Agent-Based Research Methodology for Service Science, Management and Engineering (SSME) in Industrial Cluster

Citation for published version:
Utomo, DS, Putro, US & Hermawan, P 2011, 'Agent-Based Research Methodology for Service Science, Management and Engineering (SSME) in Industrial Cluster', Paper presented at 2nd International Research Symposium in Service Management 2011, Yogyakarta, Indonesia, 26/07/11 - 30/07/11 pp. 307-316.

Agent-Based Research Methodology for Service Science, Management and Engineering (SSME) in Industrial Cluster

Dhanan Sarwo Utomo[1], Utomo Sarjono Putro and Pri Hermawan

School of business and management, Institut Teknologi Bandung
Jl. Ganeca No. 10, Bandung, Indonesia, 40132, +62222531923

Abstract *- This study aims to propose an agent-based modeling and simulation research methodology, to facilitate multi-disciplinary approach in SSME researches. This paper not only discusses the relationship between SSME and agent-based modeling and simulation, but also steps in agent-based modeling and simulation research methodology. To illustrate the proposed methodology, an agent-based model of Cibaduyut industrial cluster case is discussed. Within the Cibaduyut industrial cluster service process occurs in the form of knowledge sharing in order to reduce the number of defects. By using the proposed methodology it is possible to combines both qualitative and quantitative research as well as computer simulation and virtual experiments to formalize the interaction among agents within the industrial cluster. The experiment results show that simulation behavior can mimic the real world behavior.*

Keywords: *agent-based model, service science, industrial cluster, service system, complex system*

INTRODUCTION

Service can be viewed as a value co-creation, which is widely defined as a useful changes generated by purposeful and knowledge-intensive interactions between distinct entities (Spohrer & Maglio, 2010). Therefore, Service Science, Management, and Engineering (SSME) can be defined as a multi-disciplinary approach to study, improve, create and innovate the value co-creation process (Spohrer & Maglio, 2008; Spohrer & Maglio, 2010). As a new emerging field, research methodology in the SSME is still under development until now.

This study aims to propose an agent-based modeling and simulation research methodology, to facilitate multi-disciplinary approach in SSME researches. This paper not only outlines the relationship between SSME and agent-based modeling and simulation, but also steps in agent-based modeling and simulation research methodology. To illustrate the proposed methodology, an agent-based model of Cibaduyut industrial cluster case is discussed. Within this industrial cluster service process occurs in the form of knowledge sharing in order to reduce the number of defects. By using the proposed methodology it is possible to combines both qualitative and quantitative research as well as computer simulation and virtual experiments to formalize the interaction among agents within industrial cluster.

THEORETICAL BACKGROUND

This section discusses the theoretical foundation used in this study. The discussion in this section is organized into three sub-sections. The first sub-section discusses the relationship and role of knowledge sharing process and service science, management and engineering (SSME). The second sub-section discusses the relationship between SSME and industrial clusters. Finally, the third sub-section discusses the relationship between complexity and SSME, and why agent-based modeling and simulation is a suitable methodology for studying SSME especially in industrial clusters.

[1] *Corresponding author*
e-mail address: dhanan@sbm-itb.ac.id

Relationship between SSME and Knowledge Sharing

Service can be considered as value co-creation process, which is widely defined as a useful changes generated by purposeful and knowledge-intensive interactions between distinct entities (Spohrer & Maglio, 2010). Therefore, Service Science, Management, and Engineering (SSME) can be defined as a multi-disciplinary approach to study, to improve, to create and innovate the value co-creation process (Spohrer & Maglio, 2008; Spohrer & Maglio, 2010).

In studying the SSME, the service dominant logic is a framework that is considered to be appropriate (Maglio & Spohrer, 2008). There are five constructs in the service dominant logic that is, (1) service, (2) value, (3) system, (4) interaction and (5) resources (Lusch & Vargo, 2008 ; Lusch, et al., 2008). The description of each construct is as follows:

