Amplification in service supply chains : an exploratory case study from the telecom industry

Amplification in Service Supply Chains:

An Exploratory Case Study from the Telecom Industry

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Abstract

Evidence on the impact of amplification, or bullwhip, effects on supply chain performance has primarily been derived from studies in manufacturing industries. This paper reports on a case study from the telecommunication industry, aiming to analyze relevant root causes and associated counter-measures of the amplification phenomenon in service supply chains. Case findings confirm the occurrence of upstream amplification of workload in the service supply chain, workload being a more appropriate measure for amplification effects in service supply chains than inventory levels. Not all of the root causes for amplification effects known from research in manufacturing environments were found to apply in this particular service context. Our telecom case study did highlight an additional root cause: interactions of high workloads and reduced process quality that start reinforcing each other in a vicious cycle once workloads pass a certain threshold. In this particular case, many of the known counter-measures to eliminate amplification did not apply given the nature of the service process or could only yield limited results. A potentially very powerful counter-measure is to implement quality improvements throughout the service chain. This quality dimension links our research to the literature on service management in general, where service quality is on top of the research agenda.

KEY WORDS: SUPPLY CHAIN; SERVICE OPERATIONS; AMPLIFICATION; CASE STUDY

Introduction

Upstream amplification of demand and workload has been a notorious phenomenon in supply chain management for several decades. Forrester (1961) found evidence for such amplification effects, also known as the bullwhip effect, in a number of case studies, whereas Sterman (1989) reported evidence based on the Beer Game, an experiment involving a supply chain with four players. A seminal paper on the amplification phenomenon was written by Lee et al. (1997a, b), defining the amplification effect as the "phenomenon where orders to the suppliers tend to have larger variance than sales to the buyer (demand distortion), and the distortion propagates upstream in an amplified form (variance amplification)". Lee et al. (1997 a,b) found four root causes of the amplification effect in supply chains: demand signaling, batch ordering, supply shortages, and price variations.

Operations management research on amplification effects has primarily focused on manufacturing supply chains. However, with the ever growing importance of the service sector in our economies, the notion of service supply chains has obtained a more prominent role in contemporary OM research (see for example Chase 1996; Johnson 1999; Nie and Kellogg 1999). In service management, the normative belief is that service operations should be managed differently since they have unique characteristics not found in manufacturing. Pure services are intangible, labor intensive, heterogeneous, cannot be stored and transported since production and consumption occur simultaneously, have a high level of customer influence, and their quality is often difficult to judge (Nie and Kellogg 1999; Slack et al. 1998).

Given the inherent differences between product and service supply chains, would the amplification effect work differently in chains of services? And if so, are there other root causes at work as opposed to the ones identified for product supply chains? Finally, how can these root causes of amplification effects in service supply chains be mitigated by smart process design? This paper presents an exploratory case study investigating these questions with data from the telecom industry.

In this paper we first discuss the relevant literature on amplification effects and service supply chains. Next, the research design for addressing our research questions is discussed and subsequently we present the empirical case findings. A combination of qualitative and quantitative modeling techniques was used to collect and interpret company data. In the discussion we suggest propositions for future research and the paper ends with our main conclusions.

Literature review and research questions

Supply chain amplification

An important mechanism for coordination in a supply chain is the information flow among various stakeholders in the chain. An amplified distortion of demand information implies that upstream stakeholders will be misled, resulting in inefficiencies in the total supply chain. Lee et al. (1997b) mention the example of big variations in demand along the supply chain for printers at Hewlett Packard. The common symptoms associated with such fluctuations were excessive levels of inventories, poor customer service due to unavailable products or long backlogs, misguided capacity planning, and high costs for corrections like expedited shipments and overtime. In other words, addressing the root causes of amplification effects is a serious challenge for executives aiming to improve supply chain performance. Table 1 summarizes the root causes for the amplification effect, as identified in previous research, and possible counter-measures to reduce the negative impact of this phenomenon. The counter-measures reflect the underlying coordination mechanisms in supply chains, namely information sharing, channel alignment and operational efficiency (see Lee et al 1997b).

