Impact of Information Distortion in Service Supply Chains

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Abstract: This study analyzes the information distortion problem within the context of service industries, and measures the amplification effect in a make-to-order environment for the Mortgage Service Game. In order to measure the impact of several factors managed by the service companies, such as capacity adjustment time, service delay time, information sharing, and variability of application start rate on information distortion, a simulation model is developed for Mortgage Service Game. Based on the original Mortgage Service Game settings, it is found that higher rates of information sharing on new application rates, and service delay times as well as lower capacity adjustment times speed up the system to reach stabilization. Under the different value combinations of the factors, it should be noted that amplification effect diminishes while information sharing and service delay time increase. Somewhat surprisingly, amplification effect weakens with increasing variability in the new application start rates. In contrast, the shorter capacity adjustment times lead to less amplification on SSCs. It is noted that service delay time and rate of information sharing act very similarly in view of amplification effect at all stages.

Keywords: Service Operations Management, Supply Chain, Information Distortion, Mortgage Service Game.

I. Introduction

Service companies, especially small businesses, are striving to increase their shares in increasingly competitive world market. As demand for many services is growing rapidly, effective management of services is becoming essential for service companies. For both service and manufacturing companies, communication and information sharing are vital not only within the company itself but also among the companies. As a matter of fact, supply chain management (SCM) is becoming an important tool for not only manufacturing firms but also for service firms.

As compared to SCM, Service Supply Chain Management (SSCM) has been a relatively new area with a paucity of research in the relevant literature. Over the past few decades, service sector has dramatically become an important force in the most nations' economies contributing largely to the world gross domestic product (Ellram et al., 2004; Fitzsimmons & Fitzsimmons, 2006). Also, services account for more than two-third of overall employment in both developed and emerging countries.

Despite the growing interest in services, the distinction between manufacturing and services is not always clear (Cook et al., 2001). Baltacioglu et al. (2007) state that "the service supply chain is the network of suppliers, service providers, consumers and other supporting units that performs the functions of transaction of resources required to produce services; transformation of these resources into supporting and core services; and delivery of these services to customers." In a similar vein, but with somewhat more emphasis on customer satisfaction, Liu et al. (2008) define the service supply chain (SSC) as "a service-network that reorganizes different service entities in order to satisfy customers' requirements by using modern management technology to break down and rebuild a system which considers customers' demands as starting point and takes a complex service or an integrated service package as a series of processes in service when the service-industries are developed to some extent." Therefore, SSCM deals with the management of information, processes, capacity, service performance, and funds (Ellram et al., 2004; Fitzsimmons and Fitzsimmons, 2006).

Related to SCM, there are some models to examine the behavior of manufacturing supply chain companies such as HP, SCOR, and the global supply chain forum framework (GSFC) depicted by Croxton et al. (2001) based on Porter's value chain model (Porter, 1985). According to Ellram et al. (2004), each of these studies falls short on representing the characteristics of SSCM such as the inventory, quality, return cycle, and flow of services. Instead they propose a new SSC model/framework based on a modified GSFC model which includes six processes: capacity management, demand management, customer relationship management, supplier relationship management, service delivery management, and cash flow management.

Considering the foundational motivations and rationale behind the SCM and SSCM, it becomes reasonable to consider many problems that are related to both environments. One of these problems which have received some research attention is information distortion in supply chains of both manufacturing and services. Despite the fact that there are several studies dealing with bullwhip effect for manufacturing supply chains, there is a paucity of research on information distortion in services supply chains. A highly well known, Beer Game in the literature is the most popular game and is generally used to demonstrate the information distortion in manufacturing supply chains. Since almost all orders in services are make-to-order, Beer Game may not be suitable to demonstrate service supply chains. Very similar to Beer Game, Anderson and Morrice (2000) developed a four-stage mortgage service game to show information distortion and amplification problems in SSCs. Generally speaking, capacity planning over services supply chains is considered as one of the main sources of the information distortion. To eliminate the problem of information distortion, the companies are suggested to share their capacity plans throughout the whole chain.