- *Service*: In service dominant logic, service is defined as a relationship and interaction among service system in order to provide benefit for one another. As service system become more interdependent, relationship emerge and the potential of collaboration among service system increase (Vargo, Lusch, & Akaka, 2010).
- *Value*: In service dominant logic, value is defined as improvement in a system, as judges by the system or the system ability to fit an environment (Vargo, et al., 2008). Based on SSME perspective, value co-creation is the purpose and driver of interaction (Spohrer, et al., 2008). Value co-creation process is not limited to the activities or resources of individual exchange occurrence, but also derived through the assimilation of existing and knew knowledge (Vargo, Lusch, & Akaka, 2010).
- *System* : A system is defined as a configuration of resources (resources is the terminology given for system components), in which the properties and behaviors of the cofiguration is more than the properties and behaviors of individual resources (Spohrer, et al., 2008). The value co-creation is a complex process take places in networks of relationships and resources (Vargo, Lusch, & Akaka, 2010).
- *Interaction*: Service dominant logic see service as interdependent and interactive models that implies dynamics, non-equilibrium and non deterministic relationships and models of exchange. This logic focus on interactive and dynamic aspects of exchange, such as collaborative communication among service system and the learning that occur via exchange (Vargo, Lusch, & Akaka, 2010).
- *Resources*: Resources play important role in studying the relationship among service systems. In service dominant logic perspective, resources is not limited to physical entities. According to Maglio and Spohrer, entities within service systems exchange competence along at least four dimensons: information sharing, work sharing, risk sharing and goods sharing (Maglio & Spohrer, 2008).

From the discussion in this sub-section it can be concluded that the knowledge sharing process has an important role in the study of SSME. Knowledge is one form of resources that can be exchanged between service system, in addition, knowledge exchange is also a drivers of the interaction and learning process between service system that always occurs within the service network.

Relationship between Industrial Cluster and Service Science

Industrial clusters can be defined as spatial agglomerations of companies of related industry branches and chains of production and value-adding. In a cluster, industry branches, their individual companies and related institutions (e.g. Governmental, research organizations and NGOs) are linked to each other by close relationship to a certain use of resources or form of production, by spatial clustering and by high connectivity in terms of business and support activities. The goal of cluster concept is to support these industry branches and their companies in general by optimizing production and value-adding processes within and between different branches (e.g. improving productivity, innovation and marketing through increased communication and cooperation) (Mrosek, et al., 2010).

Based on literature review there are several types of cooperation within industrial cluster (Albino, et al. 2003; Carbonara, Giannoccaro, & Pontrandolfo, 2002; De Toni & Nassimbeni, 1995; Dei Ottati, 1994; Markusen, 1996; Piore & Sabel, 1984; Saxenian, 1996). The first type of cooperation is the horizontal cooperation such as purchasing and offering groups that organize supply or demand together in order to achieve economy scale and to increase the contractual power. The second type of cooperation is the vertical cooperation such as technical collaboration arrangement between manufacturing firms and infrastructure suppliers. The third type of cooperation is the hybrid cooperation such as educational trainings, aims to improve the industrial cluster performance that are organized by consortium or trade association. These co-operations involve a group of independents firms that not only pursuing their own autonomous objectives but also try to collaborate to achieve common goal and improve their performance (Albino, et al. 2003).

Through the discussion in this section, it can be concluded that the industrial cluster is an area suitable to study by using the service dominant logic framework. This is because the industrial cluster is composed of relationships between independent firms. In these relationships exchange and learning process that aims to improve the performance of industrial clusters occur. In SSME perspective, these processes can be viewed as value co-creation processes.

Complexity of an Industrial Cluster and Agent-Based Modeling and Simulation

The characteristics of the phenomena that occur within industrial clusters shows the characteristics possessed by a complex adaptive system, namely, non linear interaction among heterogeneous agents, distributed control and information flow, diversity in behaviors, ability to learn and so on (Gilbert, 2004; Gilbert, 2008).

An Agent-based modeling and simulation can be defined as a simulation of a system that consists of a number of software individuals, called agents. In this simulation, agents can interact with each other and with their environment (Smith & Conrey, 2007; Gilbert, 2004), with specific rules. In dealing with a complex system, just like in industrial cluster, computer simulation can help because, there are several natures of computer simulation that ease us in building a model of a complex system (Srbljinović & Škunca, 2003), namely:

- Using computer simulation, we can deal with parallel process without well defined order easily.
- It is easier to build a model that involves heterogeneous agents using computer simulation.
- The modularity of computer simulation enables us to modify our model easily.
- It is possible to model bounded rational agents.
- It is easier to model turbulence social condition especially, when agent's identities and attributes are unfix.

