gantt chart analysis capabilities, we propose a way to convert values to tasks. Converting values to tasks happens through the following steps:

1. For each  $V_i$  value, duration must be specified according to the SLA between actors who exchange  $V_i$ .

2. For each  $V_i$  value, successor values should be identified; values in value dependency graph which are connected to  $V_i$  by an arrow, while the beginning of the arrow is on  $V_i$ . Successor values of  $V_i$  are dependent to it.
3. For each  $V_i$  value, predecessor values should be identified; values in value dependency graph which are connected to  $V_i$  by an arrow, while the end of the arrow is on  $V_i$ .  $V_i$  is dependent to its predecessor values.

After converting all values to tasks, we can draw the Gantt chart of the value network.

Leveraging on the Gantt chart capabilities, we can perform the following analyses:

**(a) Find Free Slack of each value:** Free slack is the time a task could be postponed without affecting the early start of any task following it (Indelicato, 2009). It tells the actor who is responsible for that task when the deadline approaches. Free slacks can be calculated by deducting duration of the task from the closest successor task's start time. These free slacks appear visually in Gantt chart, too.

**(b) Find values in Critical Path:** the Critical Path is the longest sequence of tasks in a project plan, which must be completed on time for the project to complete on its due date. A task on the critical path cannot be started until its predecessor tasks are complete; if it is delayed for a day, the entire project will be delayed for a day unless the task following the delayed task is completed a day earlier (Shankar & Sireesha, 2009). Identifying critical tasks on the critical path enables managers to concentrate resources on these tasks in order to reduce the project completion time.

Although most of the project management software can generate the critical path by using tasks' duration and dependencies, there are different manual guidelines. For example, (Zhu & Heady, 1994) presented a method in which the critical path of the network is

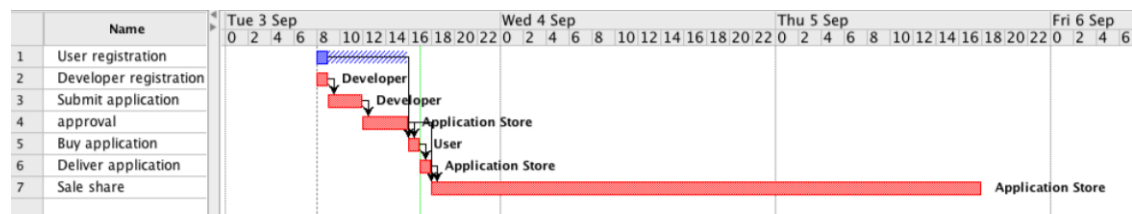
obtained based on computing the slack times. Also, (Shankar & Sireesha, 2009) defined a rooted tree for the project network to find all paths in the network. Then, the longest path in the rooted tree would be the critical path.

For instance, here are the tasks of the hypothetical online app store:

**Table 3-1: Hypothetical value network's tasks**

|   | Name                   | Work     | Start           | Finish          | Predecessors | Successors | Total Slack | Resource Names    |
|---|------------------------|----------|-----------------|-----------------|--------------|------------|-------------|-------------------|
| 1 | User registration      | 1 hour   | 9/3/13 8:00 AM  | 9/3/13 9:00 AM  |              | 5          | 0.292 days  | User              |
| 2 | Developer registration | 1 hour   | 9/3/13 8:00 AM  | 9/3/13 9:00 AM  |              | 3          | 0 days      | Developer         |
| 3 | Submit application     | 3 hours  | 9/3/13 9:00 AM  | 9/3/13 12:00 PM | 2            | 4          | 0 days      | Developer         |
| 4 | approval               | 4 hours  | 9/3/13 12:00 PM | 9/3/13 4:00 PM  | 3            | 5;7        | 0 days      | Application Store |
| 5 | Buy application        | 1 hour   | 9/3/13 4:00 PM  | 9/3/13 5:00 PM  | 1;4          | 6          | 0 days      | User              |
| 6 | Deliver application    | 1 hour   | 9/3/13 5:00 PM  | 9/3/13 6:00 PM  | 5            | 7          | 0 days      | Application Store |
| 7 | Sale share             | 48 hours | 9/3/13 6:00 PM  | 9/5/13 6:00 PM  | 4;6          |            | 0 days      | Application Store |

Figure 3-4 shows the Gantt chart of this value network. Red tasks are in critical path. While the only blue task, User registration can be delayed 0.292 days (or 7 hours); any delay to deliver other values affects the final result of the value network.

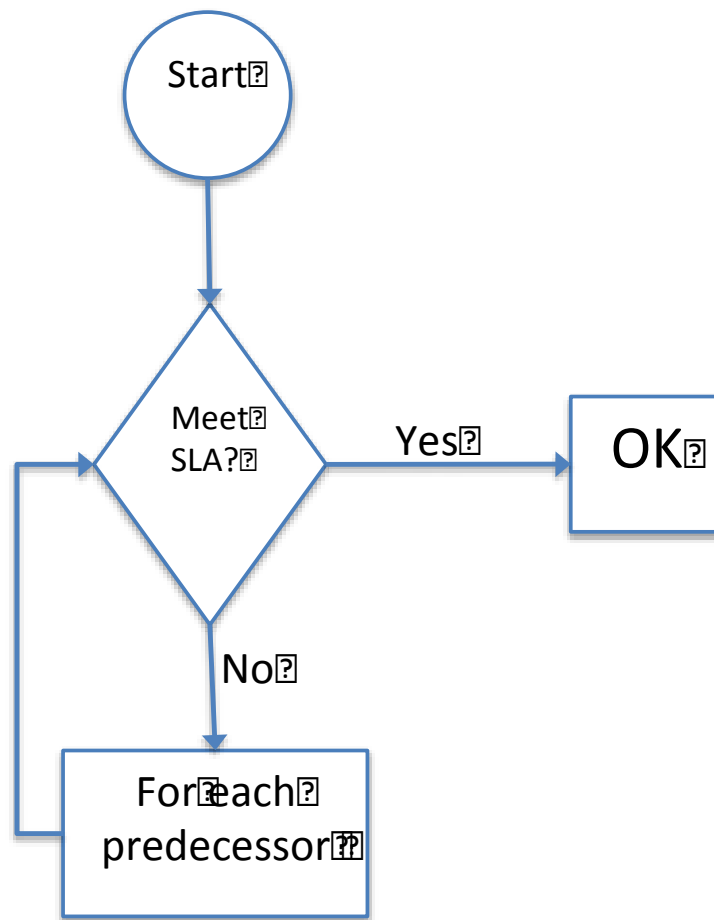


**Figure 3-4: Hypothetical value Gantt chart**

## 2.4 Identifying problematic values

SOVO Performance Measurement enables us to monitor various KPIs and check whether SLAs are met or not (S. M. A. Kamali, 2013). It illustrates which values are delivered as required, and which are delayed, incomplete or malfunctioned. However, to identify the root problems we need to know the dependency of values, because usually a corrupted value makes successor values delayed, inadequate or crashed.

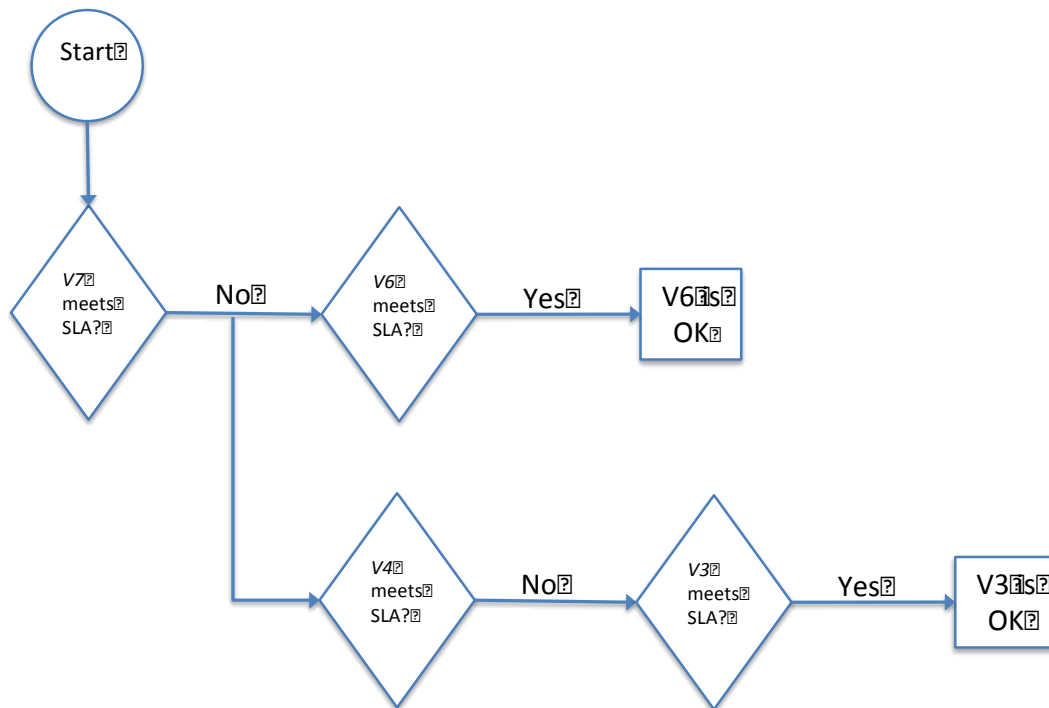
As the flowchart in Figure 3-5 demonstrates, an iterative process enables us to identify sources of problems in a value network. Starting from the last value in the network, SLAs are checked. If there are some problems, predecessor values need to be checked too. The values whose predecessor are met completely, but their own SLAs are not satisfactory, are the main cause of the problem.