In this study, information distortion problem leading to amplification effect within service industries is analyzed based on the framework of Mortgage Service Game. First, a simulation model for Mortgage Service Game is developed. Then, the model is verified and validated. The several factors managed by the service companies, such as capacity adjustment time, service delay time, information sharing, and variability on application rates are also discussed to observe their impact on information distortion.

II. Information Distortion in SSCM

Information distortion also known as Bullwhip or Forrester effect is a phenomenon where orders to supplier tend to have larger variance than sales to the buyer, and customer demand is distorted (Lee et al., 1997; Bayraktar et al., 2008). This phenomenon may appear in both manufacturing and services industries. The majority of existing research on information distortion has been concentrated in manufacturing environments with only few studies focusing in service settings. Some of the well-known causes of information distortion in manufacturing systems include internal system inefficiencies (Forrester, 1961), misperception of feedback loops and irrational reaction of decision makers (Sterman, 1989). Recently, Lee et al. (1997a, 1997b) analytically show that bullwhip effect exists even if all members of the supply chain behave optimally. They identify four main factors leading to information distortion: demand forecasting, order batching, price fluctuations, and rationing and shortage gaming. In contrast to the several studies in manufacturing, only two of the studies undertaken by Anderson and Morrice (2000) and Akkermans and Vos (2003) clearly focused on the problem of information distortion in services. The former develops the Mortgage Service Game to study decision-making in a service-oriented supply chain which consists of four steps: initial processing, credit checking, surveying and title checking. In order to measure amplification effects, Anderson and Morrice (2000) used work-backlog instead of finished goods inventories in manufacturing. Each process can only control its backlog by managing its capacity, that is, the number of employees. Anderson and Morrice (2000) show the presence of amplification effects in services, and suggest sharing the demand information throughout the SSC to diminish its effects. The latter research relies on a case study of the telecommunication industry to improve the quality and flexibility of the services. The case has also four separate stages: selling, provisioning, install and billing. Each stage has a finite capacity derived from the number of staff working in the stage as well as their skill levels and working hours. Akkermans and Vos (2003) suggest using workload in each stage to measure the amplification effects in SSC. They also confirmed the occurrence of upstream amplification of workload, and the validity of many root causes of “bullwhip effect” in manufacturing industries other than batch ordering and shortage-gaming.

Due to their intangible nature and their delivery being basically make-to-order, services are simultaneously produced and consumed. Order batching is not relevant as a root cause of amplification effects in service operations (Akkermans and Vos, 2003). Very similarly, direct interaction with the customer is quite common in services, and demand signaling is unlikely to be a major cause of amplification other than the back-office processes of services. On the other hand, rationing and shortage gaming as well as price fluctuations can be considered as major sources of amplification in services. Especially in periods of anticipated capacity shortages for services like hotel rooms or airline seats, customers may place orders to various suppliers to increase the likelihood of fulfilling their demand (Akkermans and Vos, 2003). The yield management practices to attract customers in anticipation of periods of reduced demand may also lead to differential prices.

In order to dampen down the information distortion problem leading to amplification effect in SSCs, Akkermans and Vos (2003) suggest sharing capacity and backlog information, stabilizing prices, applying strict quality controls, and advance capacity reservations. Advance capacity reservations in services would actually mean having sufficient employees to be present to deal with sudden increases in customer demand. It appears that, this may be practically impossible in case of unexpected events such as extreme weather conditions or computer breakdowns, and employees may not be readily available. Quality of service processes and strict quality controls on the workers trained to provide high-quality services to customers help to predict the performance of service as well as diminish the amplification effect.

III. Simulating a Service Supply Chain

The amplification effect in SSCs will be analyzed based on the model of the mortgage service game developed by Anderson and Morrice (2000). In this game, there are multiple, potentially autonomous, players performing a sequence of operations by make-to-order principles, and managing order backlogs by adjusting capacity. Very similarly to "Beer Game", which is a well-known supply chain game for manufacturing, the aim of the mortgage service game is to exercise how well the participants apply the SSC principles and how effectively they use end-user demand information to reduce backlog to improve their performance.