Table 1: Root causes and counter-measures of amplification effects

Root causes	Information sharing	Channel alignment	Operational efficiency
Demand signaling	- Understand system dynamics - Use point-of-sale (POS) data	- Vendor managed inventory (VMI) - Customer direct	- Lead-time reduction - Echelon-based inventory control
Order batching	- Electronic data interchange (EDI)	- Consolidation, e.g. by outsourcing logistics services - Regular delivery schedules	- EDI
Price fluctuations		- Every day low price (EDLP)	- Continuous replenishment program (CRP)
Shortage gaming	- Shared capacity & supply information	- Allocation based on past sales	

Sources: Adapted from Lee et al. (1997a,b)

Prior to discussing the listed root causes and associated counter-measures in more detail, it should be noted that two fundamental root causes, time delays and bounded rationality, are not listed in Table 1. They refer to research findings of respectively Forrester (1961) and Sterman (1989). Forrester found that amplification effects result from time varying behaviors of industrial organizations. More specifically, he identified two types of time delays as root causes of demand amplification, namely the delay of transferring demand information and the delay of transferring physical products along the supply chain (Fransoo and Wouters 2000). Chen et al. (2000) also found that the variability of demand from customers to suppliers is an increasing function of the lead-time parameter. More demand data are required to counter the amplification effect in supply chains characterized by long lead times. Sterman (1989) attributes the occurrence of amplification effects to the fact that human decision making is subject to bounded rationality (see also Simon 1969). Humans are likely to develop misperceptions on feedback signals. For example, stakeholders in a supply chain tend to lose sight on the pipeline inventories they ordered in previous periods and consequently order more than is needed.

Demand signaling

Upstream stakeholders base their expectations about future demand on orders they receive from the next downstream party in the supply chain. An increase in orders will result in higher demand forecasts, which are subsequently transferred to the next echelon in the supply chain in the form of increased order quantities. The ultimate result is that all upstream parties in the supply chain lose track of the real demand pattern at the customer end. It has already been mentioned that long lead-times throughout the chain will make the demand fluctuations even more significant.

A proposed counter-measure is to share sales (POS) and inventory data among stakeholders in the supply chain. This information transparency facilitates the implementation of an echelon-based inventory control system which yields superior performance (Lee et al. 1997a). Other potentially effective counter-measures include direct selling to customers (e.g. Dell Computers) and lead-time reduction. Recent evidence on the positive effects of reduced lead-times, is found in a recent study on upstream volatility in the machine tool industry (Anderson et al. 2000). Shorter lead-times result in supply chain benefits like reduced work-in-progress inventories for machine tool suppliers and improved matching of capacity and demand for machine tool customers.

Order batching

The root causes of order batching and demand signal processing are related since they are driven by sub-optimizing behavior from individual supply chain parties. Each member seeks to optimize its local inventory policies. Order batching is part of such policies, implying that companies often accumulate demand before issuing an order. Reasons for ordering in large batches include volume discounts; large fixed ordering costs and distribution efficiency (by shipping in full truckloads). Again, the batching effect will result in an upstream amplification of demand variability in a supply chain. Consider a company that receives customer orders daily but orders only once a week from its supplier, causing a spike in the supplier's stream of orders. Consequently, the supplier's demand variability is indeed higher than the demands posed on its downstream partner.

A counter-measure is to reduce batch sizes. This will result in more frequent, regular delivery schedules along the supply chain. EDI-based order transmission systems will enable the required reduction of fixed, administrative ordering costs. Third party logistics services providers are in a position to exploit scale advantages by consolidating orders from multiple companies to create full truckloads.

Price fluctuations

Manufacturers and retailers periodically organize special promotion campaigns like price discounts, quantity discounts, special package deals, coupons, and so on. These promotions result in price fluctuations, which in turn stimulate forward buying. In forward buy arrangements, items are bought in advance of actual requirements. Typically this forward buying occurs in larger quantities, thus amplifying the variability in demand.