**Figure 3-5: Identifying problematic values in value network flowchart**

For example, in the hypothetical online store value network when the latest value is delivered with delay, we start investigation from  $V_7$  because it has no successor. Since it is not delivered on time, we should investigate its dependent values:  $V_4$  and  $V_6$ . Assuming that  $V_6$  was done properly, but  $V_4$  had some issues, we put  $V_6$  aside and examine  $V_4$ 's predecessor:  $V_3$ . Then, if  $V_3$  is delivered as agreed in SLA,  $V_4$  would be the root of the

delay and responsible actor should be questioned. Figure 3-6 presents this scenario in the hypothetical value network.



**Figure 3-6: Finding hypothetical root problem**

Knowing problematic values assists VO managers to make decisions with slightest effort and maximum improvement in the overall performance of the value network.

## 2.5 Actors' ease of substitution

One of the change decisions in VO Management is substitution of, or adding actors. New actors play pre-defined roles in value network, but faster, better or in a larger scale. However, since every change has a cost and consequences, we should study it before taking any action. Here, we present a tool to analyze roles of a value network, and to investigate how difficult finding an actor to play that role could be.

**Table 3-2: Actors' ease of substitution**

| <b>Type</b>              | <b>Indicator</b>        | <b>Definition</b>  | <b>Source</b>                            |
|--------------------------|-------------------------|--|--|
| Internal attributes      | Role Centrality         | # of value deliverables to the other roles                                       | <i>Actors' value interchanges matrix</i> |
|                          | Values Complexity       | # of SLA terms of values associated with the role                                | SLAs                                     |
|                          | Critical Values         | # of values associated with the role in the critical path                        | Value Gantt Chart                        |
|                          | Core Values             | # of core values associated with the role.                                       | VO Management                            |
|                          | Value Creation Capacity | The maximum number of value instances that can be provided in a specific period. | VO Partners                              |
| Environmental attributes | Availability in Market  | How hard is to find a suitable actor to play this role in the market             | VO Management                            |
|                          | Service Price           | \$ amount that the role gets to deliver the values.                              | VO Partners                              |

Table 3-2 represents different characteristics of a role. It categorizes role indicators into two groups: Internal attributes and Environmental attributes. Internal attributes are describing the role inside the value network, whereas environmental attributes are related to broader aspect and nature of the roles.

There are five internal attributes for each role: *Role centrality*, *Values complexity*, *Critical values*, *Core values*, and *Value creation capacity*. *Role Centrality* is the number of values that a role delivers to the others, and reflects how much other roles are dependent to this role. When *Role Centrality* is high, changing the respective actor poses high risk and cost. Because changing the role would affect several roles, therefore multiple configurations and adjustments are required. *Values complexity* characterizes values that a role creates, and how complicated these values are. For instance, the Developers' role is much more complicated than the Users'. Accordingly, VO managers should be more cautious when it

comes to replacing actors with complex values. The number of *Critical values* displays how many values of a role are in the critical path. A delay in providing a *critical* value causes a delay in final value delivery. Thus, VO managers should always select reliable actors for roles with high *Critical values*. The number of *Core values* is another important indicator of a role. A value is considered core when it is crucial to the VO. Usually, VO management decides which values are Core and which are not, depending on their impacts on the final outcome of the value network.

Considering the hypothetical online store; submitting an application may be a Core value, while paying to the Developer may not. *Value creation capacity* illustrates how much work unit the actor who plays a role can do in a specific time period. For example, an application Store can deliver 100 applications per hour, whereas another Application store is able to deliver 200 applications per hour. VO managers normally seek actors with sufficient capacity to perform the desired roles.

On the other hand, there are two Environmental indicators: *Availability in Market* and *Service Price*. *Availability in Market* demonstrates how hard finding a suitable actor to play the role is in the market. For example, where there are only two reliable application stores, it would be tough to replace them. *Service Price* represents how much different actors would charge the VO to provide specific value. In the hypothetical Online Store, some Developers may want 30% of sales, while others may want 25%. Usually, VO managers pursue actors who perform values with desired quality and minimum *Service Price*.

### **3 Multi-Criteria Decision Making**

Selecting a suitable alternative for current actors is not simply an “optimization” problem. Many objective and subjective elements are involved. However, analyses presented in the

previous section provide critical information from which VO managers can obtain decision support criteria. The multiplicity of effective factors that should be taken into consideration to change an actor leads us to Multi-Criteria Decision Making.

Multiple-Criteria Decision-Making (MCDM) refers to making decisions while there are multiple, usually conflicting, criteria. Although MCDM problems are very common – even in our daily life, the MCDM field of science has a relatively short history of about 40 years. Leveraging advances in computer technology, it can analyze complex problems and large amount of information. Today, MCDM is very important and useful in supporting business decision-making (Xu & Yang, 2001).

### **3.1 Characteristics of a SOVO actors change decision**

In order to find and apply a proper method to solve any problem, we should first identify its characteristics. Making a decision to change actors in SOVO environment has some unique features that will be discussed here. We first review different aspects of a MCDM problem to show how it can facilitate decision making to change actors in SOVO.

MCDM problems can be described via Alternatives and Attributes. Alternatives are objects or options that we want to assess or evaluate. The assessment or evaluation is based on attributes, which are properties, qualities or features of an alternative. Decision-makers may break down attributes into one or more levels of sub-attributes. For each attribute, a criterion is set up to evaluate and examine alternatives. Since there are one-to-one correspondence between an attribute and a criterion, sometimes the word attributes and criteria are used interchangeably (Triantaphyllou, 2000).

Generally, there are two types of MCDM problems: ones which have finite number of alternative solutions, and those for which there are an infinite number of solutions (Xu & Yang, 2001). Since our problem is associated with selection and assessment, the number

of alternative solutions is limited. Accordingly, we will compare a finite number of alternatives.

A decision matrix can clarify finite MCDM problems (Triantaphyllou, 2000). Decision matrix is an  $m \times n$  matrix, when there are  $m$  alternatives to be assessed based on  $n$  criteria. In this matrix element  $V_{ij}$  represents the  $j^{th}$  criterion value of the  $i^{th}$  alternative.

**Table 3-3: Decision matrix**

|               | Criterion 1 | Criterion 2 | ...      | Criterion n |
|---------------|-------------|-------------|----------|-------------|
| Alternative 1 | $V_{11}$    | $V_{12}$    | ...      | $V_{1n}$    |
| Alternative 2 | $V_{21}$    | $V_{22}$    | ...      | $V_{2n}$    |
| ...           | ...         | ...         | $V_{ij}$ | ...         |
| Alternative m | $V_{m1}$    | $V_{m2}$    | ...      | $V_{mn}$    |

There are two types of attributes: Quantitative and Qualitative. Quantitative attributes – like the price of a car, are measured numerically, while qualitative attributes -like the comfort rating, are only described subjectively (Xu & Yang, 2001). In order to make a decision to change an actor in SOVO environment, we deal with a mixture of both qualitative and quantitative attributes. Examples could be *availability in the market* and *number of core values*. Obviously, these two types of attributes are not summable. Even quantitative attributes may have different units of measurement (for example, *service price* and *number of core values*).

In some MCDM problems, deterministic and probabilistic attributes are mixed. For example, in our problem of changing actors, *service price* is deterministic and *availability in the market* could change depending on market conditions. Yet, these probabilities are

usually uncertain, especially in subjective judgments. Moreover, insufficient or incomplete information can cause uncertainty (Xu & Yang, 2001).

### **3.2 Suitable MCDM solution for the problem of changing actors in SOVO**

MCDM problems do not always have a conclusive or unique solution. Depending on the nature of the environment and decision-makers' expectations, various solutions have been published. In this section, we discuss different methods suitable for the problem of changing actors in SOVO.

Sometimes, all criteria can be classified into two categories: criteria that have to be maximized -called Profit criteria category, and criteria that are meant to be minimized - named Cost criteria category. An ideal MCDM solution is where all Profit criteria are maximized and all Cost criteria are minimized (Xu & Yang, 2001). Because of many contradictory criteria -like high *service price* of high *capacity* actors, this does not apply to our case.

When an ideal solution is not obtainable, decision-makers need to look for best possible solutions. There are two types of solution: while in a dominated solution there are other alternatives that are better in at least one attribute and as good on other attributes, a non-dominated solution is not dominated by any other alternatives (Xu & Yang, 2001). Since there is no ideal solution for our problem, we prefer to find a satisfying non-dominated alternative. A satisfying solution is a feasible solution when each alternative exceeds all the pre-defined criteria. The level of satisfaction for each criterion depends on the decision maker's expectation.

In many MCDM problems, it is impossible to reach the best alternative without tradeoff between attributes. Methods, which permit tradeoffs between attributes, are called Compensatory methods. If a slight decline in one attribute were compensated by some

enhancement in one or more other attributes, it is reasonable to accept that. This is very probable in the process of making decisions for changing actors in a SOVO environment. For example, despite an actor's high *Service price*, when it is the only one who can meet the expected *Capacity*, there is no choice but selecting that actor.