Mortgage service game presents a simplified mortgage approval process with each mortgage application passing through four stages namely: *initial processing* (filling out the application with a loan officer), *credit checking* (confirmation of employment and review of credit history through approval), *surveying* (a survey of the proposed property to check for its value, as well as any infringements upon zoning laws or neighboring properties), and *title checking* (ensuring that the title to the property is uncontested) (Anderson and Morrice, 2000). In practice, the problem occurs when each stage is managed by different companies, because each company controls its own individual capacity and can only see its own backlog to make the decision, and the companies cannot see the new application rate or other stages' backlogs. This creates amplification effect similar to the bullwhip effect, and it is controlled by the backlogs in the Mortgage Service Game in contrast to inventories in the Beer Game.

The Model of Mortgage Service Game

In each of the four stages in the Mortgage Service Game, players manage their own backlog by controlling the number of workers, which constitutes the capacity of each stage. Mathematically, Anderson and Morrice (2000) describe the game structure for each stage as follows:

$$r_{i,t} = min\,(C_{i,t}, B_{i,t} + r_{i-1,t})$$
$$B_{i,t+1} = B_{i,t} + r_{i-1,t} - r_{i,t}$$
$$C_{i,t+1} = C_{i,t} + (C^*_{i,t} - C_{i,t})/\tau \qquad (1)$$
$$C^*_{i,t} = \begin{cases} \alpha\, r_{0,t} + (1-a)B_{i,t}/\lambda & \text{if mod } t = 0 \\ C^*_{i,t-1} & \text{otherwise} \end{cases}$$

Where

$B_{i,t}$: Backlog at stage i on day t
$C_{i,t}$: Capacity at stage i on day t
$r_{i,t}$: Completion rate at stage i on day t
$r_{0,t}$: New application start rate
α : Rate of information sharing $(0 \le \alpha \le 1)$
λ : Service delay time
$C^*_{i,t}$: Target capacity ($C^*_{i,t} \ge 0$)
τ : Capacity adjustment time.

For simplicity, it is assumed that each employee has a productivity of one application per day (Anderson and Morrice, 2000). Each stage's backlog and capacity are initialized at the beginning of the game to $B_{i,0} = \lambda(r_{i,0})$ and $C_{i,0} = r_{i,0}$, respectively so that the backlogging and completion rates at each stage are in balance. At the beginning of a week (i.e., every 5 business days), each player can change its target capacity by deciding to hire or fire employees, but reaching to the desired number of employees may take time due to the delay associated with the process of advertising, interviewing, and hiring the employees. In case the capacity is adjusted before the previous target capacity adjustment is completed, the previous target will be ignored, and the capacity will begin to adjust next day from its current value toward the new target.

Simulation of the Mortgage Service Game

The simulation model representing a four-stage SSC measures the impact of the main control parameters on the amplification effect, which include variability in application start rate for each day ($r_{0,t}$), target capacity adjustment time (τ), the nominal service delay time (λ), and the proportion of information sharing rate (α). The amplification effect is calculated as the ratio of variance of the completion rate at stage i ($r_{i,t}$) to the variance of the new application start rate ($r_{0,t}$), which is *Amplification effect (i) = Var* $(r_{i,.})/Var(r_{0,.})$.

The SSC model above is simulated for 540 weeks (2700 business days). The first 54 weeks (270 business days) of simulation run is considered as the warm-up period, and eliminated from the output analysis. The rest of the data (495 weeks, 2430 business days) is used for effective simulation output analysis. Additionally, 20 replications are performed for each scenario.