The nature of programming language that is more expressive than verbal language and less abstract than mathematical equation (Srbljinović & Škunca, 2003), enable researcher to model both quantitative and qualitative theories (Gilbert & Terna, 2000). Therefore, agent based simulation can facilitate the collaboration among disciplines (Axelrod, 2005), this nature is very approprate to fulfill the multidiciplinary approach requirement of SSME. Thus, it can be concluded that the Agent-based modeling and simulation is a methodology that is suitable to be used in SSME research, especially in industrial clusters.

METHODOLOGIES

This section discusses the agent-based modeling and simulation methodology used in this study. This methodology builds upon the agents-based modeling and simulation research methodology that is commonly used, but adapted to facilitate the paradigm SSME research, especially the service dominant logic framework.

The first step in agent-based research methodology is to identify the phenomenon that we want to understand better clearly (Gilbert , 2008). To accommodate the service dominant logic, the researcher must identify and try to answer the following questions:

- *Service*: Who are the actors involved in the service system being studied? What is the position and status of each actor in the service system being investigated? What are the tasks performed by each actor?
- *Value*: What parameters that can characterize the performance of the service system being studied? How to operationalize these parameters?
- *System*: How is the relationship between one actor to another actor? What is the role of each actor to other actors?
- *Resources*: What are the attributes possessed by each actor? Whether the attributes possessed by each actor are fixed or dynamic? What are the factors that influence the attributes of each actor?

- *Interaction*: How does each actor behave? What decisions can be taken by each actor? How does an actor's decision may affect the attributes and decision of other actors?

In identifying the service system being studied, collecting a sufficient body of theory is very important. Like in other agent-based modeling and simulation research, theory about the dynamics and process about social phenomena are better than static or equilibrium relationship (Gilbert, 2004). By the way, any theories are better than none (Gilbert, 2004).

The second step of agent-based research methodology is to define the scope of the model. In this process, researchers need to specify clearly all assumptions that will be used in the model. The model can be started from a simple model that is easy to implement (Gilbert, 2004).

The next step is to begin the simulation design. In this step, the types of objects in the simulation are defined. Usually, there will be two types of objects in the simulation namely, agents and environment. If, one object consists of several sub-objects, then these objects must be arranged into a hierarchical class (Gilbert, 2004). After that, the attributes for all objects must be specified. An attributes is a characteristic or feature of an objects (Gilbert, 2004). An attribute can serve as object's identity or, varies over time.

The fourth step is to design interactions among objects. A list all possible actions that can be carried out by each object is created (Gilbert, 2004). Then, rules that are used by an object to execute each action must be specified.

The fifth step is to validate the model. There are two steps of validation in agent-based simulation namely, internal validation and external validation. There are two processes in the internal validation steps first, is the conceptual validity check and second, verification process. Model validity determines whether the model is appropriate to serve its purpose or not (this parameter has yes or no decision value) (Schmid, 2005). While, verification process aims to getting rid of bugs (Gilbert, 2008). During the external validation process, model's accuracy is tested. Model accuracy determines how close the model can reflect the reality (sometimes it can be measured from 0% to 100%) (Schmid, 2005).

The last step is to conduct virtual experiment in order to generate some hypotheses or explore the dynamic of service system. To conduct a good virtual experiment, proper experimental design should be followed (Carley, 1999). At first the core variables or parameters that are assumed to be the most relevant variables affecting the emergence properties must be identified. After that, the range of core variables values that are going to be explored must be defined. The noncore variables can be set according to the real world data (if available) or as random numbers. Then, we should run the simulation multiple times for each experiment set. Ideally we could obtain much larger data than, that can be obtained in real world experiment. Finally, conduct the analysis for the simulation result.

CASE STUDY : AGENT-BASED SIMULATION OF KNOWLEDGE SHARING PROCESS IN CIBADUYUT INDUSTRIAL CLUSTER

This section illustrates how to implement the proposed methodology using a case study. The case studies discussed in this study is the case of footwear industrial cluster located in Cibaduyut Bandung. The purpose of this case study is to describe the service performed in the industrial cluster in order to reduce the number of defects produced. Service processes are carried out through knowledge sharing among actors by exchanging technical capabilities possessed by each actor.