One way to reduce the impact of price fluctuations is to reduce both the frequency and the level of promotion campaigns. In retail environments, this pricing strategy is well known as Every Day Low Pricing (EDLP). In terms of operational efficiency, continuous replenishment programs (CRP) can help to control retailers' tactics, such as diversions, that contribute to the amplification effect.

Shortage gaming

Shortage gaming, also known as rationing, and price fluctuations are related root causes. They both reflect the responses of individual stakeholders to market dynamics (Lee et al. 1997a). As with price fluctuations, the effect of shortage gaming is also that the customer's orders do not reflect the real demand pattern, albeit for different reasons. "Gaming" occurs when customers order more than they really need, because they know that the supplier will have to ration his product quantities in times of capacity shortages. Customers may even place orders with multiple suppliers, buy from the first one that can satisfy their needs and subsequently cancel all other orders (Li 1992).

An effective counter-measure is to apply different rules for allocating scarce capacity across customers in (genuine) shortage situations. For instance, the introduction of allocation mechanisms based on past sales records rather than on actual orders eliminates the incentive for customers to exaggerate their order sizes.

Service supply chains and amplification effects

The previous section clearly showed that amplification effects can have a tremendous impact on the performance of supply chains. Lee (1997b) posed a very clear choice for companies: “either let the amplification effect paralyze your supply chain or find innovative ways to conquer it”.

Naturally, this choice also applies to companies acting in service industries, but the underlying mechanisms can still be different. For this purpose, we need to explore the distinctive characteristics of service operations in more detail. These unique characteristics may pose different challenges to service operations managers in their attempts to mitigate amplification effects. Different root causes may be at work, implying that managers may also need other measures and tools to conquer the phenomenon. It cannot be assumed *a priori* that service operations can be managed the same way as manufacturing.

Impact of service characteristics on root causes of amplification effects

Service’s unique characteristics include customer influence, inseparability of production and consumption, intangibility, heterogeneity, perishability, and labor intensity (Nie and Kellogg 1999). Intangibility is often cited as a key differentiator between goods and services (see also Chase 1996). This intangible nature of services is also the most striking characteristic in the context of this paper since it implies that inventories are no option in service supply chains. There is no way for stakeholders in such chains to use finished goods inventories as a buffer against demand fluctuations. The delivery of services is essentially make-to-(customer) order. From this characteristic it follows that order batching is not relevant as a root cause of amplification effects in service operations.

For similar reasons, it is also unlikely that demand signaling will be a major root cause of amplification effects in service environments. Lee et al. (1997a, p. 556) already noted that “the direct marketing channel design is not subject to the bullwhip effect created by demand signal processing by the distribution channel”. This direct interaction with customers is common for service operations. It should be noted, however, that amplification effects might be expected in the back office processes of service companies. This is in line with Chase’s point of view that the back office parts of service operations function very much like a factory (Chase 1996).

Finally, the remaining two root causes of amplification effects, price fluctuations and shortage gaming, may also be relevant in service supply chains. In fact, yield management is an established practice in many service environments to use differential pricing to allocate time-dependent in order to maximize total revenues (see Chase 1996). In essence, services are offered at discount prices to attract customers in anticipation of periods of reduced demand.

We have found no clear examples of shortage gaming in service operations, but customers may apply rationing practices when buying certain services. For example, in periods of anticipated capacity shortages for services like hotel rooms or airline seats, customers may place orders with various suppliers to increase to likelihood of satisfying their demand.

Occurrence of amplification effects in service supply chains

We could only find one study on the amplification phenomenon in service settings, being one on the Mortgage Service Game (Anderson and Morrice 2000). This game was developed to study decision-making in service-oriented supply chains. The mortgage services supply chain modeled encompasses four process steps: initial processing, credit checking, surveying, and title checking. The first process step involves direct contact with the customer, the remaining three processes are typical examples of back office operations in service companies. Based on a number of classroom experiments with the mortgage game, Anderson and Morrice (2000) clearly showed the presence of amplification effects. These effects occurred with greater force upstream in this four-stage service supply chain.