### **3.3 Introducing three MCDM methods**

Various MCDM methods have been presented and applied effectively to select the most appropriate alternatives. However, decision makers face the problem of selecting the most appropriate MCDM method among several feasible alternatives. Because of the large number of available MCDM methods, varying complexity and possible solutions, it might complicate the process of decision-making.

Depending on the case, its complexity and situational factors, SOVO managers may choose different methods. In this section we introduce following MCDMC methods.

#### **3.3.1 Simple Additive Weighting method**

Simple Additive Weighting (SAW), also known as weighted linear combination or scoring method, is simple and the most often used multi-attribute decision technique. This method quantifies the values of attributes (criteria) for each alternative, constructs the decision matrix, normalizes the decision matrix, assigns the importance (weights) to criteria, and calculates the overall score for each alternative. The alternative with the highest score would be announced as the favorable one (Afshari, Mojahed, & Yusuff, 2010).

Normalization is usually required in MCDM problems as the criteria are often of incongruous dimensions (Zavadskas, Zakarevicius, & Antucheviciene, 2006). When  $x_{ij}$  is an element of the  $m \times n$  decision matrix  $A$ , and represents the original value of the  $j^{th}$  criterion of the  $i^{th}$  alternative, normalized decision matrix  $R$ , is an  $m \times n$  matrix. In  $R$ ,

$r_{ij}$  is the normalized rating of the  $i^{th}$  alternative for the  $j^{th}$  criterion, and can be calculated as follows:

$$r_{ij} = \frac{x_{ij}}{\max(x_j)} \text{ for positive criteria, and } r_{ij} = \frac{\min(x_j)}{x_{ij}} \text{ for negative criteria}$$

$\max(x_j)$  is the maximum value in criterion  $j$ , and  $\min(x_j)$  is the minimum value in criterion  $j$ .

Then,  $S_i$ , the overall score of  $i^{th}$  alternative, is:

$$S_i = \sum_{j=1}^M w_j r_{ij}, \text{ for } i = 1, 2, \dots, N$$

Where  $w_j$  is the importance (weight) of the  $j^{th}$  criterion,  $N$  is the number of alternatives, and  $M$  is the number of criteria (Janic & Reggiani, 2002).

### 3.3.2 *Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) Method*

In TOPSIS method, the optimum alternative has the shortest geometric distance from the positive ideal solution, and the longest geometric distance from the negative ideal solution (Hwang, Lai, & Liu, 1993). The ideal alternative has the best score in every criterion. This compensatory method compares a set of alternatives by identifying weights for each criterion, normalizing scores for each criterion and calculating the geometric distance between each alternative and the ideal alternative (Hwang & Yoon, 1981).

The TOPSIS process is carried out through seven steps (Janic & Reggiani, 2002):

1. Create a decision matrix  $A$ ; consisting of  $m$  alternatives and  $n$  criteria, with the intersection of  $i^{th}$  alternative and  $j^{th}$  criteria given as  $x_{ij}$ .

2. Normalize matrix A, and form matrix R, (the normalizations process is the same as in the SAW method).
3. Calculate the weighted normalized decision matrix T:

$$t_{ij} = w_j r_{ij}, \text{ for } i = 1, 2, \dots, m$$

where

$$w_j = \frac{W_j}{\sum_{j=1}^n W_j}, \text{ for } j = 1, 2, \dots, n$$

so that

$$\sum_{j=1}^n w_j = 1$$

and  $W_j$  is the original weight given to the criterion  $j$ .

4. Determine the worst alternative:

$$A_w = \{(\max(t_{ij}|i = 1, 2, \dots, m) | j \in J_-), (\min(t_{ij}|i = 1, 2, \dots, m) | j \in J_+)\} \equiv (t_{wj}|i = 1, 2, \dots, n)$$

and the best alternative:

$$A_b = \{(\min(t_{ij}|i = 1, 2, \dots, m) | j \in J_-), (\max(t_{ij}|i = 1, 2, \dots, m) | j \in J_+)\} \equiv (t_{bj}|i = 1, 2, \dots, n)$$

where  $J_+$  is associated with the criteria having a positive impact, and  $J_-$  is associated with the criteria having a negative impact.

5. Calculate the L2-distance between the target alternative  $i$  and the worst condition  $A_w$ :

$$d_{iw} = \sqrt{\sum_{j=1}^n (t_{ij} - t_{wj})^2}, i = 1, 2, \dots, m$$

and the distance between the alternative  $i$  and the best condition  $A_b$ :

$$d_{ib} = \sqrt{\sum_{j=1}^n (t_{ij} - t_{bj})^2}, i = 1, 2, \dots, m$$

where  $d_{iw}$  and  $d_{ib}$  are respectively L2-norm distances from the target alternative i to the worst and best conditions.

6. Calculate the similarity to the worst condition

$$S_{iw} = \begin{cases} \frac{d_{ib}}{(d_{ib} + d_{iw})}, & 0 \leq s_{iw} \leq 1 \\ 1, & \text{worst solution} \\ 0, & \text{best solution} \end{cases}$$

7. Rank the alternatives according to  $S_{iw}$ .

### 3.3.3 Analytic Hierarchy Process (AHP) method

AHP was developed about thirty years ago (Saaty), to organize and analyze complex decisions. Using mathematics and psychology, it has been extensively studied and refined since then. This method provides a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. Bhushan and Rai (2004) claims that AHP is most useful where teams of people are working on complex, high stakes and long-term problems, especially those involving human perceptions and judgments.

AHP consists of three steps (Winston & Goldberg, 2004):

1. Decomposition of the problem; overall objective and the decision alternatives are classified through a hierarchical schematic representation.
2. Comparative judgment; it includes the formation of the pairwise matrices and their comparison at two levels: in Level 1, all alternatives are compared with respect to each criterion. And then in Level 2, the criteria are compared with respect to the overall objective.

Level 1:

For each criterion, a pairwise comparison matrix,  $A_{N \times N}$ , is formed, when  $N$  is the number of alternatives. There are  $M$  matrices of type A, as it corresponds to the number of criteria. An element of matrix A,  $a_{ij}$ , is assigned by decision makers and express the relative importance of a particular criterion when compared across  $i^{th}$  and  $j^{th}$  alternatives. So,

$$a_{ij} = \begin{cases} \frac{1}{a_{ji}}, & i \neq j \\ 1, & i = j \end{cases}$$

Then, the normalized matrix  $A_{norm}$  is obtained by:

$$r_{ij} = \frac{a_{ij}}{\sum_{i=1}^N a_{ij}}, \text{ where } i = 1, 2, \dots, N$$

Next, the matrix of weights,  $W$  is computed. The weight for the  $i^{th}$  row of the matrix  $W$ ,  $w_i$  is determined as the average of elements in row  $i$  of the matrix

$A_{norm}$ :

$$w_i = \frac{\sum_{j=1}^N r_{ij}}{N}, \text{ for } i = 1, 2, \dots, N$$

Level 2:

Matrix of criteria C, which has dimensions equivalent to the number of criteria, is created. Then, a similar procedure is carried out with matrix C. The overall score for each alternative  $S_i$  is computed as follows:

$$S_i = \sum_{j=1}^M w_j v_{ij}, \text{ for } i = 1, 2, \dots, N$$

Where  $v_{ij}$  is the element of a priority vector of the  $i^{th}$  alternative with the  $j^{th}$  criterion.

3. Synthesis of priorities; the alternative which gains the highest overall score is selected as the preferred solution.

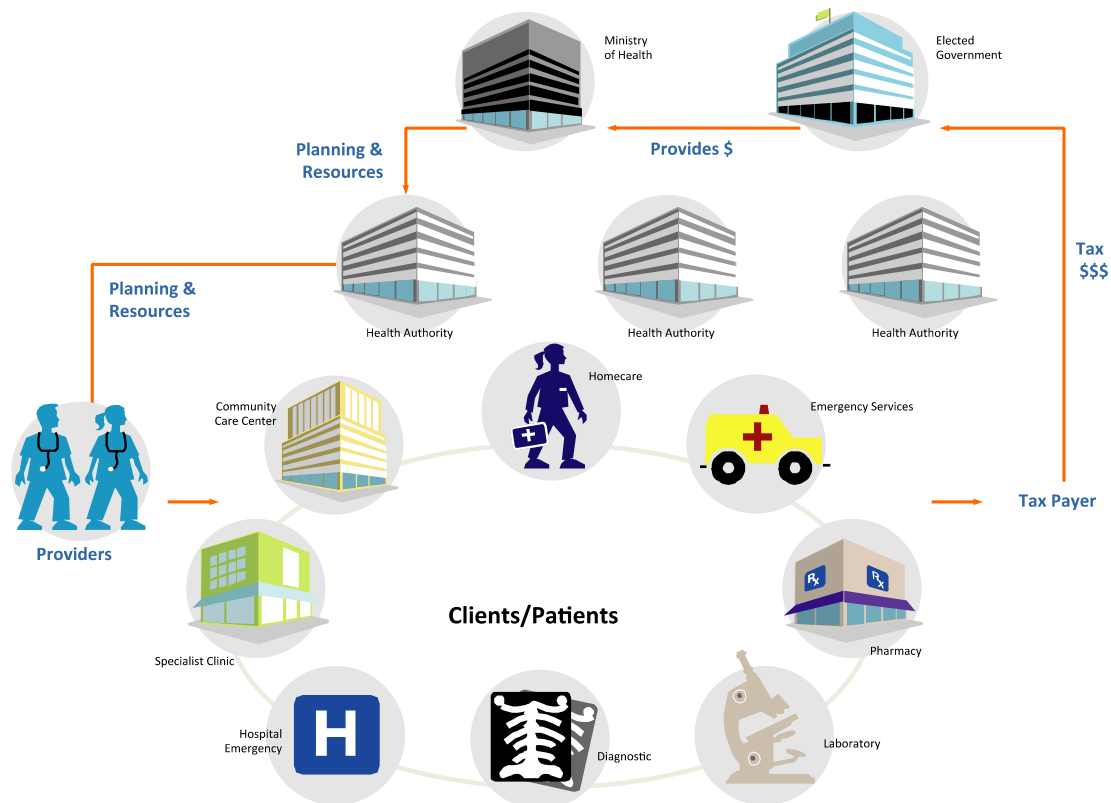
We will use this method in Chapter 4 where we present a scenario in healthcare environment.