System Identification

In knowledge sharing process in Cibaduyut industrial cluster, there are three actors who interact with each other. The first actor is shoe maker companies. These companies can be classified into two types. The first type is called the champion i.e. companies that have been able to produce shoes with very good quality. The second type is called non-champion, this type generally consist of SMEs who do not have perfect technical capability. The second actor is the technical implementation unit (called as UPT) of Indonesian Ministry of Industry. This actor does not produce shoes but is responsible for distributing the orders and provide technical coaching to the SMEs (Syairudin, et al. 2008).

Orders generally will come through UPT or companies with champion status. Orders coming to UPT will then be distributed to SMEs. Meanwhile, the champion will distribute the orders that come to it if the order exceeds the amount of production capacity owned by the champion. When SMEs take orders from UPT or champion, UPT and the champion will provide technical guidance to the

SME by so that SMEs can produce shoes with suitable quality according to costumer's specification. In addition, during the shoe production, SMEs may also seek to improve their technical capabilities both by consulting with the champion, or UPT (called as external knowledge sharing process), as well as learning to other SMEs (called as internal knowledge sharing process) (Syairudin, et al. 2008). In this system value that is exchanged is the technical capability operationalized by measuring the number of defects that arise.

Agent and Environment Specification

In this simulation, an agent is assumed to represents a shoes company. For each agent a factory spot is assigned. The number of agents and factory spot is included in this simulation as an input variable. Each agent and factory spot in this simulation has similar attributes, namely:

- *Champion*: a Boolean keyword variable that indicates whether an agent is a champion or not. At the beginning of the simulation, the number of agents whose *champion* variable value equal to *yes* is determined as an input parameter.
- *Champion factory*: a Boolean keyword variable that indicates whether the agent who own the given factory is a champion or not.
- *Incoming order (IO)*: indicates the number of order that is received by the given factory in a month.
- *Working order (WO)*: indicates the number of shoes that should be produced by the given factory in the given month.
- *Capacity (C)*: indicates the number of shoes that can be produced by an agent in a day. This variable is initiated randomly from 8 to 24 shoes / day.
- *Monthly Capacity (MC)*: indicates the number of shoes that can be produced by an agent in a month (25 * *Capacity*).
- *Taken orders (TO):* The number of order that is obtained from other agents or from UPT spot.
- *Production skill (Ps)*: the minimum quality that can be produced by an agent. At the beginning of the simulation, this variable is initiated randomly from 1 to 10.
- *Produced quality (Pq)*: the quality of shoes produced by agents.
- *Number defect*: the number of defect produced by an agent.
- *Probability to give external knowledge sharing*: the probability of a champion agent to give knowledge sharing to non-champion agents.
- *Probability to give internal knowledge sharing*: the probability an agent to give knowledge sharing to other agents.
- *Posted external knowledge*: portion of agent's production skill that is shared to other agents thorough external knowledge sharing process.
- *Posted internal knowledge*: portion of agent's production skill that is shared to other agents thorough internal knowledge sharing process.
- *Learned knowledge:* knowledge that is learned from other agent.

In addition, in this simulation two other spots are defined namely, UPT Spot and Model spot. UPT spot, representing the UPT, has the same attributes with the factory spot, it's just that production process does not occur in this spot. While, model spot is a spot that is used to control the simulation process. The attributes of model spot are:

- *Day*: represents a working day in the real world system.
- *Month*: represents a month in the real world system. In this simulation it is assumed that a month consists of 25 working days.
- *Maximum order (MO)*: represents the maximum order that can be received by the industrial cluster in a month.
- *Total order (TotO)*: the total number of order that can is received by the industrial cluster in a month.
- *Order per champion (OpC)*: represents the incoming order that is received by each champion and UPT in a month.
- *Number champion (Nc)*: Indicates the number of champion agents in the given month.
- *List champion*: an array containing the name of factory spots with champion status and UPT spots.
- *List factory*: an array containing the name of all factory spots in the simulation.

- *Required quality (Rq)*: the standard production quality that should be met by agents. In this simulation it is assumed that the *quality required* is a constant with the value of 10.
- *Total Monthly Defect*: total defect products from all agents in a month.