In order to verify and validate the simulation we compared the application processing rates and backlogs of each state over time with the ones provided by Anderson and Morrice (2000: 45-46). So, the new application start rate was initially set to 20 until after 8 weeks and then increased to 27 per day and remained constant until the end of the week 100. Additionally, capacity adjustment time (τ), service delay time (λ) and the rate of information sharing (α) were set to 20, 10, and 0, respectively. Also, each stage began with a backlog of 200, the capacity of 20, and the target capacity of 20 applications per day. The results showed that the simulation model was capable of producing the same outputs as shown in Figures 1 and 2 in terms of applications processing rates and stage backlogs for all stages over time.

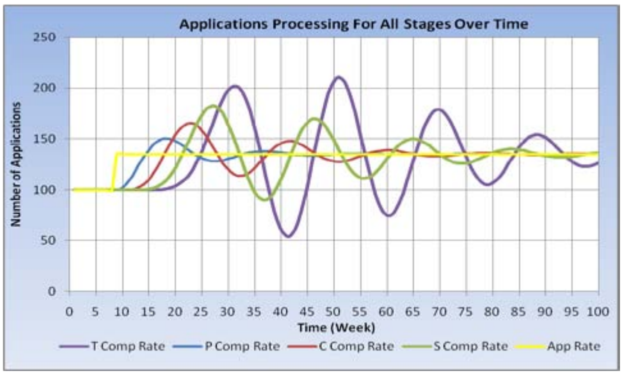

Figure 1: Applications processing rates for all stages over time

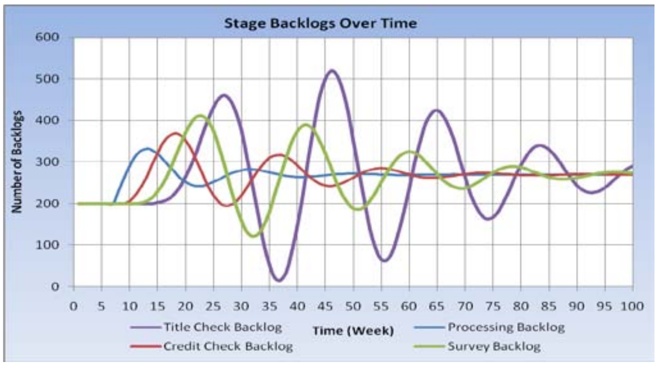

Figure 2: Stage backlogs over time

Table 1: Independent factors of the experimental design

Independent factors	Levels		
	1	2	3
New application start rate ($r_{0,t}$)	U[19,21]	U[18,22]	U[15,25]
Adjustment capacity time (τ)	15 day	20 day	25 day
Service delay time (λ)	5 day	10 day	15 day
Proportion of information sharing rate (α)	0	0.5	1

Experimental Design

A total of four factors, which are considered as influential factors over amplification effect in SSCs, are selected in the simulation model. These factors are namely variability of new application start rate, capacity adjustment time, service delay time, and the rate of information sharing. Each of these factors is analyzed in three levels in the simulation. The levels of these factors with their respective values are listed in Table 1. With three different levels for each of the four factors, $3^4 = 81$ different scenarios are simulated in total.

IV. Results

The first part of the analysis sticks on the original service mortgage game settings where the initial new application start rate is set to 20 for the first 8 weeks and changed to 27 for the rest of the game, as we explained further in the Section 3.2, where verification and validation of our findings are stated. Other than new application start rate, all factors in Table 1 are simulated to measure the time the system reaches stabilization where the application processing rate of each stage reaches to merely 27 (within the proximity of ± 0.001), new application start rate. The results of the analysis are shown in Table 2, which are also shown in Figures 4 and 5 graphically as main and interactive effect plots of the factors, respectively.

