Performance Analysis and Strategic Interactions in Service Networks

Marina Bitsaki
Transformation Services Lab
University of Crete
Crete, Greece
e-mail: bitsaki@tsl.gr

Christos Nikolaou
Transformation Services Lab
University of Crete
Crete, Greece
e-mail: : nikolau@tsl.gr

Manolis Voskakis
Transformation Services Lab
University of Crete
Crete, Greece
e-mail: voskakis@tsl.gr

Willem-Jan van den Heuvel
European Research Institute in Service Science
Tilburg University
The Netherlands
e-mail: wjheuvel@uvt.nl

Konstantinos Tsikrikas
Transformation Services Lab
University of Crete
Crete, Greece
e-mail: cotsik@tsl.gr

***Abstract*—Service businesses are currently viewed as interdependent entities that achieve competitive advantage by fostering partnerships and co-evolving with competitors. Service networks are formed to describe these relationships and reveal value created and shared among them. In this paper, we analyze network participants' behavior aiming to optimize their own value. We describe ecosystems in which more than one competing networks co-exist and interact with one another to their own benefit. We perform simulations to measure the performance of service networks and investigate optimal strategies for competing systems. We describe various scenarios defining dynamic strategies for competing players and show experimentally that after a small number of time slots these strategies reach an equilibrium in which no one is willing to diverge from its decision to his own benefit.**

Keywords-service networks; value optimization; performance analysis; strategic behavior; competing networks

I. INTRODUCTION

In recent years, economic globalization combined with rapid technological progress has led most service companies to coordinate their corporate operations in a world of interactions and partnerships. Companies organize their fundamental structure into service networks capitalizing on the advantage of collaboration. This paper is an extension of [1] and studies the behavior of competing service networks in terms of customer satisfaction and value.

Service networks consist of interdependent companies that use social and technical resources and cooperate with each other to create value [2], [3], [4] and improve their competitive position. The concept of service networks includes a network of relationships between companies where flexibility, quality, cost effectiveness and competitiveness are better achieved than in a single company. The interaction between two participants of a network does not depend solely on their direct connection, but on the impact other relationships within the network have on them. In addition, the network can strengthen business innovation as different parts contribute services to an overall value proposition combining their know-how and core capabilities.

The emergence of service networks forces companies to use alliances in order to achieve a competitive advantage. Man [5] describes various tactics followed by companies to advance their position and analyzes the types of competition that emerge in the network economy. He identifies three forms of competition: competition in networks (collaborating partners compete with each other), competition between networks and competition with organizational forms (smaller companies joining forces to compete with a network).

While various approaches have been proposed to measure the performance of service networks [6], [7], [8], [1], little experimental testing or theoretical investigation on competing networks has been done [9], [10]. Most of the research has focused on describing models that represent inter-organization exchanges. In [6], a quantifiable approach of value calculation is proposed that connects value with expected revenues. In contrast, Biem and Caswell [7] describe building block elements of a value network model and design a network-based strategy for a prescriptive analysis of the value network. Allee [8] provides a systematic way for approaching the dynamics of intangible value realization, inter-convertibility, and creation. Biem and Caswell [7] and Allee [8] use qualitative methods to describe value in a service network in contrast to Caswell et al. [6] that calculates value in a quantifiable manner. The above approaches do not study strategic behavior of network participants that would result in value optimization.

In [9], strategic behavior of service providers *within* service value networks is studied. An auction-based mechanism is proposed in order to efficiently match service offers and service requests and determine prices. It is shown that incentive compatibility holds under certain conditions.

In [10], industry structure is analyzed in the presence of value networks. A model was developed that deals with a number of design aspects such as the number of suppliers and the importance of partner investments. It is shown that industry structure is more likely to shift to competition between value networks with IT playing an important role on that. Systems that encounter competition *between* service networks and are analyzed with respect to their evolution through well defined strategies have received little attention in literature.

In this paper, we study the impact of strategic changes on the performance both at the level of the network as well as its participants compared to that of a competing network. In particular, we describe a framework to analyze competing networks based on the model introduced in [1]. In [1], we measured the performance of one service network solving value optimization problems with respect to service prices. Comparing to previous work that has been done, we improved the estimation techniques and we used a powerful simulation tool to perform our experiments and analyze dynamic "what-if" questions such as: what is the impact of setting optimal – for one participant - prices on the performance of the other participants as well as the entire network? What is the impact on the performance if a new participant suddenly enters the service network? Are there any equilibrium strategies among the participants that eliminate their conflicts of interests?

We observed that participants' value depends on their expected profits. Expected profits express the additional value that will be accrued by the relationship levels a participant develops when it sells goods and services to other participants or to the end customers. This value is related to the degree of satisfaction it obtains from its customers. There are many approaches that have been proposed to measure customer satisfaction. We used the methodology proposed by Fornell et al., known as American Customer Satisfaction Index [11].

In this paper, we extend the initial model to account for competitors of the existing service network. We define the conditions under which two competing networks co-exist, the types of information the networks share and various strategies chosen by the competing participants. We simulate those strategies and observe the behavior of our system over time in terms of profits and market share.

We use the System Dynamics approach [12], [13] to analyze the behavior of a complex system (competing car repair service networks) over time. System dynamics tools allow modelers to succinctly depict complex (service) networks, visualizing processes as behavior-over-time graphs, stock/flow maps, and causal loop diagrams. These models can be tested and explored with computer simulation providing for example better understanding of the impact of policy changes (e.g., through animation of (service) systems) and facilities for sensitivity analysis. Examples of such tools include iThink [13], Vensim [14] and PowerSim [15].