## **CHAPTER FOUR: SCENARIO**

As a proof of concept, we select a use case in healthcare to test the framework and its analytical methods. The health care environment is comprised of several departments who interact in ways not unlike a Virtual Organization: several actors are involved, information exchange is complex, and the players change on a regular basis. These factors create a collaborative environment.

### **1 Background**

The health care environment in Canada is complex and changing. In Figure 4-1, different players in this collaborative environment are stated. According to a report released by the Canadian Institute for Health Information (CIHI), total spending on health care in Canada reached \$200.5 billion in 2011. This translates into \$5,800 per Canadian. Many public and private organizations and players are working together to improve and provide long, healthy and productive lives for Canadians (“Canada Health Infoway,” 2012).



**Figure 4-1: Canadian healthcare players (Canada Health Infoway, 2012)**

While health care spending continues to rise faster than inflation and population growth (Canadian Institute for Health Information, 2012), Canadians still face different problems including long waiting times. A patient wait time quantifies the delays patients experience in the care service delivery. It represents the gap between the time that a requested care service is expected to be delivered, and the time at which it actually takes place. Wait time limits hospitals' abilities to deliver quality care. Hypothetically, to avoid wait times, patients need to be processed at least at the same rate as the one at which they arrived in Emergency Department (Hall, 2006). However, in reality, hospitals are far from being able to achieve this. Table 4-1 shows the long time that Ontarians spend in Emergency Rooms, which is frustrating (Government of Ontario, 2013). In other provinces, like Quebec, it is even worse.

Table 4-1: Time spent in Ontario Emergency Rooms (Government of Ontario, 2013)

| Type of ER Visits   | Baseline (Hours) <sup>1</sup> | Current (Hours) July 2013 | Target (Hours) | ER Visits     |                         | % of Visits Within Target |
|---|-------------------------------|---------------------------|----------------|---------------|-------------------------|---------------------------|
|   |                               |                           |                | Volume        | % of Total <sup>2</sup> |                           |
| <b>Total</b>  | <b>9.4</b>                    | <b>7.8</b>                | <b>NA</b>      | <b>480929</b> |                         | <b>87</b>                 |
| <b>Complex conditions /requiring more time for diagnosis, treatment or hospital bed admission</b>     |                               |                           |                |               |                         |                           |
|   | <b>14.0</b>                   | <b>9.9</b>                | <b>8.0</b>     | <b>306304</b> | <b>64</b>               | <b>86</b>                 |
| <b>Admitted Patients</b>  | <b>36.4</b>                   | <b>25.9</b>               |                | <b>47160</b>  | <b>10</b>               | <b>44</b>                 |
| <b>Non-Admitted Patients</b>  | <b>8.5</b>                    | <b>7.0</b>                |                | <b>259144</b> | <b>54</b>               | <b>93</b>                 |
| <b>Minor or uncomplicated conditions /requiring less time for diagnosis, treatment or observation</b> |                               |                           |                |               |                         |                           |
|   | <b>4.8</b>                    | <b>4.1</b>                | <b>4.0</b>     | <b>173955</b> | <b>36</b>               | <b>90</b>                 |

1. Baseline Time Spent in ER is based on April 2008 data.

2. The total percentages may not add up to 100% due to missing data elements and/or rounding.

There are many complex reasons for longer wait times, including but not limited to poorly organized services, shortages of health care workers and cuts to hospital services and beds. Through better understanding and control of wait times, hospitals can have higher performance, optimized operations, quicker service and better patient satisfaction (Tchemeube, 2013).

On the other hand, in 2011, there were 72,529 physicians in Canada, meaning 209 physicians per 100,000 populations, and the average gross fee-for-service income for a family physician in 2010 was \$239,000, while for a specialist it was \$341,000 (Canadian Institute for Health Information, 2012).

Now, the big question is: “With limited budget and human resources, what is the best solution to decrease wait time, and consequently increase the care quality and patients’ satisfaction?” The optimum answer will be gained through next sections using our

proposed framework: analyzing the value network, identifying the bottle necks and their impacts, considering all the consequences and conditions, and then deciding the possible solutions using a multi-criteria decision making (MCDM) method.

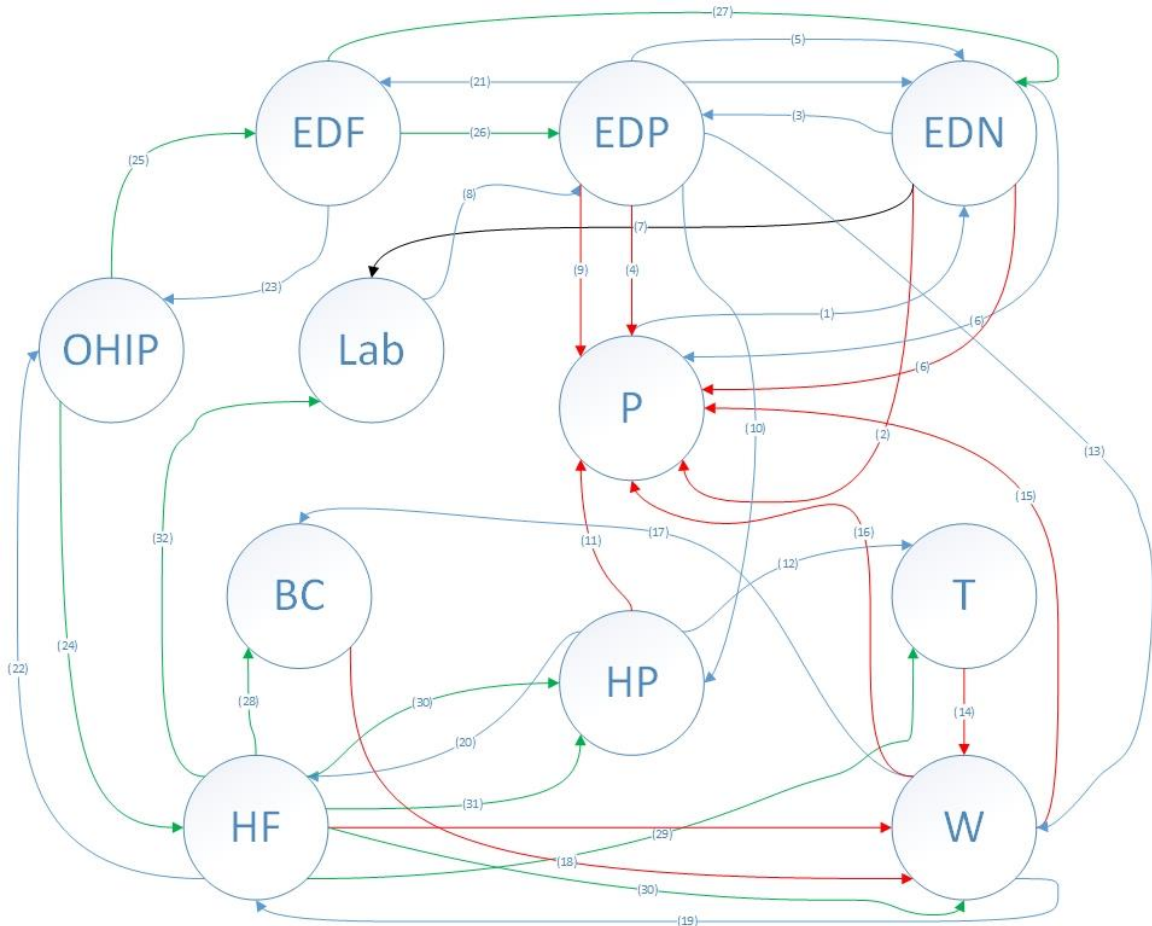
## **2 Scenario Description**

In this research, a healthcare process of the William Osler Health Center Hospital located in Brampton, Canada, is considered as a scenario. Although we mapped the value network based on the observations in this particular hospital (Bahrani, 2013; Mouttham, 2012; Tchemeube, 2013), others are generally similar. Alain Mouttham, clinical researcher, and his team studied the wait times in Emergency Department and cardiac ward of Osler Hospital for two years. They modeled the patient flow using RFID tags in a non-invasive and accurate fashion. We consulted the team to verify the validity and sequences of the processes.