An interesting feature of the mortgage service game is the use of backlogs instead of finished good inventories as a measure for amplification effects. Each process stage can only control its backlog by managing its capacity, that is the number of people it employs. In adjusting capacity levels, it should be realized that it takes time to interview, hire and train new employees who are capable of providing high-quality services to customers.

In terms of counter-measures, Anderson and Morrice (2000) concluded that sharing end-user demand information throughout the supply chain contributed to a reduction of amplification effects. This focus on the sharing of demand information is a plausible measure to counter amplification effects (see also Table 1). However, in our research we have chosen for a broader perspective when studying the effectiveness of potential counter-measures to improve the quality and flexibility of service processes.

Research questions

Our overview of the existing literature on amplification effects gives rise to the following three research questions.

Research question 1: To what extent and in what form do amplification effects occur in service supply chains?

It seems plausible to expect that amplification effects do occur, but it is less obvious in what ways they will manifest themselves. Clearly, variations in inventory levels are not applicable to the vast majority of service contexts. Would order backlogs be an appropriate other measure or should we look elsewhere?

Research question 2: What are the main root causes for amplification effects in service supply chains?

The listing of Lee et al (1997b) of root causes for amplification has rapidly become a standard for manufacturing environments (see for example Anderson et al. 2000 and Chen et al. 2000). But to what extent is it also applicable in a service context? Are there perhaps other root causes that are more prominent in service supply chains than the one's mentioned in Lee et al. (1997a,b)?

Research question 3: What are effective counter-measures to reduce or eliminate amplification effects in service supply chains?

Similarly, Lee et al. (1997b) also list a number of plausible counter-measures to reduce or even eliminate amplification effects in manufacturing supply chains. Can one simply copy this list to service supply chains or are there differences? Again, are there other, emerging measures that are especially effective in a service environment?

These three questions form the basis on which we designed and conducted the exploratory research described in the remainder of this article.

Research design

Selection of research design

A case study research design appeared to be a logical choice to address our research questions. There was very little academic research available on how amplification would manifest itself in a service context. Therefore, exploratory, theory-building research was required. In general, research of this type has been lamented as sorely missing in POM research (Flynn et al. 1990, Meredith 1993, Neely 1993). Case studies are the research tool par excellence for exploratory, theory-building research (Yin 1989, Eisenhardt 1989, Meredith 1993).

Selection of service supply chain case

Our selection criteria for the company to be studied were driven by our research questions (Yin 1989, Eisenhardt 1989, Meredith 1993). This implies that our research design required a service supply chain that appeared to

a) exhibit amplification effects;
b) have information available on root causes of these effects;
c) have information available on possible counter-measures to overcome these.

The service supply chain we selected fitted all the criteria above. It was part of a U.S. telecom company and entailed the establishing of new telecom services to customers. It had experienced severe order backlog and workload fluctuations in the past. At the outset of our research project, only anecdotal evidence was available of such fluctuations. The company was in the process of developing a number of initiatives to overcome these effects.

Case data collection and analysis

Our case data collection and analysis can be described as consisting of four related analytical steps.

Step 1: Interviews for basic data collection on amplification phenomenon

At the start of our data collection, interviews were conducted with representatives from all stages of the process. These interviews yielded important information on the recent history of the company and the structure of the part of the organization studied as well as anecdotal evidence on recent occurrences of workload amplification.

Step 2: Causal diagramming workshops for identification of root causes

An important means of both data collection and analysis was formed by so-called group model-building workshops (Vennix 1996). In these workshops, representatives from various parts of the service supply chain studied convened to discuss root causes of the amplification effects experienced. During these workshops, their information was captured visually in causal loop diagrams, which were shared with the informants at the company. For more details on the use of causal modeling techniques, the reader is referred to such diverse fields as social science data analysis (Miles and Huberman 1984), so-called “soft OR” (Rosenhead 1989), the quality movement (Hall 1987) and systems thinking (Coyle 1983, Wolstenholme 1993, Hall 1984, Senge 1990, Vennix 1996).