In this paper, we have adopted the iThink tool to investigate existence of equilibrium prices chosen by the keystone member of each network. The results of these simulations provide predictions about the future of the service networks in order to increase its adaptability to the changes of the environment and enable network participants to determine the most profitable co-operations and attract new ones. We show that the interactions among the participants of the competing networks force them to reach equilibrium otherwise the network will collapse.

The remainder of this paper is organized as follows: Section II describes the car repair service system. Section III presents the methodology proposed in [1] to estimate value in service systems. In Section IV, we describe the model of two competing networks and identify the objectives of our analysis. In Section V, we run experiments to measure the performance of a single service network as presented in [1]. The results of the simulations are presented in Section VI. In Section VII, we run experiments to derive equilibrium strategies of companies of competing networks. In Section VIII, we show the results. Finally, in Section IX, we provide some concluding remarks.

II. Case Study

The motivating scenario revolves around a service network that links four types of participants: an Original Equipment Manufacturer (e.g., Volvo), Car Dealers (with repair facilities), Suppliers and Customers.

The scenario that we will use during the remainder of this article is an extension to [6] and basically looks as follows. OEM-franchised dealers may service and repair cars for their clients. Both activities require a car parts catalogue to ensure that repairs can be performed efficiently either in the replacement of parts or repairing after accidents. The part catalogue facilitates efficient installation, operation and lifecycle maintenance of intricate products describing detailed part information that can be fully integrated with other service applications supporting customer support processes, human resource management, and other service provisions.

The quality of the OEM parts, catalogues, and OEM support services influences how many OEM parts will be ordered and used for a car repair and how many parts will be used from Third Party Suppliers (TPS), and how many customers will go to OEM dealers or to TPS dealers. OEM obtains parts from certified supply-chain suppliers (SCS).

The technicians report the car service requirements that may include replacing teardowns, warranty replacements and collision repairs. On the basis of the car diagnosis, a cost estimate will be computed and communicated to the client for authorization. Once authorized the automotive technician will scrutinize failure symptoms, detect faulty parts, order parts and perform the repair. Ordering parts is a complex process that involves asking advice from expert technicians from the OEM, including acquiring information about parts under warranty, and getting approval from the dealer's part manager. The part manager then checks local inventory for the required part, and if necessary checks the stock at the OEM or supplier stocks, and eventually places an order. The part manager may either use third-party suppliers or suppliers from certified supply-chain suppliers.

III. THE MODEL

In this section, we introduce our service performance analytics model in support of strategic analysis of service network changes and improvements as presented in [1]. Theorizing on service networks, and particularly performance analysis, can be addressed from multiple and often complementary perspectives. In our work, we propose a methodology to calculate value in service systems. We focus on the dynamic environment in which service networks emerge, and especially on connectivity and profitable cooperation that play an important role in value creation. We use our model to investigate network profitability and give answers to the following:

- Determine the conditions under which it is profitable for a firm to participate in the network and identify the factors that influence its value.
- Identify keystone participants (participants that create the most value for the network).
- Determine participants' optimal strategic decisions (cooperating with someone or not, joining the network or not, etc.).

We consider the service network as a set *B* of participants connected through transfer of offerings that delivers value to them. All offerings are treated as services that are composed by participants' interactions and co-operations to provide a final service to a set *C* of end customers. Let p_{ij} denote the price participant i charges participant j for offering its services and r_{ij} denote the service time of the interaction between participants i and j. Price and time are the main parameters that affect customer satisfaction which is in turn the corner-stone for calculating value as we will see below.

A. Customer Satisfaction

Customer satisfaction measures the willingness of end customers to buy the services offered by the network and influences the increase or decrease of new entries. The calculation of satisfaction $SAT_{ij}(T_N)$ of participant j for consuming services from participant i at the end of the time interval $[T_{N-1}, T_N]$ for our model is a variation of the American Customer Satisfaction Index (ACSI) [12] and is basically described as follows. ACSI is operationalized through three measures: q_1 is an overall rating of satisfaction, q_2 is the degree to which performance falls short of or exceeds expectations, and q_3 is a rating of performance relative to the customer's ideal good or service in the category. Without loss of generality, we quantify the above measures using the following formula:

$$q_k = [(\beta_k/p_{ij})0.6 + (\gamma_k/r_{ij})0.4],\ k=1,2,3, \qquad (1)$$

where [x] denotes the integer part of x and β_ks, γ_ks are the parameters that determine the effect of price p_{ij} and time t_{ij} respectively on q_k. In our analysis, we use the following function (see [11] for further details) to calculate the satisfaction:

$$SAT_{ij}(T_N)=(w_1q_1+w_2q_2+w_3q_3-w_1-w_2-w_3)/(9w_1+9w_2+9w_3), \qquad (2)$$

where w_k are weights that indicate the importance of each measure q_k.

B. Participants' Value

We consider that an economic entity within a service network has value when it satisfies the entity's needs and its acquisition has positive tradeoff between the benefits and the sacrifices required. We emphasize on the gains or losses captured by the relationships between participants in order to compute value. We define the expected profits $Ep_{ij}(T_N)$ of participant i due to its interaction with participant j to be the expected value of participant i in the next time interval $[T_N, T_{N+1}]$ increased (or decreased) by the percentage change of the expected satisfaction $ESAT_{ij}(T_N)$ in the next time interval and is given by:

$$Ep_{ij}(T_N)=(ESAT_{ij}(T_N)/ESAT_{ij}(T_{N-1}))(ER_{ij}(T_N)-EC_{ij}(T_N)), \qquad (3)$$

where $ER_{ij}(T_N)$ and $EC_{ij}(T_N)$ are the expected revenues and costs respectively for the next time interval. Thus, the value $V_i(T_N)$ of participant i at the end of time interval $[T_{N-1},T_N]$ is the sum of its realized profits (revenues minus costs) and the expected profits that come from its relationships with all other participants. The total value of the network is the sum of the value of each participant.