Patients enter the Emergency Department (ED), and get prioritized based on their health conditions, test results and need for immediate clinical support. Then, the patient is transferred to respective ward where the patient is visited by a nurse, then by a doctor. Depending on the diagnosis process in each case, the doctor may order a lab test, an x-ray, an MRI, or alike. The patient is referred to the lab. When the lab results become available, the ER doctor might be able to diagnose the disease, or he/she might ask for a specialist to examine the patients. After the diagnosis is complete, the patient might need to be transferred to the in-patient care of the hospital, or discharged to go home. After being treated, the patient will be discharged, the bed will be cleaned and financial issues will be taken care of by the OHIP and financial departments of the hospital and the ED.

We chose this case because of its similarity to the described collaborative environment in the previous chapter. Participating actors in this value network -where each patient can be

viewed as a unique opportunity to bring together different health care partners, are semi-autonomous. For example, the ED is partially independent from the hospital, in terms of administration, access and management.



**Figure 4-2: Value network map of the healthcare case**

Figure 4-2 shows the value network Map of this scenario. The various values are listed in . In this case, there are four types of values: Information –which are shown in blue, Services –which are indicated in red, Materials –which are presented in black, and Money –which are shown in green.

Table 4-2. In this case, there are four types of values: Information –which are shown in blue, Services –which are indicated in red, Materials –which are presented in black, and Money –which are shown in green.

Table 4-2: Legend of the healthcare case value network map

| No | Value                     | Type of Value    |  |             |                               |
|----|---------------------------|------------------|--|-------------|-------------------------------|
| 1  | Intake info               | Info (Blue)      |  |             |                               |
| 2  | Triage                    | Service (Red)    |  |             |                               |
| 3  | Triage info to EDP        | Info (Blue)      |  |             |                               |
| 4  | Initial consultation      | Service (Red)    |  |             |                               |
| 5  | Call for blood test       | Info (Blue)      |  |             |                               |
| 6  | Take blood sample         | Service (Red)    |  |             |                               |
| 7  | Send sample to Lab        | Material (Black) |  |             |                               |
| 8  | Test result to EDP        | Info (Blue)      |  |             |                               |
| 9  | Diagnosis                 | Service (Red)    |  |             |                               |
| 10 | Call specialist to admit  | Info (Blue)      |  |             |                               |
| 11 | Admit Patient to Ward     | Service (Red)    |  |             |                               |
| 12 | Call Transportation       | Info (Blue)      |  |             |                               |
| 13 | Send Patient info to Ward | Info (Blue)      |  |             |                               |
| 14 | Move Patient to Ward      | Service (Red)    |  |             |                               |
| 15 | Treat Patient             | Service (Red)    |  |             |                               |
| 16 | Discharge Patient         | Service (Red)    |  |             |                               |
| 17 | Ward Calls BC             | Info (Blue)      |  |             |                               |
| 18 | BC cleans up the bed      | Service (Red)    |  |             |                               |
| 19 | Ward claims to HF         | Info (Blue)      |  |             |                               |
| 20 | HP claims to HP           | Info (Blue)      |  |             |                               |
| 21 | EDP claims to EDF         | Info (Blue)      |  |             |                               |
| 22 | HF claims to OHIP         | Info (Blue)      |  |             |                               |
| 23 | EDF claims to OHIP        | Info (Blue)      |  |             |                               |
| 24 | OHIP pays HF              | Money (Green)    |  |             |                               |
| 25 | OHIP pays EDF             | Money (Green)    |  |             |                               |
| 26 | EDF pays EDP              | Money (Green)    |  |             |                               |
| 27 | EDF pays EDN              | Money (Green)    |  |             |                               |
| 28 | HF pays BC                | Money (Green)    |  |             |                               |
| 29 | HF pays T                 | Money (Green)    |  |             |                               |
| 30 | HF pays W                 | Money (Green)    |  |             |                               |
| 31 | HF pays HP                | Money (Green)    |  |             |                               |
| 32 | HF pays Lab               | Money (Green)    |  |             |                               |
|    |                           |                  |  | <b>Node</b> | <b>Role</b>                   |
|    |                           |                  |  | EDN         | Emergency Department Nurse    |
|    |                           |                  |  | EDP         | Emergency Department          |
|    |                           |                  |  | Lab         | Laboratory                    |
|    |                           |                  |  | P           | Patient                       |
|    |                           |                  |  | HP          | Hospital Physician            |
|    |                           |                  |  | W           | Ward                          |
|    |                           |                  |  | T           | Transportation                |
|    |                           |                  |  | BC          | Bed Cleaning                  |
|    |                           |                  |  | HF          | Hospital Finance              |
|    |                           |                  |  | EDF         | Emergency Department Finance  |
|    |                           |                  |  | OHIP        | Ontario Health Insurance Plan |

In (Mouttham, 2012), the author claims that although the first solution for reducing waiting time is to increase the number of physicians, there are several events in which unclean beds, or even delayed transportation are the cause of the delay to admit new patients. Accordingly, hiring more bed cleaners could be an alternative, since their wage is considerably lower than that of physicians and nurses. We are now going to present a

formal analysis based on our proposed solution to demonstrate how the quality of health delivery can be improved in this specific scenario.

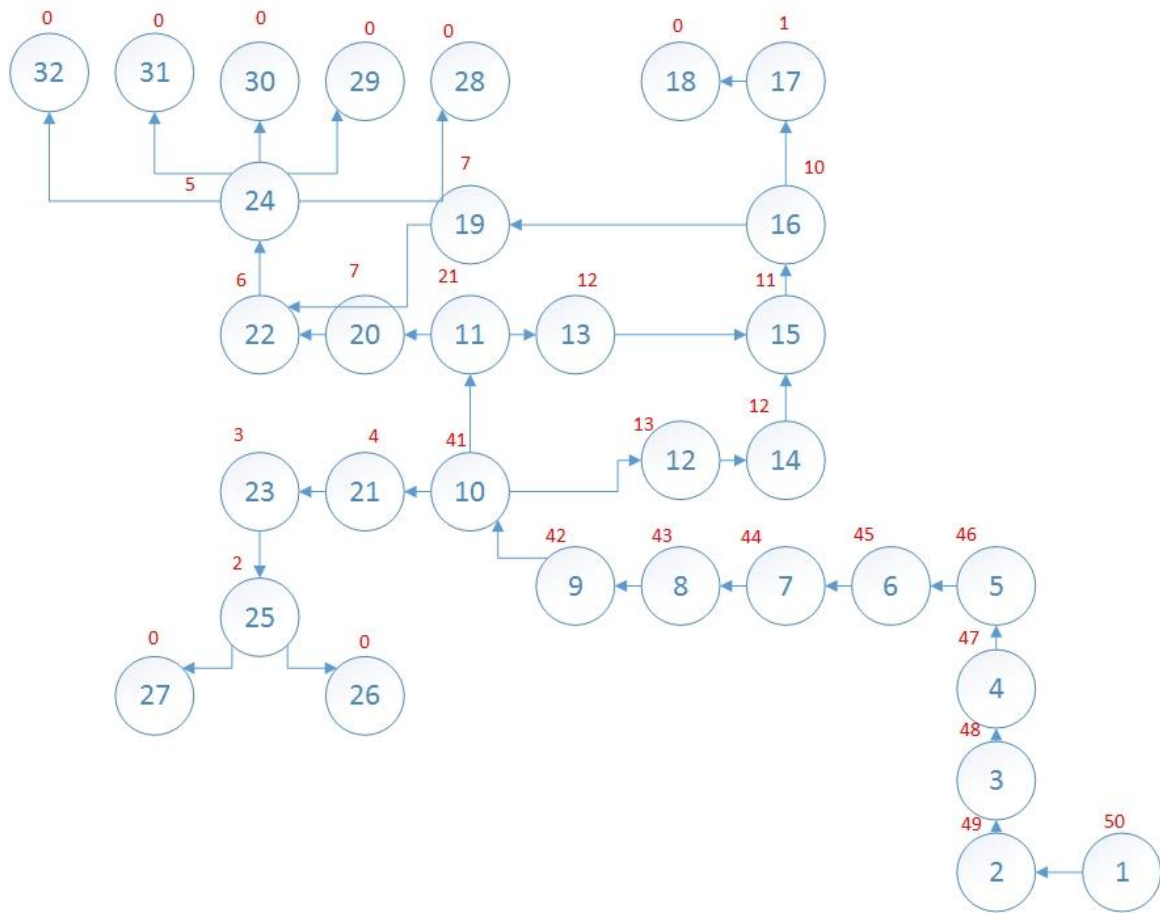
### **3 Analyzing the Value Network**

Based on our proposed framework, the following steps are taken to analyze the value network of this scenario:

- (a) Generating the *Value Dependency Graph*
- (b) Generating the *Value Dependency Matrix*
- (c) Generating the *Actors' value Interchanges Matrix*
- (d) Generating the *Value Gantt chart*
- (e) Generating *Actors' Ease of Substitution*

Based on the value network map, and communications among partners, and by following the steps described in Chapter Three: 2.1, *Value Dependency Matrix* can be created as follows:

|    | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
|----|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 2  | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 3  | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 4  | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 5  | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 6  | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 7  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 8  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 9  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  |    |
| 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  |    |
| 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |    |



**Figure 4-3: Value dependency graph of the case**

Figure 4-3 shows dependencies between interchanged values in the case. The nodes represent values, while the numbers on top of each node depict that value's depth of influence. Furthermore, values number 18, 26, 27, 28, 29, 30, 31 and 32 have 0 depth of influence. It means no other value is dependent on them. Value number 1 has the most depth of influence among all, which is a depth of influence of 50. Although there are only 32 values in the value network, depth of influence of 50 is achieved because of closed loops in the value network map. For instance, the depth of influence of value number 10 is calculated by adding the depth of influence of value number 11 (21), to the depth of influence of value number 12 (13), to the depth of influence of value number 21 (4), and to the number of its successors (3). However, the depth of influences of values number

11 and 12, both are the result of adding the depth of influence of value number 15 to other elements.