Simulation Design

Order generation and distribution

Each time the value of *day* variable on model spot is equal to 1, order is generated in the *spot model*. The *total order*that is generated will fluctuate depending on the value of *month* variable and *maximum order* variable on the spot model. If the value of *month* variable in the spot model is less than or equal to 2 then, the *total order*is randomized between 0% and 20% of the *maximum order*.If the value of *month* variable in the spot model is between 3 and 11 then, the *total order*is randomized between 80% and100% of the *maximum order*.If the value of *month* variable in the spot model is equal to 12 then, the *total order* is randomized between 20% and 80% of the *maximum order*.

In this model the *total order* is assumed to be distributed evenly to all champions and UPT. The incoming order that will be received by each champion and UPT is determined as follows:

$$OpC = \frac{TotO}{(Nc+1)} \tag{1}$$

All factory spots which belong to a champion, and UPT spot, are then set the value of their *incoming order* variable equal to the value of *order per champion* variable at the model spot.

Each factory spot which belong to champion agent will then calculate the value *working order* variable. If the *incoming order* value at the given factory spot is higher than or equal to the value of *monthly capacity* then the value of *working order* is set to be equal to the *monthly capacity* value. If the *incoming order* value at the given factory spot is greater than zero but less than the value of *monthly capacity* then the value of *working order* is set to be equal to the *incoming order* value. After that, the *incoming order* of the given spot is subtracted by the *working order* value. If the *incoming order* value is greater than zero after this operation, then the rest of the *incoming order* value will be distributed to the non-champion agents.

Once the order is generated and distributed to all champion agents and UPT, each non-champion agent will move randomly to one element of *champion list* at model spot or move to UPT spot. If the *incoming order* value at the given spot is greater than agent's *monthly capacity*, then agent will set the value of its *taken order* variable to be equal to its *monthly capacity*. If the *incoming order* value at the given spot is greater than zero but less than agent's *monthly capacity*, then agent will set the value of its *taken order* variable to be equal to the value of *incoming order* variable in the given spot. If the *incoming order* value at the given spot is equal to zero, then the agent will set the value of its *taken order* variable to be equal to zero. After that, the agent will subtract the *incoming order* variable value in the given spot by the value of its *taken order* variable and record the spot where it takes its order in *my champion* variable. If after this process the value of *incoming order* variable in the given spot is higher than zero, then the rest of *incoming order* will be distributed to other non champion agents who come to the same spot.

After all non champion agents execute this procedure, they will then move to their own factory. All non champion agent then set the value of *incoming order* variable at their factory to be equal to the value of their *taken order* variable.

Production process

Every day, as long as the value of *working order* in the factory spot is greater than zero, agent will produce shoes. The number of shoes produced in a day is determined by the value of *production iteration* variable. The value of production iteration variable is determined by the *working order* and *production capacity* variable. If the value of *working order* variable is greater than or equal to the *production capacity*, then the *production iteration* value is set to be equal to the *production capacity* value. If the value of *working order* variable is greater than zero but less than the value of *production capacity* variable, then the value of *production iteration* variable is set to be equal to the *working order*. If the value of *working order* variable is equal to zero, then the value of *production iteration* is set as zero.

As long as the value of *production iteration* is greater than zero, factory spots will produce shoes. The quality of a show that is produced is indicated by the produced *quality variable*. In this simulation, agents are assumed to be always trying to fulfill the *required quality*. But, since agents have different *production skill*, the resulting quality may fall between agent's *production skill* and the *required quality*. Therefore, the value of *produced quality* variable is determined as follows:

$$Pq = Ps + random(0, Rq - Ps) \qquad (2)$$

The *produced quality* value is then compared to the *required quality* value. If the value of *produced quality* variable is less than the *required quality,* then the number of defect (*number defect* variable) is increased by one. The value of *working order* and *production iteration* are then subtracted by one.

At the end of the month, when the value of *month* variable at model spot reach 25, the *number defect* value of all factory is accumulated and displayed in *total monthly defect*plot. The value of *number defect* variable in all factories is then set as zero.