Step 3: Quantitative analysis for checking consistency of respondent reports

The subjective respondent data obtained in step 2 were triangulated with several quantitative analyses. Partly thanks to the extensive Business Process Redesign (BPR) project that had led to this newly designed service chain, quantitative data for each of the stages in the service supply chain was available. These data included sales rates over time, staffing levels, average operating times and process delays and quality levels. Also, some of the anecdotal evidence of earlier workload amplification could be quantified by respondents. Figure 4 shows the estimated amplification effects on rework and overtime in one particular incident.

The consistency of the respondent reports was further checked by developing an exploratory system dynamics simulation model of the amplification effects in this service supply chain. This system dynamics model was based upon the causal relationships identified in the group model-building workshops and the quantitative data from the BPR study. It enabled us to see if the structural root cause relationships that our respondents reported could actually lead to the dynamic amplification behavior observed in the recent past.

Step 4: System dynamics simulation for exploring the potential of selected counter-measures

In general, system dynamics is a suitable method to investigate complex systems in an exploratory manner. In our case study, the system dynamics simulation model developed was instrumental in evaluating the potential of counter-measures that had not been tested in the actual service chain yet. Not all possible counter-measures were evaluated in this manner. Many of the measures listed by Lee et al. (1997b) had already been thought about and either discarded as not applicable or acceptable or as yielding only minor benefits. By changing selected parameter values in the simulation model, we could explore what, according to the model’s logic, might be the most promising counter-measures for further investigation.

Empirical findings

Basic case data on the amplification phenomenon

Case setting: The “establishing customer service” process at a major telecom company

The interviews revealed that this U.S. telecom company is typical of its industry in the 1990s, a decade in which the telecom sector as a whole has been undergoing drastic changes as a result of deregulation and increased competition. This has in many cases led to improved service to customers (Beardsley and Patsalos-Fox 1995) but also to profound organizational changes and substantial layoffs.

In response to these turbulent times, the case company had taken two drastic steps. Externally, it had decided upon an aggressive revenue growth strategy for new service products such as ISDN, Caller ID or call-waiting. These should ensure lock-in of customers, as the competition in the POTS (plain old telephony services) segments such as long-distance calls and local calls was becoming increasingly brutal. Sharp-pitched telesales campaigns played an important role in this marketing strategy, supported by strong advertising. As attention spans of customers keep decreasing, these campaigns had to be intense, with a great deal of promotional activity happening in relatively short periods of time.

Internally, an even more drastic step had been taken. The company had recently undergone a major BPR downsizing process in which the organization was redefined into a number of key processes. The process under investigation here was called ''establish customer service'' and we discuss it next.

Structure: a capacitated service supply chain

Our informants described the "establish customer service process" as a four-stage service supply chain, as is visualized in Figure 1 in stocks-and-flow notation (Sterman 2000). In its structure, it appears very similar to another recently described service supply chain, the ''mortgage service supply chain'' (Anderson and Morrice 2000). It consisted of four separate stages, each subject to a finite capacity, derived from the number of staff working in this process stage, their skill level and their working hours. This supply chain was designed and calibrated to fulfill incoming orders for new services within one workweek and send a bill for these by the end of the same month. Its four main stages were labeled as follows:

1. Selling;
2. Provisioning;
3. Install;
4. Billing.

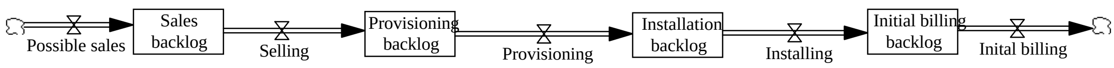

Figure 1: The service supply chain of the "establish customer service" process

Selling was the obvious first stage in this service chain. Selling was done by sales agents, who required considerable technical skills for this job, not just the classical selling skills. The sales agent would also need to understand the specific characteristics of the product involved. Moreover, the company used an increasingly outdated mainframe system for order capturing, in which it was often cumbersome to note customer-specific details, especially for newer products. Therefore, hiring and training competent sales agents was a fairly lengthy process. The delays involved in the sales process itself were minimal: this stage of the process was designed to be completed within the same day.