Table 2: Time for system stabilization with respect to three factors

T	λ	α	Time (day)
15	5	0	1250
15	10	0	568
15	15	0	488
20	5	0	1713
20	10	0	777
20	15	0	662
25	5	0	2154
25	10	0	1006
25	15	0	803
15	5	0.5	570
15	10	0.5	403
15	15	0.5	367
20	5	0.5	777
20	10	0.5	571
20	15	0.5	483
25	5	0.5	962
25	10	0.5	705
25	15	0.5	614
15	5	1	117
15	10	1	117
15	15	1	117
20	5	1	142
20	10	1	142
20	15	1	142
25	5	1	167
25	10	1	167
25	15	1	167

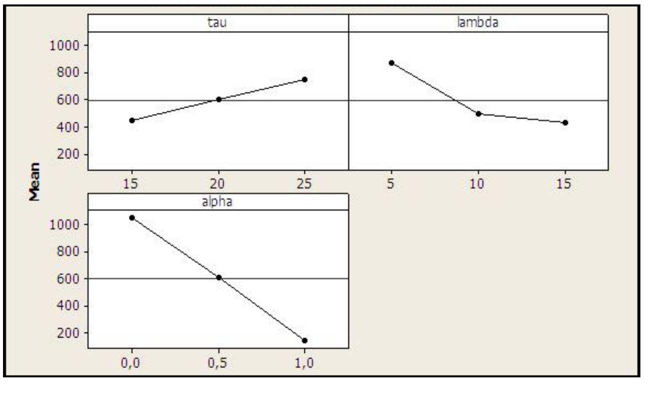

Figure 3: Main effects plot for time for system stabilization

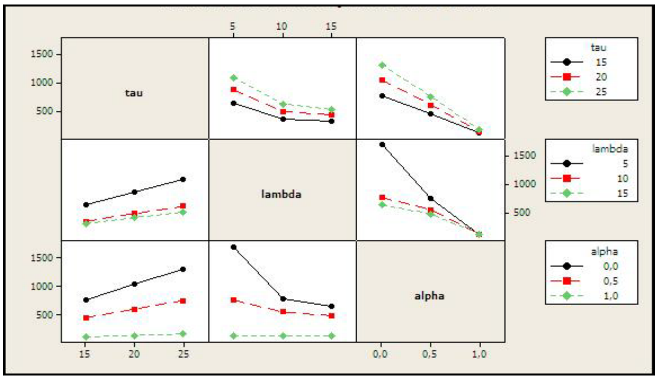

Figure 4: Interaction plot for time for system stabilization

Table 1 and Figure 3 clearly depict that higher rates of information sharing (α) about new application start rates, and service delay times (λ) as well as lower capacity adjustment times (τ) help the system to reach stabilization sooner. Moreover, service delay time (λ) does not have any effect on system stabilization when there is full information sharing on the new application start rates, as indicated in Figure 4. In other words, the target capacity is set directly based on the new application start rate. These findings related to information sharing are also consistent with those of Anderson and Morrice (2000).

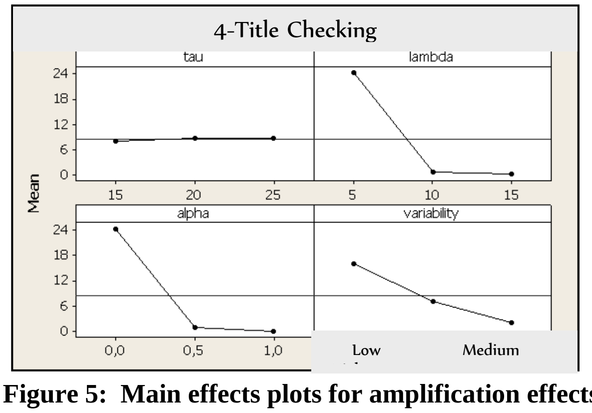

Figure 5: Main effects plots for amplification effects

The second part of the analysis attempts to measure the impact of variability of new application start rate, capacity adjustment time (τ), service delay time (λ), and information sharing (α) on amplification effect for a four-stage SSC. Figure 5 illustrates the amplification effects on stage 4 under different experimental settings with respect to capacity adjustment time, service delay time, information sharing, and variability on new application start rates. Interaction effects of the same factors among each other are also displayed in Figure 6.