External knowledge sharing process

Every day, with the probability of *probability to give external knowledge sharing*, factory spot with *champion factory* variable value equal to *yes*, and UPT spot will give external knowledge sharing to non-champion agents. If the *probability to give external knowledge sharing* is fulfilled, the keyword variable *give external knowledge sharing* at the given spot is set to *yes*. Spots whose keyword variable *give external knowledge sharing* value equal to yes will then transmittheir *production skill* to the non-champions agents through *posted knowledge* variable. In giving external knowledge sharing, it is assumed that only a portion of agent's *production skill* that can be transmitted. This value of *production skill* that can be transmitted will be depends on agent's *knowledge sharing ability*as follows.

posted external knowledge = P_s **external knowledge sharing ability* (3)

Every day, with the probability of *probability external knowledge sharing*, agents whose *champion* variable value equal to *no*, will go to external knowledge sharing. If the *probability external knowledge sharing* is fulfilled and agent's production skill is less than 10, then keyword variable *go to external knowledge sharing* is set to *yes*. Agents with keyword variable *go to external knowledge sharing* value equal to *yes* will then move to the spot that is recorded in agent's*my champion* list.

In this simulation, it is assumed that agents will learn new knowledge only if the knowledge that is transmitted by its champion is higher than its own production skill. When an agent arrive at its champion spot, if the value of keyword variable *give external knowledge sharing* is equal to *yes,* agent will then compare the value of *posted external knowledge* variable at the visited spot with its own *production skill*value. If the value of *posted knowledge* variable at the visited spot is greater than agent's *production skill,* then agents will learn new knowledge from its champion. The value of new knowledge learned from its champion (*learned knowledge*) will depends on agent's *learning ability*.

learned knowledge = (*posted external knowledge* – P_s)**learning ability* (4)

The *learned knowledge* is then added to agent's current *production skill*. All agents with keyword variable *go to external knowledge sharing* equal to *yes* will then move to their own factory and save the new *production skill* value at their factory.

Internal knowledge sharing process

Every day, with the probability of *probability to give internal knowledge sharing*, all factory spot with *champion factory* variable value equal to *no*, will give internal knowledge sharing to other non-champion agents. If the *probability to give internal knowledge sharing*is fulfilled, the keyword variable *give internal knowledge sharing* at the given spot is set to *yes*. Spots whose keyword variable *give internal knowledge sharing* value equal to *yes* will then transmit their *production skill* to the other non-champions agents through *posted internal knowledge* variable. In giving internal knowledge sharing, it is assumed that only a portion of agent's *production skill* that can be transmitted. The*production skill*value that can be transmitted will be depends on agent's *knowledge sharing ability*as follows.

posted internal knowledge = P_s **internal knowledge sharing ability* (5)

Every day, with the probability of *probability internal knowledge sharing*, agents whose *champion* variable value equal to *no,* will go to internal knowledge sharing. If the *probability internal knowledge sharing* is fulfilled and agent's production skill is less than 10, then keyword variable *go to* *internal knowledge sharing* is set to *yes*. Agents with keyword variable *go to internal knowledge sharing* value equal to *yes* will then move to random element of *factory list* at model spot.

When an agent arrive at destination spot, if the value of keyword variable *give external knowledge sharing* is equal to *yes,* agent will then compare the value of *posted internal knowledge* variable at the visited spot with its own *production skill*value. If the value of *posted internal knowledge* variable at the visited spot is greater than agent's *production skill*, then agents will learn new knowledge from other non-champion agent. The value of new knowledge learned from other non-champion agent (*learned knowledge*) will depends on agent's *learning ability*as follow.

$$learned\ knowledge = (posted\ internal\ knowledge - P_s)*learning\ ability \quad (6)$$

The learned knowledge is then added to agent's current *production skill*. All agents with keyword variable *go to internal knowledge sharing* equal to *yes* will then move to their own factory and save the new *production skill* value at their factory.

Change in agent role

Every month, when the value of *day* variable model spot is equal to 25, non-champion agents whose *production skill* has reached 10, will turn into champion. Agent's *champion* keyword variable is then set to *yes*, and the *number champion* variable in model spot is increased by 1. From this moment, the given agent will act as a champion and will start receiving orders from the customer.

Experiment

To test the model sensitivity, several experiments using hypothetical data are carried out. These experiments are conducted to test the impact of probability to give external knowledge sharing value of champion agent and UPT, to the *number defect*. The number of agents in these experiments is 100 (99 non-champion agents and 1 agent as initial champion). The *maximum order* variable value is set as 100,000 pairs of shoes per month. In the first experiment the *probability to give external knowledge sharing* value is set as random number between 0.33-0.66. While, in the second experiment the *probability to give external knowledge sharing* value is set as random number between 0.66-1. Other variables in the model are set as random umber. The results of these experiments are shown in the following figures.