C. The Mechanism for Value Calculation

In this subsection we present our value-based model that provides a mechanism to calculate value divided in various hierarchical levels. Fig. 1 (generated by iThink) shows the upper level of the hierarchy and visualizes the basic elements of our framework. We use the example of Section II to simplify our description. Each node represents a module that calculates the value of a participant. Arrows represent dependencies between modules. Each module encloses a sub-system that calculates the value of the module (second hierarchical level). Complex variables inside the module are presented as modules too. Fig. 2 shows the dealer's value calculation process. The green arrows show the impact a module has on another module (e.g., dealer's expected profits increase as dealer's revenues increase). The module dealer's cost in the third hierarchical level is depicted in Fig. 3.

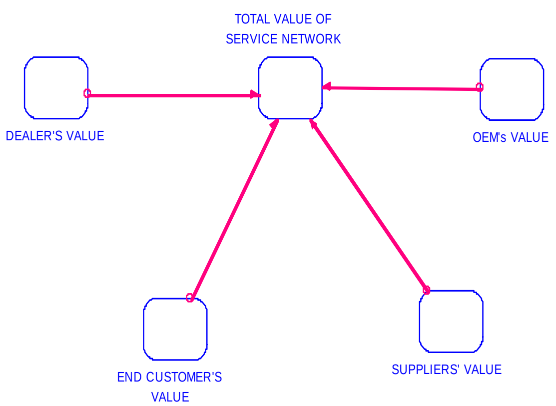

Figure 1. First hierarchical level of value mechanism.

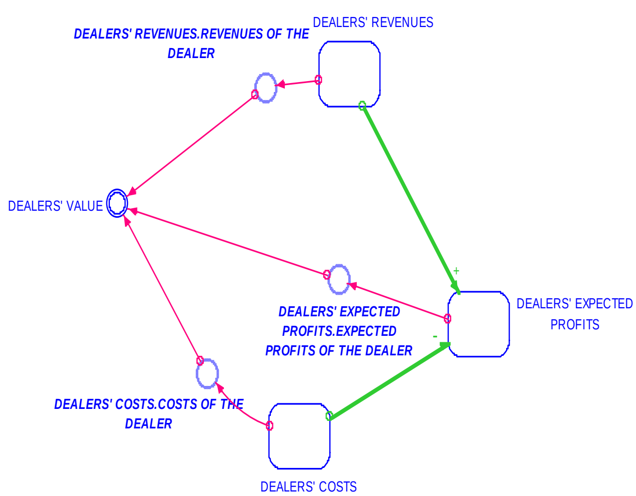

Figure 2. Second hierarchical level – dealer's value.

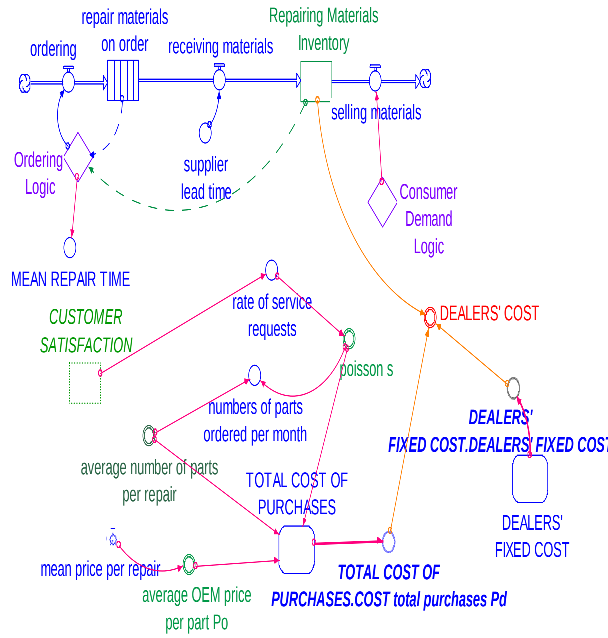

Figure 3. Third hierarchical level – dealer's cost.

IV. COMPETING SERVICE NETWORKS

We consider a complex system comprising two competing service networks A and B that provide the same service k. Our formalization captures the networks characteristics combining service-oriented economy with game theoretic tools.

We are interested in the case where network B is a new entry in the market of service k so that network A has already its own customers. Existing customers may move from network A to network B and vice-versa according to their satisfaction for their provider. New customers may choose a provider based on service price, service time and provider's reputation. We also assume that the two networks might share a common participant (e.g. they might have the same supplier).

Our model studies a two-player game where service providers make choices for prices and service times, have only one type of customers and compete for market share. We define a pure strategy s_i for provider i (i = A, B), the pair $s_i = (p_i, t_i)$, where p_i is the price for the service k and t_i is the service time needed to provide service k. Let S be the set of all pure strategies for each provider.

This game is different from the traditional economic models where providers are considered to be autonomous entities whose set of actions do not include interactions with others. The providers in our analysis are part of more complex systems whose actions affect other participants' actions that in turn affect them and so on.

In the absence of competition, a provider seeks to maximize its individual profits rather than the overall social welfare of the system it belongs to. In this case, the social welfare achieved by the provider's actions is less than the maximum social welfare achievable if a social planner were to select the provider strategies. In the model of competing providers (this is the case of oligopoly market and not perfect competition), the equilibrium strategies do not necessarily maximize social welfare as well.