The following matrix illustrates value interchanges between different actors/roles in the value network of this case:

|             | <b>P</b> | <b>EDN</b> | <b>EDP</b> | <b>Lab</b> | <b>HP</b> | <b>T</b> | <b>W</b> | <b>BC</b> | <b>HF</b> | <b>EDF</b> | <b>OHIP</b> |
|-------------|----------|------------|------------|------------|-----------|----------|----------|-----------|-----------|------------|-------------|
| <b>P</b>    | 0        | 1          | 0          | 0          | 0         | 0        | 0        | 0         | 0         | 0          | 0           |
| <b>EDN</b>  | 2,6      | 0          | 3          | 7          | 0         | 0        | 0        | 0         | 0         | 0          | 0           |
| <b>EDP</b>  | 4,9      | 5          | 0          | 0          | 10        | 0        | 13       | 0         | 0         | 21         | 0           |
| <b>Lab</b>  | 0        | 0          | 8          | 0          | 0         | 0        | 0        | 0         | 0         | 0          | 0           |
| <b>HP</b>   | 11       | 0          | 0          | 0          | 0         | 12       | 0        | 0         | 20        | 0          | 0           |
| <b>T</b>    | 0        | 0          | 0          | 0          | 0         | 0        | 14       | 0         | 0         | 0          | 0           |
| <b>W</b>    | 15,16    | 0          | 0          | 0          | 0         | 0        | 0        | 17        | 19        | 0          | 0           |
| <b>BC</b>   | 0        | 0          | 0          | 0          | 0         | 0        | 18       | 0         | 0         | 0          | 0           |
| <b>HF</b>   | 0        | 0          | 0          | 32         | 31        | 29       | 30       | 28        | 0         | 0          | 22          |
| <b>EDF</b>  | 0        | 27         | 26         | 0          | 0         | 0        | 0        | 0         | 0         | 0          | 23          |
| <b>OHIP</b> | 0        | 0          | 0          | 0          | 0         | 0        | 0        | 0         | 24        | 25         | 0           |

This matrix is derived from the value network map. For example, in Figure 4-2, role *P* (i.e. Patient) provides value number 1 to EDN, while it gets values number 2 and 6 from EDN, 4 and 9 from EDP, 11 from HP, and 15 and 16 from W. This matrix helps the decision makers understand the relations between different roles.

In Table 4-3, using the proposed method described in Chapter 3, Section 2.3, values of this case are converted to tasks. Unfortunately, since we did not have access to the decision makers of this case in real life, we used literature data (Fernandes &

Christenson, 1995) to set duration for each value. By applying successors and predecessors' conditions, critical path and free slack are derived.

**Table 4-3: Converting the values of the case to tasks**

|    | Name                   | Duration  | Successors     | Predecessors | Critical | Free Slack |
|----|------------------------|-----------|----------------|--------------|----------|------------|
| 1  | intake info            | 15 mins   | 2              |              | Yes      | 0 mins     |
| 2  | Triage                 | 15 mins   | 3              | 1            | Yes      | 0 mins     |
| 3  | Triage info to EDP     | 5 mins    | 4              | 2            | Yes      | 0 mins     |
| 4  | Initial consultation   | 15 mins   | 5              | 3            | Yes      | 0 mins     |
| 5  | Call for blood test    | 5 mins    | 6              | 4            | Yes      | 0 mins     |
| 6  | Take blood sample      | 15 mins   | 7              | 5            | Yes      | 0 mins     |
| 7  | Send sample to Lab     | 10 mins   | 8              | 6            | Yes      | 0 mins     |
| 8  | Test result to EDP     | 60 mins   | 9              | 7            | Yes      | 0 mins     |
| 9  | Diagnosis              | 15 mins   | 10             | 8            | Yes      | 0 mins     |
| 10 | Call specialist to adm | 5 mins    | 11,12,21       | 9            | Yes      | 0 mins     |
| 11 | Admit Patient to War   | 15 mins   | 13,20          | 10           | Yes      | 0 mins     |
| 12 | Call Transportation    | 5 mins    | 14             | 10           | No       | 0 mins     |
| 13 | Send Patient info to ' | 30 mins   | 15             | 11           | Yes      | 0 mins     |
| 14 | Move Patient to War    | 15 mins   | 15             | 12           | No       | 25 mins    |
| 15 | Treat Patient          | 2880 mins | 16             | 13,14        | Yes      | 0 mins     |
| 16 | Discharge Patient      | 120 mins  | 17,19          | 15           | Yes      | 0 mins     |
| 17 | Ward Calls BC          | 5 mins    | 18             | 16           | No       | 0 mins     |
| 18 | BC cleans up the bed   | 60 mins   |                | 17           | No       | 1400 mins  |
| 19 | Ward claims to HF      | 5 mins    | 22             | 16           | Yes      | 0 mins     |
| 20 | HP claims to HF        | 5 mins    | 22             | 11           | No       | 3030 mins  |
| 21 | EDP claims to EDF      | 5 mins    | 23             | 10           | No       | 0 mins     |
| 22 | HF claims to OHIP      | 5 mins    | 24             | 20,19        | Yes      | 0 mins     |
| 23 | EDF claims to OHIP     | 5 mins    | 25             | 21           | No       | 0 mins     |
| 24 | OHIP pays HF           | 1440 mins | 28,29,30,31,32 | 22           | Yes      | 0 mins     |
| 25 | OHIP pays EDF          | 1440 mins | 26,27          | 23           | No       | 0 mins     |
| 26 | EDF pays EDP           | 15 mins   |                | 25           | No       | 3045 mins  |
| 27 | EDF pays EDN           | 15 mins   |                | 25           | No       | 3045 mins  |
| 28 | HF pays BC             | 15 mins   |                | 24           | Yes      | 0 mins     |
| 29 | HF pays T              | 15 mins   |                | 24           | Yes      | 0 mins     |
| 30 | HF pays W              | 15 mins   |                | 24           | Yes      | 0 mins     |
| 31 | HF pays HP             | 15 mins   |                | 24           | Yes      | 0 mins     |
| 32 | HF pays Lab            | 15 mins   |                | 24           | Yes      | 0 mins     |

DETAIL GANTT

This chart is created using Microsoft Project 2010. There are also other similar tools, including OpenProj, which is an open-source, multi-platform software.