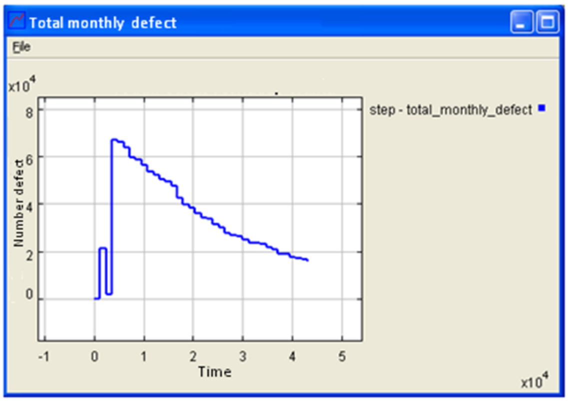

Figure 1. The result of the first experiments

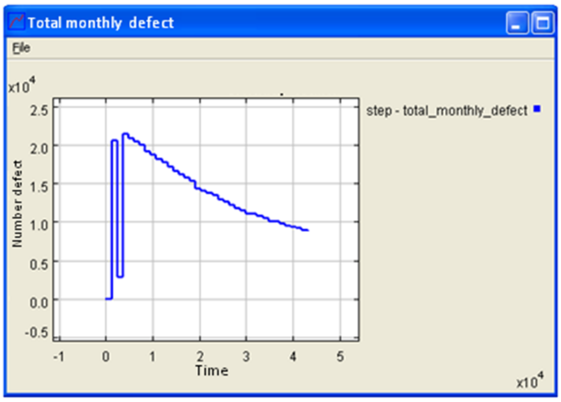

Figure 2. The result of the second experiment

Because these experiments use the hypothetical input parameter, then the results of both of experiments cannot be validated empirically. But the validity of the simulation model behavior is conceptually acceptable. The first reason is that the asymptotic shape of defects versus time curve is in accordance with the theory that has been accepted generally regarding the learning curve. The second reason is that, in optimal conditions (without any interference) it is logically acceptable that the more time given by champion agents and UPT to give technical coaching the faster the number of defect decline.

Since the behavior of the constructed simulation model has been valid (at least conceptually), then this model can be developed further to study the Cibaduyut industrial cluster. Furthermore, this model can be used to generate scenarios and infer policies that can be implemented in Cibaduyut industrial cluster. Of course, for these purposes this model need to be calibrated by using data gathered from the real world.

CONCLUSSIONS

This study has shown why the agent-based modeling and simulation is an appropriate methodology for the SSME researches, especially in industrial clusters. Agent-based modeling and simulation can help researchers to develop a model involving heterogeneous and autonomous agents, that are interrelated, have a dynamic attributes, and interact each other on an ongoing basis. These kinds of model specifications are the one want to be addressed by service dominant logic, which is the framework of the SSME. Through case study conducted in this study it can be concluded that, agent-based modeling and simulation can be used to model the interaction process that occurs within an industrial cluster. Although the experiments were conducted using a hypothetical data, but the behavior exhibited by the model that has been constructed are conceptually acceptable. For further research, the assumptions used in this model should be expanded so that the interactions that occur in the simulation become more realistic. In addition, this model also needs to be calibrated by using data collected from the real world.

REFERENCES

Albino, V., Carbonara, N., & Giannoccaro, I. (2003). Coordination Mechanism Based on Cooperation and Competition within Industrial Districts: An Agent-Based Computational Approach. *Journal of Artificial Societies and Social Simulation , 6*(4), 3.

Axelrod, R. (2005). Agent-Based Modeling as a Bridge Between Disciplines. In K. L. Judd, & L. Tesfatsion (Eds.), *Handbook of Computational Economics Vol.2: Agent-Based Computational Economics.* North Holland.

Carbonara, N., Giannoccaro, I., & Pontrandolfo, P. (2002). SupplFrameworky Chains Within Industrial Distrcts: A Theoretical. *International Journal of Production Economics , 76*(2), 159-176.