Our objective is twofold. First, we seek to derive equilibrium strategies for the providers, given that all other participants of their own networks have revealed their actions. A Nash equilibrium is a pair of strategies, one for each provider, in which each provider is assumed to know the equilibrium strategies of his opponent, and no one benefits by changing only his own strategy unilaterally [16], [17]. In our game, $s^* = (s_1^*, s_2^*)$ is a Nash equilibrium in pure strategies if for each $s_1, s_2 \varepsilon S$, value satisfies the inequalities:

$$V_A(s_1^*, s_2^*) \geq V_A(s_1, s_2^*), \quad (4)$$

$$V_B(s_1^*, s_2^*) \geq V_B(s_1^*, s_2), \quad (5)$$

where V denotes the value at a fixed time interval as given in Section III.

Second, we investigate the evolution of the two networks over time in terms of survivability and dominance in the market.

V. Simulation Experiments for the Car Repair Service Network

In this section, we describe in short, simulation experiments (as performed in [1]) to measure the performance of a single service system. In Section VII, we design experiments involving two competing networks, in order to derive equilibrium strategies and observe the system's evolution over time.

We make use of 4 scenarios. First, we apply our approach to the car repair service system (Section II) to examine the network's evolution over time. We represent technicians, the parts manager, and the help desk experts as economic entities, each of which is offering its labor as a service to the service system. We measure rates of offerings and payment flows per month over a period of about 30 months. End customer service requests denoted by *s* are strongly affected by end customer satisfaction, since satisfied customers attract new customers to enter the network. Without loss of generality, we consider that the service requests are produced by the Poisson distribution with mean *es* being the output of the function:

$$es = -a_1SAT^2 + a_2SAT, \quad (6)$$

where $a_2>2a_1>0$ so that es is an increasing function of SAT in the range [0,1]. (We have chosen (6) because the rate of increase of *es* decreases with respect to SAT.) We also consider that the number of technicians is a function of the number of service requests; we take that the number of technicians increases linearly with the number of service requests. We calculate the value of each participant as a function of price and time and determine its optimal level with respect to price.

Second, we use the transformation of the basic model, as in [6], in order to cut costs and increase value. Specifically, a solution provider achieves interoperability between participants' information systems through application software operated by the OEM. The application allows everyone to have access to up-to-date information about parts at any time, as soon as this information becomes available to the data base of the application. The gain from the new IT infrastructure is twofold: repair time is reduced resulting in customer satisfaction increase and OEM's mailing costs are eliminated. We apply our methodology to the transformed network to show that the continuous changes of the environment push the network to restructure itself in order to remain competitive. We determine the time interval in which we observe positive effects in profitability in the transformed network compared to the initial one. We also determine which of the participants benefit from the transformation and which not.

Third, we consider a model in which the group of dealers is replaced by a new one that offers more complementarities to the end customers without increasing the mean repair price. This action seems to be profitable due to the increase of the satisfaction of the end customers of the service network. However new dealers have higher costs that may affect service network's value. We examine the value of these dealers and the value of the entire service network provided that OEM chooses to cooperate with them.

Fourth, we investigate Nash equilibrium strategies [16], [17] between OEM and the dealer. We define as a strategy for OEM and the dealers the mean profit rates a and b of selling parts and repair services respectively. Let p_s, p_0, p_d be the mean prices set by the suppliers, OEM and dealers respectively for offering their services. Then it holds that:

$$p_0 = p_s + ap_s = (1+a)p_s, \quad (7)$$

$$p_d = p_0 + bp_0 = (1+b)p_0. \quad (8)$$

We examine the existence of equilibrium strategies considering that the rest of the network participants (apart from OEM and the dealer) do not affect their decisions. We assume that OEM buys parts from certified suppliers at a given price p_s.

VI. Results For The Performance of the Network

In this section, we present the simulation results from our analysis. First, we compare the basic model with the transformed one.

A .Value Optimization in Basic and Transformed Network

We show the mean repair price p* that maximizes the dealers' and OEM's value in Table I.

TABLE I. Comparison Between the Basic and the Transfomed Nework

Value	Model			
	Basic Network		***Transformed Network***	
p*	111 (dealer)	225 (OEM)	116 (dealer)	218 (OEM)
Dealer	51.469.012	34.700.000	46.874.332	34.985.000
OEM	$8500*10^6$	$26793*10^6$	$9100*10^6$	$29990*10^6$

We observe that:

- The dealers' optimal mean repair price in the basic service network is lower than in the transformed service network, since the mean repair time (that affects value) decreases, so the dealer charges his customers less. Consequently, the dealer is forced to increase the mean repair price in order to increase its revenues. Nevertheless, at the optimal mean repair price, dealers' value is less in the transformed network since the customer satisfaction has decreased as well (higher charges).
- OEM's value is much higher in the transformed network than in the basic one. This is explained by the fact that the mean repair time decreases and the customers are more satisfied (at OEM's optimal mean repair price). In addition, OEM in the transformed network has much lower mailing and labor costs.
- In both networks OEM's value at dealer's optimal mean repair price (111 and 116 respectively) is very low compared to OEM's value at his optimal mean repair price. This means that OEM will never be satisfied to offer its services at prices that reach dealer's optimal level.
- Dealers' value at OEM's optimal mean repair price is higher in the transformed network, since OEM's optimal price is lower (218).

Furthermore, the simulation results show that, OEM's value in the transformed network is not higher than that of the basic network from the first month. It dominates after 10-12 months, when both networks offer their final services at their optimal mean repair price (Fig. 4). When both networks offer their services at common prices in the range of 80 to 350, the transformed network dominates the basic network at month 8 to 17.