Provisioning was the label for the internal (back office) activities that were started up after a sales order had been electronically captured. This involved manipulations in the internal systems of the company that regulated telecom traffic, such as assigning a number of new features to an existing number. This process was highly automated. However, if an error was detected that could not be solved by the computer, the order would literally "fall out" in paper format on the office floor. Human staff was then required to deal with it. Target delays in provisioning were minimal for flow-through orders, and 1-2 days for fall-out orders.

Installing is the process stage where actual visits to customer sites were made to physically install telecom equipment, such as an additional line. Not all new telecom services required actual field visits. Services such as call waiting or voice mail could move from the provisioning stage straight to billing. The about one-third of new services that needed field visits required a substantial labor force of skilled service technicians. Hiring and proper training of technicians proved to be a lengthy process. The installing process was designed under normal conditions to take three days for planning and executing an installation visit.

Billing was an activity that was only partially covered by this particular service supply chain. Obviously, the vast majority of bills that any telecom company sends out every month are bills for repeated services. The initial billing process stage covered by the “establish customer service” process entailed preparing and sending out the first bill for the new service. Sending out these initial bills took place at the end of the month, so the billing delay was designed to be half a month on average.

Anecdotal evidence on amplification effects

Our case company’s recent history of chain performance showed clear indications of amplification effects. Although the quantitative evidence remains anecdotal and partial, its more general applicability was strongly confirmed in the interviews and workshops. During the year prior to our investigation, it had become apparent that the current design of the process was highly sensitive to changes in the volume of incoming orders or available capacity. These changes resulted in substantial fluctuations in backlogs and workloads throughout the supply chain. To give three specific examples:

1. During a sales campaign for several ‘’hot’’ and new, complex products, such as ISDN, a huge amount of errors occurred in entering sales orders. This was partly due to the work pressure, partly to the lack of training with the sales staff and partly to the outdated functionality of the order processing system. This system needed complex and technical codes to activate specific customer features and, in general, was fairly inflexible and not user-friendly. Under pressure to close the deal, sales agents would put everything they could not immediately place in their input screen, in the input field for ‘’comments’’, where it would not be recognized by the automated systems in provisioning. The increase in overall order volume was around 10% of normal volume, the increase in workload was several times that percentage.
2. During a computer malfunctioning in one of the regional provisioning centers, a ‘’meltdown’’ occurred. This implied that in a few days time a huge build-up of backlog occurred because large numbers of sales orders were rejected. Despite massive overtime and additional capacity from other centers, it took over half a year to get workloads more or less back to normal.
3. During extreme weather conditions in a winter storm, a host of errors occurred in POTS operations. As a result of one period of bad weather, call centers became practically inaccessible, with queue times of up to an hour. It took the company weeks to make the necessary emergency fixes, and then a much longer time to return to normal working hours and workloads again.

Identification of root causes

Batch ordering and shortage gaming did not apply

Of the four generic root causes of amplification effects identified by Lee et al. (1997a), two did not apply in this specific service context. Given the nature of these telecom services, ‘’make to stock’’ was not possible and hence batch ordering effects did not occur. Shortage gaming did also not apply: customers requesting a second line certainly do not ask for an extra line to make sure they will at least get one installed.

Demand signaling: Functional silos remain

Amplification effects arising from delays in demand signaling did apply to some extent in this telecom company. Despite its recent re-labeling of organizational units and the nomination of specific ‘’process owners’’, the telecom company remained highly compartmentalized in its operational processes. In particular, sales and operations people seemed to operate in separate worlds, or at least in different office buildings. Coordination between these two functions at the operational level remained minimal, although they were now operating adjoining process steps. Consultation on the operations impact of planned sales campaigns appeared to hardly take place beyond the level of informing operations of forecasted order volumes per period. This consultation was certainly not a two-way process: sales simply informed operations of what it was going to do, assuming that operations would be able to comply.