Carley, K. M. (1999). On Generating Hypotheses Using Computer Simulations. *Proceedings of the 1999 International Symposium on Command and Control Research and Technology.* Vienna.

De Toni, A., & Nassimbeni, G. (1995). Supply Network: Genesis, Stability and Logistic Implications. A Comparative Analysis of Two Districts. *Omega, International Journal of Management Science , 23*(4), 403-418.

Dei Ottati, G. (1994). Co-operation and Competition in the Industrial as an Organization Model. *European Planning Studies* (4).

Epstein, J. M. (2008). Why Model? *Journal of Artificial Societies and Social Simulation , 11*(4).

Gilbert, N. (2008). *Agent-Based Models.* Los Angeles: SAGE Publications.

Gilbert, N. (2004, December 18). *Agent-based Social Simulation: Dealing with Complexity.* Retrieved June 6, 2009, from http://www.econ.iastate.edu/tesfatsi/ABM.DealingWithComplexity.Gilbert.pdf

Gilbert, N., & Terna, P. (2000). *How to Build and Use Agent-based Models in Social Science.* Retrieved March 3, 2008, from Facoltà di Economia Torino: http://web.econ.unito.it/terna/deposito/gil_ter.pdf

Lusch, R., & Vargo, S. (2008). The Service-Dominant Mindset. In B. Hefley, & W. Murphy, *Service Science, Management and Engineering Education for the 21st Century*. New York: Springer.
Lusch, R., Vargo, S., & Wessels, G. (2008). Toward a Conceptual Foundation for Service Science: Contributions from Service Dominant Logic. *IBM Systems Journal , 47*(1), 5-14.
Maglio, P., & Spohrer, J. (2008). Fundamentals of Service Science. *Journal of the Academy of Marketing Science , 36*(1), 18-20.
Markusen, A. (1996). Sticky Places in Slippery Space: A Typology of Industrial Districts. *Economic Geography , 72*(3), 293-313.
Mrosek, T., Assmann, M., Kies, U., Allen, S., & Schulte, A. (2010). A Framework for Stakeholder Analysis of Forest and Wood-Based Industry Clusters – Case Study at the State of North Rhine-Westphalia,Germany. *The Open Forest Science Journal , 3*, 23-37.
Piore, M., & Sabel, C. (1984). *The Second Industrial District Divide.* New York: Basic Book.
Saxenian, A. (1996). *Regional Advantage. Culture and Competition in Silicon Valley and Route 128.* Hardvard University Press.
Schmid, A. (2005). What is the truth of simulation? *Journal of Artificial Societies and Social Simulation , 8*(4).
Smith, E. R., & Conrey, F. R. (2007). Agent-Based Modeling: A New Approach for Theory Building in Social Psychology. *Personality and Social Psychology Review , 11*(87), 87-104.
Spohrer, J., & Maglio, P. (2010). Service Science: Toward a Smarter Planet. In W. Karwowski, & G. Salvendy, *Introduction to Service Engineering.* New York: Wiley & Sons.
Spohrer, J., & Maglio, P. (2008). The Emergence of Service Science: Toward Systematic Service Innovation to Accelerate Co-Creation of Value. *Production and Operation Management , 17*, 1-9.
Spohrer, J., Vargo, S., Caswell, N., & Maglio, P. (2008). The service System is The Basic Abstraction of Service Science. *41st Annual HICSS Conference Proceedings.*
Srbljinović, A., & Škunca, O. (2003). An Introduction to Agent Based Modelling and Simulation of Social Process. *Interdisciplinary Description of Complex Systems , 1*, 1-8.
Syairudin, B., Sudirman, I., Samadhi, T. M., & Suryadi, K. (2008). Pengembangan Model Knowledge Sharing Berbasis Agen Untuk Klaster Industri Kecil dan Menengah. *Seminar Nasional Sains dan Teknologi-II 2008*, (pp. 136-146). Lampung.
Vargo, S., Lusch, R., & Akaka, M. (2010). Advancing Service Science with Service-Dominant Logic: Clarification and Conceptual Development. In P. Maglio, C. Kieliszewski, & J. Spohrar, *Handbook of Service Science.* New York: Springer.
Vargo, S., Maglio, P., & Akaka, M. (2008). On Value and Value Co-Creation: A service System and Science Logic Perspective. *European Management Journal , 26*, 145-152.