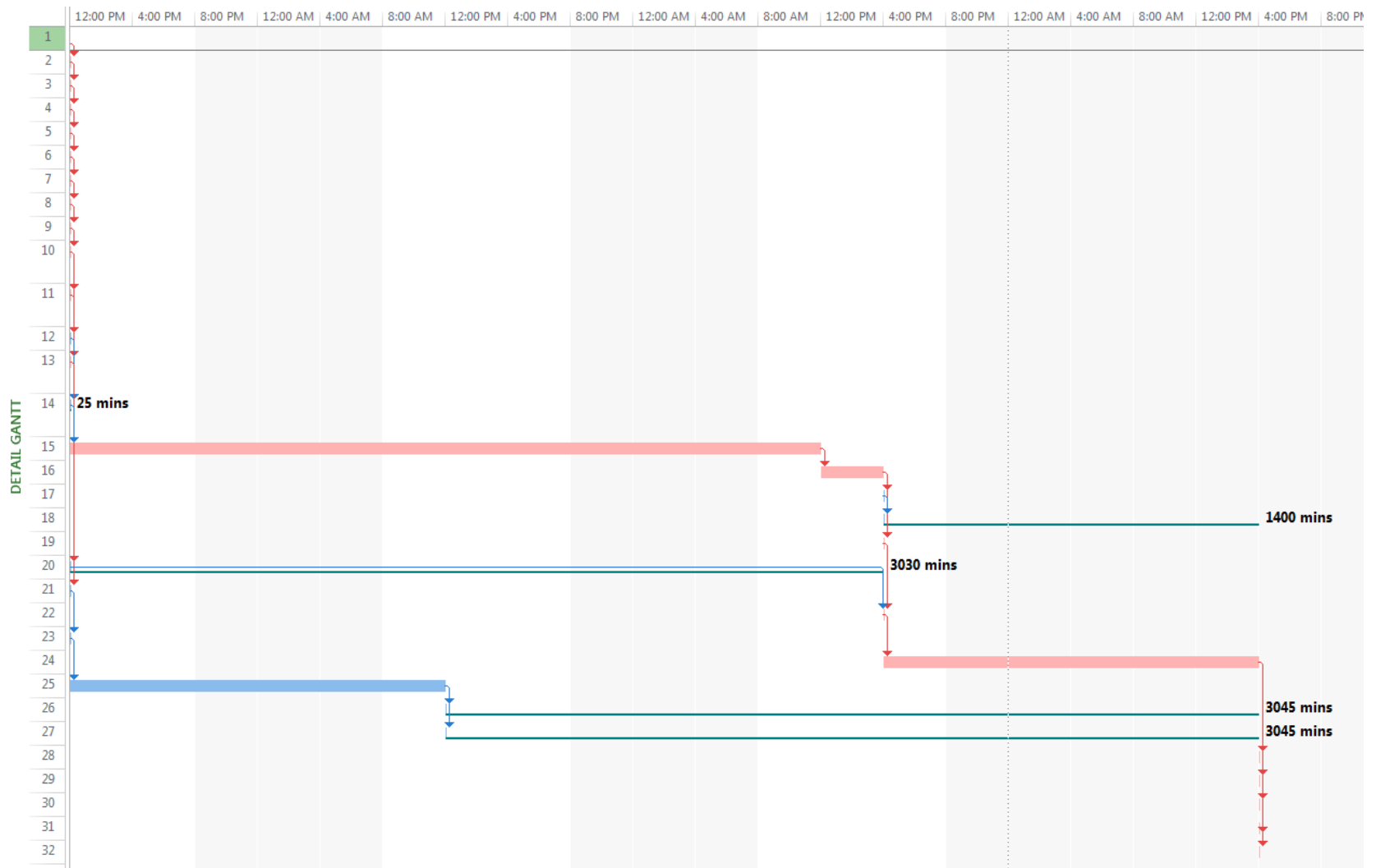


Figure 4-4: Value Gantt chart of the case

Table 4-4 shows different characteristics of the involved roles in the case. *Centrality* presents the number of values that a role provides to other values, and is derived from the *Actors' value interchanges* matrix. *Complexity* is our assumption of the role's complexity in the absence of real SLAs. The number of a role's values in the critical path is represented in the *Critical* column. Our understanding of the number of core values of a role is shown in the *Core* column. Likewise, we took data from the literature (Fernandes & Christenson, 1995) to fill the *Capacity*, *Availability* and *Price* columns.

**Table 4-4: Actor's ease of substitution in the case**

| <b>Roles\Criteria</b>                | <b>Centrality<br/>(C<sub>1</sub>)</b> | <b>Complexity<br/>(C<sub>2</sub>)</b> | <b>Critical<br/>(C<sub>3</sub>)</b> | <b>Core<br/>(C<sub>4</sub>)</b> | <b>Capacity<br/>(C<sub>5</sub>)</b> | <b>Availability<br/>(C<sub>6</sub>)</b> | <b>Price<br/>(C<sub>7</sub>)</b> |
|--------------------------------------|---------------------------------------|---------------------------------------|-------------------------------------|---------------------------------|-------------------------------------|---|----------------------------------|
| <b>Patient</b>                       | 1                                     | N/A                                   | 1                                   | 1                               | N/A                                 | N/A                                     | N/A                              |
| <b>Emergency Department Nurse</b>    | 4                                     | Average                               | 4                                   | 2                               | 200                                 | Average                                 | Average                          |
| <b>Emergency Department</b>          | 6                                     | Average                               | 5                                   | 2                               | 200                                 | Low                                     | Average                          |
| <b>Laboratory</b>                    | 1                                     | Average                               | 1                                   | 1                               | 50                                  | Average                                 | Average                          |
| <b>Hospital Physician</b>            | 3                                     | High                                  | 1                                   | 1                               | 10                                  | Low                                     | Very High                        |
| <b>Ward</b>                          | 4                                     | High                                  | 3                                   | 2                               | 30                                  | Low                                     | High                             |
| <b>Transportation</b>                | 1                                     | Low                                   | 0                                   | 0                               | 15                                  | High                                    | Low                              |
| <b>Bed Cleaning</b>                  | 1                                     | Low                                   | 0                                   | 0                               | 10                                  | High                                    | Low                              |
| <b>Hospital Finance</b>              | 6                                     | Average                               | 6                                   | 0                               | 30                                  | High                                    | Low                              |
| <b>Emergency Department Finance</b>  | 3                                     | Average                               | 0                                   | 0                               | 30                                  | High                                    | Low                              |
| <b>Ontario Health Insurance Plan</b> | 2                                     | Average                               | 1                                   | 0                               | 300                                 | N/A                                     | Low                              |

#### **4 Multi-Criteria Decision Making using AHP**

The Analytic Hierarchy Process (AHP) has proved to be one of the more widely applied MCDM methods (Saaty). At the core of AHP, lies a way for converting subjective

assessments of relative importance to a set of overall scores or weights. Because of its simplicity and functionality, we chose to apply it in our case.

In this case, we compare three alternatives:

$A_1$ : Hire 1 family doctor and 1 specialist and 2 nurses: increase skillful human resources.

$A_2$ : Hire 2 clerks, 3 bed cleaners and 2 transporters: increase ordinary human resources.

$A_3$ : Buy 20 new beds for wards and expand laboratory by 20%: increase infrastructure.

We consider the following criteria to compare these alternatives: Centrality, Complexity, Critical, Core, Capacity, Availability, and Price. The primary input to the AHP is the decision maker's answers to a series of questions of the typical form, 'How important is criterion  $A$  relative to criterion  $B$ ?' for different alternatives. The reference for the responses to the pairwise comparison questions is Table 4-4, which is in subjective format. Answers are codified on a nine-point scale as shown in Table 4-5. Preference indexes 2, 4, 6 and 8 also can be assigned to intermediate values.

**Table 4-5: AHP criteria pairwise comparison (Dodgson, et. al, 2009)**

| <b>How important is A relative to B?</b> | <b>Preference index assigned</b> |
|--|----------------------------------|
| Equally important                        | 1                                |
| Moderately more important                | 3                                |
| Strongly more important                  | 5                                |
| Very strongly more important             | 7                                |
| Overwhelmingly more important            | 9                                |

For each criterion in Table 4-4, a  $3 \times 3$  matrix is created to compare its importance in different alternatives. An element of matrix  $A$ ,  $a_{ij}$ , is assigned by decision makers and

express the relative importance of a particular criterion when compared across  $i^{th}$  and  $j^{th}$  alternatives:

$$a_{ij} = \begin{cases} \frac{1}{a_{ji}}, & i \neq j \\ 1, & i = j \end{cases}$$

The matrices are then normalized:

$$r_{ij} = \frac{a_{ij}}{\sum_{i=1}^N a_{ij}}, \text{ where } i = 1, 2, \dots, N$$

And the weights are calculated, based on this formula:

$$w_i = \frac{\sum_{j=1}^N r_{ij}}{N}, \text{ for } i = 1, 2, \dots, N$$

Hence,

**Centrality:**  $A_1 \quad A_2 \quad A_3$

$$\begin{matrix} A_1 \\ A_2 \\ A_3 \end{matrix} \begin{bmatrix} 1 & 3 & 5 \\ 1/3 & 1 & 3 \\ 1/5 & 1/3 & 1 \end{bmatrix} \Rightarrow R: \begin{bmatrix} 15/23 & 9/13 & 5/9 \\ 5/23 & 3/13 & 3/9 \\ 3/23 & 1/13 & 1/9 \end{bmatrix} \Rightarrow W: \begin{bmatrix} 0.63 \\ 0.26 \\ 0.09 \end{bmatrix}$$

**Complexity:**  $A_1 \quad A_2 \quad A_3$

$$\begin{matrix} A_1 \\ A_2 \\ A_3 \end{matrix} \begin{bmatrix} 1 & 9 & 5 \\ 1/9 & 1 & 5 \\ 1/5 & 1/5 & 1 \end{bmatrix} \Rightarrow R: \begin{bmatrix} 45/59 & 45/51 & 5/11 \\ 5/59 & 5/51 & 5/11 \\ 9/59 & 1/51 & 1/11 \end{bmatrix} \Rightarrow W: \begin{bmatrix} 0.70 \\ 0.21 \\ 0.09 \end{bmatrix}$$

**Critical:**  $A_1 \quad A_2 \quad A_3$

$$\begin{matrix} A_1 \\ A_2 \\ A_3 \end{matrix} \begin{bmatrix} 1 & 1 & 5 \\ 1 & 1 & 3 \\ 1/5 & 1/3 & 1 \end{bmatrix} \Rightarrow R: \begin{bmatrix} 5/11 & 3/7 & 5/9 \\ 5/11 & 3/7 & 3/9 \\ 1/11 & 1/7 & 1/9 \end{bmatrix} \Rightarrow W: \begin{bmatrix} 0.48 \\ 0.40 \\ 0.12 \end{bmatrix}$$

**Core:**  $A_1 \quad A_2 \quad A_3$

$$\begin{matrix} A_1 \\ A_2 \\ A_3 \end{matrix} \begin{bmatrix} 1 & 9 & 5 \\ 1/9 & 1 & 7 \\ 1/5 & 1/7 & 1 \end{bmatrix} \Rightarrow R: \begin{bmatrix} 45/59 & 63/71 & 5/13 \\ 5/59 & 7/71 & 7/13 \\ 9/59 & 1/71 & 1/13 \end{bmatrix} \Rightarrow W: \begin{bmatrix} 0.68 \\ 0.24 \\ 0.08 \end{bmatrix}$$