Finally, the total value of the transformed network (32.190.040.300) is maximized at mean repair price 216 and is higher than that of the basic network (28.593.400.000) which is maximized at mean repair price 223. This is explained by the fact that end customers are more satisfied and OEM (the keystone participant) has managed to cut costs at a great extend in the transformed network. Moreover, we see that the optimal mean repair price for both service networks is very close to the optimal mean repair price of OEM, since OEM contributes the largest part of the total value of the network.

B. Sensitivity Analysis of the Mean Repair Price

In this section, we investigate the impact of mean repair price changes to the dealers' value. As the mean repair price increases, the difference between the dealers' value in the basic network and that in the transformed network is smaller. This is justified by the fact that although the service requests decrease the mean repair price increases resulting in a decrease of the total value as shown in Fig. 5.

C. The Impact of New Entries

We call the network with the new group of dealers, the competitive network. We calculate values in the new scenario at mean repair price 216 which is the optimal price for the transformed network. We investigate the impact of the change of dealers letting the price unchanged so that the end customers are motivated to remain in the network. We show that dealers' value (31.527.812) is lower in the competitive network compared to the transformed one (35.481.031), since the new dealers' cost is higher due to the complementarities they offer. In addition, OEM's value increases (from 29.793.000.000 to 31.713.504.020) due to the increase of the service requests. The total value of the network increases from 32.190.040.300 to 32.792.529.000.

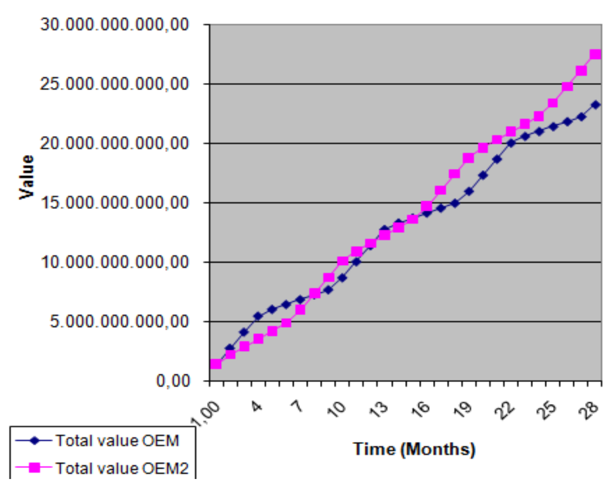

Figure 4. OEM's value in basic (1) and transformed (2) network at common mean repair prices.

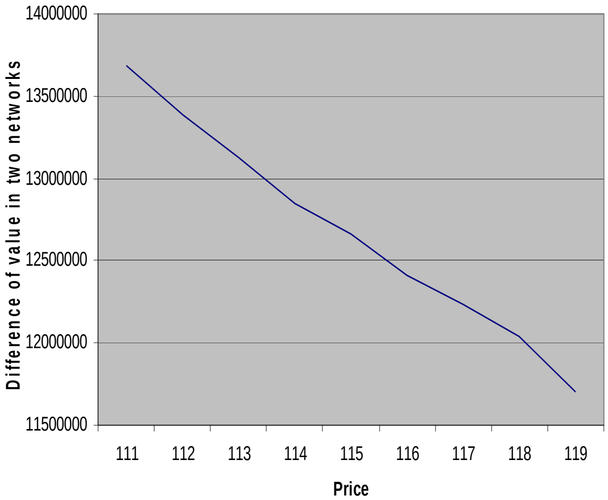

Figure 5. Dealers' difference of value in basic and transformed networks.

From the above we observe that a change in the network that improves its performance may affect positively some participants and negatively others. Naturally, dissatisfied participants abandon the network causing side effects to the others.

D. Participants' Equilibrium Strategies

We perform two experiments in order to investigate strategic interactions and determine equilibrium strategies of OEM and dealers. In the first experiment we calculate OEM's optimal profit rate at a given profit rate for the dealer. Simulations show that when the dealer increases its profit rate (e.g., from 6% to 10%), OEM's optimal choice is to decrease its optimal profit rate (from 24% to 21%). Conversely, if OEM increases its profit rates (e.g., from 14% to 21%), the dealer optimally decreases its profit rate (from 15% to 10%).

The second experiment calculates a set of equilibrium strategies for OEM and the dealer: at dealer's profit rate of 10% the optimal OEM's profit rate equals 21%. Conversely, at OEM's profit rate of 21% the optimal dealer's profit rate equals 10%.

VII. SIMULATION EXPERIMENTS FOR THE MODEL OF TWO COMPETING SERVICE NETWORKS

In Section V, we defined strategies involving two participants within the same repair service network (OEM and dealer). We figured out that their decisions were aligned so that value was increased for both of them.

In this section, we use the same model for value calculation to design experiments on a complex system of two competing networks; A and B as shown in Fig. 6. We consider that service network B has lately entered the market and serves a smaller portion of customers than service network A.

New customers are free to choose any of the two service networks to have their car repaired. More interestingly, customers may choose to abandon one network for the other when they are not satisfied from the services of their dealers. Even though OEMs are not directly connected to customers, their actions affect dealers' decisions which in turn affect customer satisfaction resulting in the restructuring of market share (Fig. 6).

We are interested in strategic behavior of the two OEMs provided that the other participants' and competitors' actions are kept fixed. Both OEMs seek to maximize their own value and achieve this by participating in a sequential game rather than solving the problem defined in Section IV in a one-shot game. At each time period, each OEM exploits information revealed by his opponent and makes decisions on which prices to charge dealers and which delivery times to complete dealers' orders for parts for the next time period.