Figure 5 shows that amplification effect diminishes while information sharing and service delay time increase. This inverse relationship is very influential on the amplification when the service delay time and information sharing are moving from a low value to a medium value. For higher values of the service delay time and information sharing, their impact on amplification is only marginal. Somewhat surprisingly, amplification effect weakens with increasing variability in the new application start rates. In contrast, it is positively associated with capacity adjustment time, and so the shorter capacity adjustment times lead to less amplification on SSCs.

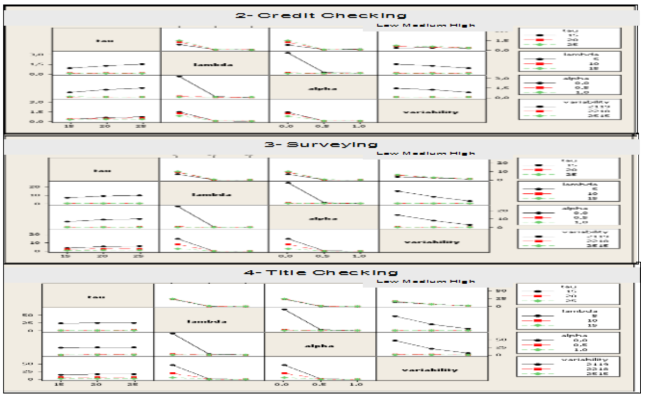

Figure 6: Interaction plots for amplification effects

The interaction effect plots of the factors on amplification effect for stage 4 are shown in Figure 6. It is apparent that service delay time and rate of information sharing react very similarly to the amplification effect and the other factors at all stages. If either of them is set as a low value, the selection of the other one with higher values and/or having a high variability on the application rates may help to reduce amplification. In addition, the value of capacity adjustment times has not a much strong effect on amplification under the higher values of service delay time, information sharing, and variability on the new application start rates. Figure 6 also indicates that even not full information sharing becomes remarkably important to be able to reduce the amplification. Under all factor combinations, higher variability on the service start rates helps to dampen down amplification effects.

V. Discussion and Conclusion

This study has analyzed the information distortion problem within the service industries, and measured the amplification effect in a make-to-order environment for the Mortgage Service Game. A simulation model is developed for Mortgage Service Game, and then verified and validated. Several factors managed by the service companies, such as capacity adjustment time, service delay time, information sharing, and variability of application start rate are examined in the simulation model to observe their impact on information distortion.

Based on the original service mortgage game settings, the first part of the analysis investigates the impact of several factors on the time to reach the system stabilization. It is noted that higher rates of information sharing (α) about new application rates, and service delay times (λ) as well as lower capacity adjustment times (τ) speed up the system to reach stabilization. Moreover, service delay time (λ) does not have any effect on system stabilization when there is full information sharing on the new application start rates, since the target capacity is set directly based on the new application start rate.

The second part of the analysis evaluates the impact of several factors on amplification effect for a four-stage SSC. It should be noted that amplification effect diminishes while information sharing and service delay time increase. Somewhat surprisingly, amplification effect weakens with increasing variability in the new application start rates. On the other hand, the shorter capacity adjustment times lead to less amplification in SSCs. It is found that service delay time and rate of information sharing behave very similarly in terms of amplification effect at all stages. If either of them is set as a low value, the selection of the other one with higher values and/or having a high variability on the application rates may help to reduce amplification. In addition, the value of capacity adjustment times has not a much strong effect on amplification under the higher values of service delay time, information sharing, and variability on the new application start rates. It should be noted that even not full information sharing becomes remarkably important to be able to reduce the amplification. SSC managers are therefore strongly suggested to operate with higher information sharing, while at the same time to increase the accuracy of target capacity. Also SSC managers are recommended to select higher values for service delay time, lower value for capacity adjustment time to reduce the information distortion based on the findings of this study.

This preliminary study may further be extended to evaluate the impact of amplification effect on the performance measures of a four-stage SSC (e.g., backlog cost of the stages, total chain backlog cost, total cost of the stages, total chain cost). Examination of different heuristics on the calculation of target capacity in a SSC would also be another potential area for future research.

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