**Capacity:**  $A_1 \quad A_2 \quad A_3$

$$\begin{matrix} A_1 \\ A_2 \\ A_3 \end{matrix} \begin{bmatrix} 1 & 1 & 1/5 \\ 1 & 1 & 1/5 \\ 5 & 5 & 1 \end{bmatrix} \Rightarrow R: \begin{bmatrix} 1/7 & 1/7 & 1/7 \\ 1/7 & 1/7 & 1/7 \\ 5/7 & 5/7 & 5/7 \end{bmatrix} \Rightarrow W: \begin{bmatrix} 0.14 \\ 0.14 \\ 0.72 \end{bmatrix}$$

**Availability:**  $A_1 \quad A_2 \quad A_3$

$$\begin{matrix} A_1 \\ A_2 \\ A_3 \end{matrix} \begin{bmatrix} 1 & 1/3 & 1 \\ 3 & 1 & 3 \\ 1 & 1/3 & 1 \end{bmatrix} \Rightarrow R: \begin{bmatrix} 1/5 & 1/5 & 1/5 \\ 3/5 & 3/5 & 3/5 \\ 1/5 & 1/5 & 1/5 \end{bmatrix} \Rightarrow W: \begin{bmatrix} 0.20 \\ 0.60 \\ 0.20 \end{bmatrix}$$

**Price:**  $A_1 \quad A_2 \quad A_3$

$$\begin{matrix} A_1 \\ A_2 \\ A_3 \end{matrix} \begin{bmatrix} 1 & 1/5 & 1/5 \\ 5 & 1 & 9 \\ 5 & 1/9 & 1 \end{bmatrix} \Rightarrow R: \begin{bmatrix} 1/11 & 9/59 & 1/51 \\ 5/11 & 45/59 & 45/51 \\ 5/11 & 5/59 & 5/51 \end{bmatrix} \Rightarrow W: \begin{bmatrix} 0.09 \\ 0.70 \\ 0.21 \end{bmatrix}$$

On the other hand, Criteria Matrix compares different criteria to each other. After normalizations, weight of each criterion for final decision is calculated.

$$\begin{array}{c}
C_1 \quad C_2 \quad C_3 \quad C_4 \quad C_5 \quad C_6 \quad C_7 \\
\begin{array}{l}
C_1 \\
C_2 \\
C_3 \\
C_4 \\
C_5 \\
C_6 \\
C_7
\end{array}
\begin{bmatrix}
1 & 1 & 1/3 & 1 & 1/3 & 1/3 & 1/7 \\
1 & 1 & 1/3 & 1 & 1/3 & 1/7 & 1/9 \\
3 & 3 & 1 & 1 & 1 & 1/3 & 1/5 \\
1 & 1 & 1 & 1 & 1/3 & 1/5 & 1/7 \\
3 & 3 & 1 & 3 & 1 & 1 & 1/3 \\
3 & 7 & 3 & 5 & 1 & 1 & 1/3 \\
7 & 9 & 5 & 7 & 3 & 3 & 1
\end{bmatrix}
\end{array}$$

$$\Rightarrow R: \begin{array}{l}
C_1 \\
C_2 \\
C_3 \\
C_4 \\
C_5 \\
C_6 \\
C_7
\end{array}
\begin{bmatrix}
1/19 & 1/27 & 1/35 & 1/19 & 1/21 & 35/631 & 135/2139 \\
1/19 & 1/27 & 1/35 & 1/19 & 1/21 & 15/631 & 105/2139 \\
3/19 & 3/27 & 3/35 & 1/19 & 3/21 & 35/631 & 189/2139 \\
1/19 & 1/27 & 3/35 & 1/19 & 1/21 & 21/631 & 135/2139 \\
3/19 & 3/27 & 3/35 & 3/19 & 3/21 & 105/631 & 315/2139 \\
3/19 & 7/27 & 9/35 & 5/19 & 3/21 & 105/631 & 315/2139 \\
7/19 & 9/27 & 15/35 & 7/19 & 9/21 & 315/631 & 945/2139
\end{bmatrix}$$

$$\Rightarrow W: \begin{array}{l}
C_1 \\
C_2 \\
C_3 \\
C_4 \\
C_5 \\
C_6 \\
C_7
\end{array}
\begin{bmatrix}
0.04 \\
0.04 \\
0.10 \\
0.05 \\
0.14 \\
0.20 \\
0.41
\end{bmatrix}$$

Then, the overall score of each alternative is calculated:

$$S_i = \sum_{j=1}^M w_j v_{ij}, \text{ for } i = 1, 2, \dots, N$$

$$A_1 = (0.63*0.04) + (0.70*0.04) + (0.48*0.10) + (0.68*0.05) + (0.14*0.14) + (0.20*0.20) + (0.09*0.41) = 0.2317$$

$$A_2 = (0.26*0.04) + (0.21*0.04) + (0.40*0.10) + (0.24*0.05) + (0.14*0.14) + (0.60*0.20) + (0.70*0.41) = 0.4975$$

$$A_3 = (0.09*0.04) + (0.09*0.04) + (0.12*0.10) + (0.08*0.05) + (0.72*0.14) + (0.20*0.20) + (0.21*0.41) = 0.2501$$

Consequently, the most preferred solution is  $A_2$  (Hire 2 clerks, 3 bed cleaners and 2 transporters: increase ordinary human resources), followed by  $A_3$  (Buy 20 new beds for wards and expand laboratory by 20%: increase infrastructure), and the least favorable option is  $A_1$  (Hire 1 family doctor and 1 specialist and 2 nurses: increase skillful human resources).

## **5 Case Conclusion**

Although we used hypothetical data in this case, applying the proposed analytical tools and using a common MCDM method (AHP) indicated that in complex value networks, decision-making could be challenging. Identifying the roots of the problems and selecting the best possible change strategy with minimum cost and maximum benefit, is not always obvious. As it appeared in the case, instead of just simply asking for more doctors and specialists, increasing ordinary human resource can resolve many issues without too much cost as compared to option A1.

## CHAPTER FIVE: CONCLUSIONS

### 1 A Summary of the Research

Today's global, competitive and fast-changing economy demands more collaboration among independent entities in order to deliver high quality values to the customers. The increasing formation of Collaborative Networked Organizations is a response to this need. However, management of the collaboration between autonomous organizations who share values and create value networks is challenging. The roots of problems, i.e. low performance, and consequently, low satisfaction of the end customers, are not easily identified in large, complex, and multi-player environments –like healthcare.

In this thesis, we developed a framework in order to assist decision-makers gain a better understanding of the value network, identify problematic values, and accordingly, choose the best possible alternatives. The proposed framework clarifies the current situation of a value network based on inputs from *Performance Measurement*, *Value network map*, and *Communications among partners*. Then, through different techniques (*Actors' value interchanges matrix*, *Value Gantt chart*, *Identifying problematic actors* flowchart, and *Actors' ease of substitution table*), it provides a thorough analysis of the value network. After identifying bottlenecks, problematic actors, and consequences of substituting them, through a Multi-Criteria Decision-Making method, the most preferred solutions are identified. Depending on the criteria and the selected method, the process of the last phase may vary.

At the end, to test our proposed methods, we studied a scenario in healthcare: the journey of a patient, from Emergency Department to Wards, and finally being discharged from hospital. We mapped the value network, defined different roles and values, and via some assumptions, identified critical values, slack times and problematic actor. Then, using the

Analytic Hierarchy Process (AHP) method, we ranked three alternatives according to the pre-defined criteria.

## **2 Contribution of the Thesis**

In this research, we provided a framework and its associated analytical methods to facilitate decision making in changing actors of the value networks, for the management of the collaborative environment. In order to do so, we devised four components: *Actors' value interchanges* matrix, *Value Gantt chart*, *Identifying problematic actors* flowchart, and *Actors' ease of substitution* table. *Actors' value interchanges* matrix clarifies the dependency of roles to each other. Leveraging on the Gantt chart capabilities, the *value Gantt chart* is proposed to calculate slack times, and identify values in critical path. Using the *Identifying problematic actors* flowchart, decision makers start from the final value and move backward, until they find the roots of the problems. In *Actors' ease of substitution* table, we summarized various criteria, which should be addressed by decision makers. They help decision makers to understand the feasibility and consequences of changing an actor in their value network.

All methods are introduced formally, accompanied by a hypothetical example, and applied to a scenario in healthcare.

## **3 Limitations and Future Works**

The limitations, as well as the opportunities for future works arising from this research are:

- a) **Scenario:** We applied the proposed framework to a healthcare case. This case was validated by (Mouttham, 2012), (Bahrani, 2013) and (Tchemeube, 2013). However, because we did not have access to the original decision makers in this environment, in some parts we relied on literature data.

Studying this framework and its associated techniques in a case where the management is willing to fill in questionnaires and provide real information would put the framework to a more realistic test.

- b) **MCDM:** In this research, we reviewed a few Multi-Criteria Decision-Making methods, we introduced three of them, and based on the characteristics of the case, we applied the Analytic Hierarchy Process (AHP) method. Other MCDM methods can be applied in the future works, with an equal likelihood of success, for decision-making in collaborative environments.

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