We describe 4 scenarios defining dynamic strategies for the OEMs and show that after a small number of time slots these strategies reach an equilibrium in which no one is willing to diverge from its decision to his own benefit.

Let $v_i(t)$ be the value at time slot t, $n_i(t)$ be the number of ordered parts at time slot t, $p_i(t)$ the mean price per part at time slot t and $d_i(t)$ the mean delivery time at time slot t for OEM i.

In the first scenario, information revealed for each OEM in each time slot is the number of ordered parts of its opponent for the previous time slot. We consider symmetric strategies (same rule for both OEMs), where delivery time $d_i(t)$ is left fixed for the whole duration of the experiment and price $p_i(t)$ is changed according to the algorithm 1 shown in Fig. 7 (where i, j = A, B, $i \neq j$ and $\varepsilon > 0$).

As can be seen in Fig. 7, we use two criteria to determine the price for OEM i; we compare its value in two consecutive time slots and the number of orders with that of its competitor. At this point, we should mention that if we observe a loss in the value and a higher market share than our opponent, then we decide to increase price by a small increment since we can afford a small reduction in the

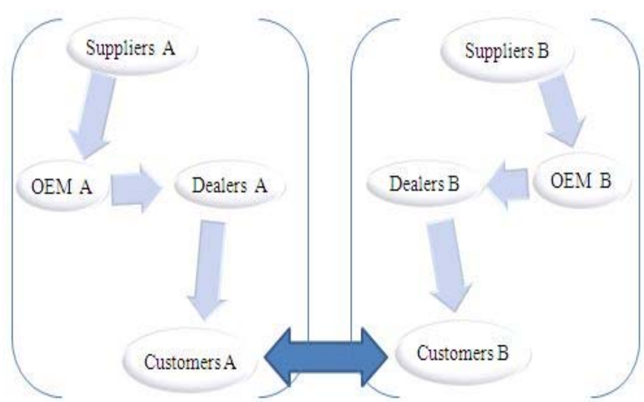

Figure 6. The competing networks interacting through their customers.

number of customers but we will gain more revenues aiming at a total increase of value.

In the second scenario, information revealed for each OEM in each time slot is the number of ordered parts of its opponent for the previous time slot and additionally for OEM of network B, the price of the previous time slot set by OEM of network A.

The strategy for each OEM is not symmetric (the two OEMs follow a different strategy), taking delivery time to be fixed for the whole duration of the experiment and price to be changed as shown in Fig. 8.

In this case, we change the order of the criteria placing the comparison of the number of orders first. Additionally, player B uses its opponent's former prices to gain competitive advantage when the performance of the network it participates is observed to be decreased.

In the third scenario, information revealed for each OEM in each time slot is the number of ordered parts of its opponent for the previous time slot. The strategy for OEM of network A is the same as in scenario 2 but OEM of network B follows a different strategy that is considered to be more risky since it takes into account the variability of mean delivery time (see Fig. 9).

In the fourth scenario, we study the behavior of the weaker competitor (network B) given that he first observes the behavior of his opponent. Again, the number of ordered parts in the two networks is common knowledge to both of them. OEM of network A (price leader) determines its own price following the same strategy as in scenario 1 (see Fig. 7). According to this price, OEM of network B (price follower) sets its price for the next time slot according to the rule given in Fig. 10.

We conduct simulations for the above scenarios and examine whether the strategies defined in each of them reach an equilibrium in the sequential game. In addition, we compare the values of the competitors and draw conclusions for their evolution over time in terms of dominance and survivability.

The time slot in all experiments is measured in months. We run simulations for 60 months and set the initial price

```
if  v_i(t) < v_i(t-1)
        if   n_i(t-1) < n_j(t-1)
                p_i(t) = p_i(t-1) – ε
        else
                p_i(t) = p_i(t-1) + ε
else
        p_i(t) = p_i(t-1)
```

Figure 7. Algorithm 1: strategy for OEM i in the first scenario.

```
STRATEGY FOR A

if  n_A(t-1) < n_B(t-1)
        if   v_A(t) < v_A(t-1)
                p_A(t) = p_A(t-1) – ε
        else
                p_A(t) = p_A(t-1)
else
        p_A(t) = p_A(t-1)

STRATEGY FOR B

if  n_B(t-1) < n_A(t-1)
        if   v_B(t) < v_B(t-1)
                p_B(t) = p_A(t-1) – ε
        else
                p_B(t) = p_B(t-1)
else
```

Figure 8. Algorithm 2: strategy for OEMsA and B in the second scenario.

```
if  n_B(t-1) < n_A(t-1)
        if   v_B(t) > v_B(t-1)
                p_B(t) = p_B(t-1) + ε
                d_B(t) = d_B(t-1) – ε
        else
                p_B(t) = p_B(t-1) – ε
                d_B(t) = d_B(t-1) + ε
else
        p_B(t) = p_B(t-1)
        d_B(t) = d_B(t-1)
```

Figure 9. Algorithm 3: strategy for OEM B in the third scenario.

for OEM A to be higher ($p_A(1) = 200$) than that of OEM B ($p_B(1) = 190$) since the new competitor needs to provide incentives to the forthcoming customers.

VIII. Results For The Startegic Behavior of Competing Service Networks

The main results for the strategic behavior of the competing OEMs are presented in this section. In the first scenario, the value of OEM A decreases and the value of OEM B increases up to month 4, where equilibrium is reached as shown in Fig. 11. That is, neither OEM A nor OEM B are willing to change the derived prices followed by their strategies after month 4.

The intuition behind this result is that higher prices for OEM A imply higher service prices for dealers, thus, decreasing customer satisfaction. As a consequence, a considerable portion of market share has moved from OEM A to OEM B so that symmetric strategies have created networks of comparable size.

The second scenario in which the most recently set up network imitates its opponent's decisions in case of unstable situations, has similar results as the first one. Customers of network A join network B in presence of lower prices up to month 4 at which an equilibrium is reached (see Fig. 12). Despite the same shapes of value curves between the two networks under the two scenarios, the actual value level for each network is increased in the second scenario. This is due to the fact that the prices change more aggressively in the second scenario without implying losses in value.

In the third scenario, OEM B changes his strategy to encounter delivery time in addition to price. This has as a result an aggressive increase in customer satisfaction, since customers are given the opportunity to choose a relatively small increase in price at a shorter service time. This entails an increase in value for OEM B up to month 8 after which an equilibrium is reached. On the contrary, OEM A faces a loss in its value in the absence of time reductions (see Fig. 13). At month 4, the value of OEM B becomes higher compared to the value of OEM A showing that at this time slot the number of customers of the second network gets larger than that of the first one. The flexibility practiced by OEM B gave him the opportunity to change the balance of the market to its own benefit.

The simulations of the forth scenario verify our intuition that the leader (network A) faces the smaller loss in value (and consequently in the number of customers) compared to the other scenarios. This is explained by the fact that it is the first to choose a price and predict its opponent's choice that will be based on this price. As can be seen in Fig. 14, equilibrium is reached at month 6 with OEM A having a significantly larger value than that of OEM B.

if $v_B(t) < v_B(t-1)$
    if $n_B(t-1) < n_A(t-1)$
        $p_B(t) = p_A(t) - \varepsilon$
    else
        $p_B(t) = p_A(t) + \varepsilon$
else
    $p_A(t) = p_A(t-1)$

Figure 10. Algorithm 4: strategy for OEM B in the forth scenario.

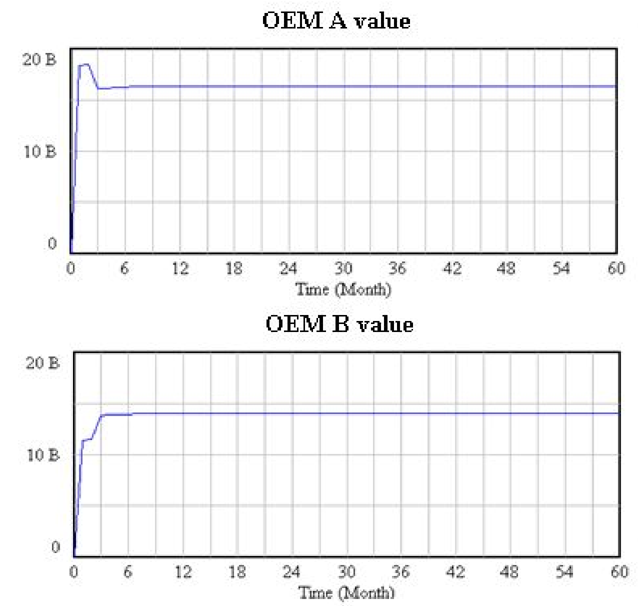

Figure 11. Value comparison in the first scenario.

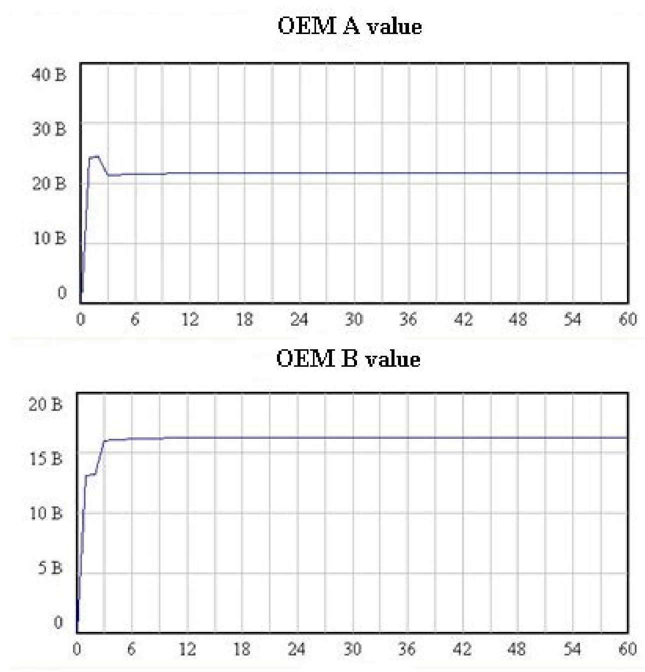

Figure 12. Value comparison in the second scenario.

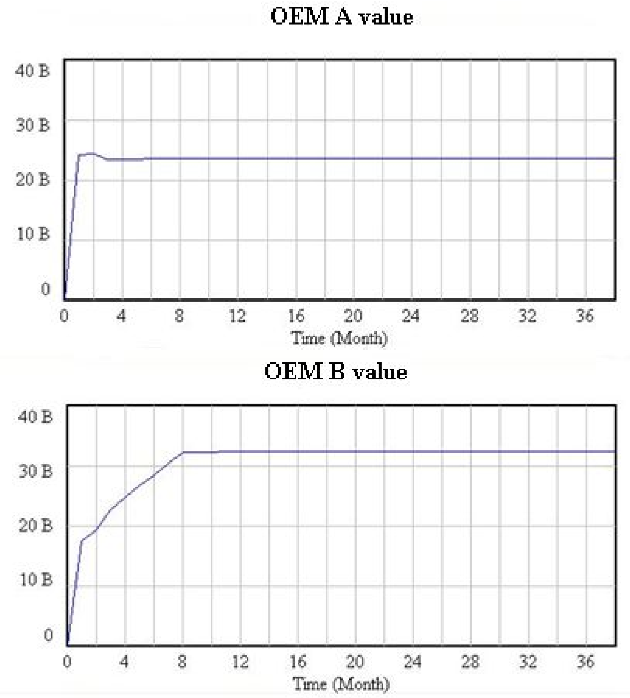

Figure 13. Value comparison in the third scenario.

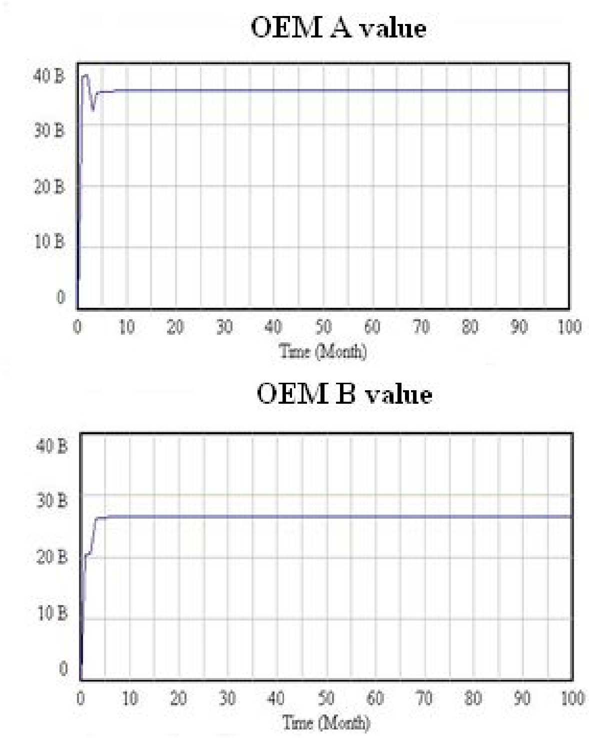

Figure 14. Value comparison in the forth scenario.

IX. Conclusions and Future Work

In this paper, we proposed a methodology that evaluates the performance of service systems and analyzes strategic interactions between competing service networks. We applied this methodology to a car repair service network. We run simulation experiments to maximize the value of each participant and the total value of the network. In addition, we defined suitable scenarios to study the internal relationships that are developed inside the service network. We examined the interactions between the participants inside the service network in order to determine their optimal choices. We further designed simulations to investigate equilibrium strategies followed by leading participants of competing car repair service networks. We showed that in order to gain competitive advantage, a company has to align its objectives with those of the network it belongs to.

Directions for future work include the study of competitive service networks in which all participants take into account their rivals' and partners' strategies in order to calculate their optimal choice. Furthermore, additional work is needed on the estimation of value of intangible assets such as knowledge, sense of community, etc.

References

[1] M. Voskakis, C. Nikolaou, Willem-Jan den Heuvel, and M. Bitsaki: "Servive network modelling and performance analysis". Proc. International Conference on Internet and Web Applications and Services (ICIW 2011), St, maarten, The Netherlands Antilles, 2011.

[2] J. Spohrer, P. Maglio, J. Bailey, and D. Gruhl, " Steps towards a science of service systems", Computer 40(1), pp. 71–77, 2007.

[3] V. Allee, "The future of knowledge: increasing prosperity through value networks", Butterworth-Heinemann, Boston, 2002.

[4] J. Gordijn and H. Akkermans, ''Designing and evaluating e-business models,'' IEEE Intelligent Systems 16, No. 4, 11–17, 2001.

[5] Ard-Pieter de Man: "The network economy: strategy, structure and management", Edward Elgar, USA, 2004.

[6] N.S. Caswell, C. Nikolaou, J. Sairamesh, M. Bitsaki, G.D. Koutras, and G. Iacovidis, "Estimating value in service systems", IBM System Journal, vol. 47, nr. 1, pp. 87-100, 2008.

[7] A. Biem and N. Caswell, "A value network model for strategic analysis", Proc. 41st Hawaii International Conference on System Sciences, 2008.

[8] V. Allee "Value network analysis and value conversion of tangible and intangible assets". Journal of Intellectual Capital , Volume 9, No. 1, 5-24, 2008.

[9] Clemens Van Dinther , Benjamin Blau , and Tobias Conte : "Strategic behavior in service networks under price and service level competition". Proc. International Conference on Business Informatics, 2009.

[10] Evangelos Katsamakas: "Competing value networks, incomplete contracts and IT". Proc. International Conference on System Sciences, 2005.

[11] C. Fornell, M.D. Johnson, E.W. Anderson, J. Cha, and Bryant B.E., "The American customer satisfaction index: nature, purpose, and findings", Journal of Marketing 60, 7–18, 1996.

[12] Jay W. Forrester, "Industrial Dynamics", Pegasus Communications, 1961.

[13] "http://www.iseesystems.com/softwares/Business/IthinkSoftware.aspx", January 2012.

[14] "http://www.vensim.com", January 2012.

[15] "http://www.powersim.com", January 2012.

[16] J.D. Sterman, "Business dynamics: systems thinking and modeling for a complex world", McGraw-Hill, 2000.

[17] D. Fudenberg and J. Tirole, "Game theory". MIT Press, 1991.