Price Variations: Essential part of marketing but havoc for operations

The aggressive use of sales campaigns, in which price variations were of great importance, was a central element in the marketing strategy of the company. At the same time, our respondents believed it to be a key cause of demand amplification in this otherwise fairly stable business. Sales campaigns led to considerable increases in incoming order loads during short, concentrated periods. This led to considerable problems in provisioning, as a result of which errors in installation proliferated even more, especially if the sales campaign concerned complex, new products, which would lead to many small errors in the order capturing process.

Emerging root cause: Interactions of workload and quality

The importance of process quality and its interactions with workloads was stressed by many of our respondents. They stated that if workloads increased above a certain level, backlogs would rise. This would not just lead to longer lead times or to attempts to increase processing capacity, but also to lower process quality. As employees were trying to process more orders per time unit, they would typically make more errors and correct fewer of them. This would lead to an increase of rework, which in turn leads to more work and hence higher workload, which would provoke even higher error levels, etcetera. Moreover, errors made upstream would cascade down to subsequent process stages, creating higher error levels, more rework and hence higher workloads there as well. It would take overtime and a decreased inflow of new orders to enable the supply chain to work its way out of this vicious cycle. All these causal relations are visualized in Figure 2.

This figure incorporates the close but sometimes confusing relation between backlog and workload, two concepts often used interchangeably in this context. *Backlog* is the cumulative number of unfulfilled orders; *workload* is backlog divided by available capacity, expressed in number of orders that can be processed in one day. Therefore, workload should under normal conditions be somewhat under 1.0.

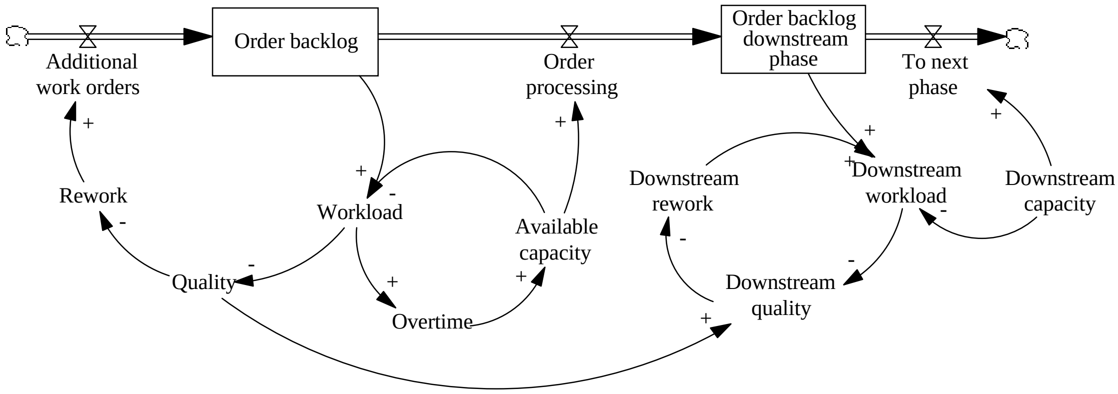

Figure 2: Interactions of order backlogs, workloads and quality in the service supply chain

Quantitative data to check respondent reports

The case analysis so far focused on respondents' perception of reality. To triangulate their reports, quantitative data was collected. Largely, these data confirmed what we found earlier on in the interviews and workshops.

The recently-completed BPR project proved to be a valuable source of information for data on various key process indicators, such as sales rates over time, staffing levels, average operating times and process delays and quality levels. For instance, Figure 3 shows the forecasted customer demand rates from the sales department, normalized to the yearly average. It shows that there were indeed considerable fluctuations in demand over the year. A major peak should occur in autumn, but also in spring considerable demand fluctuations were expected. This demand behavior was partly seasonal, partly determined by specific sales campaigns.

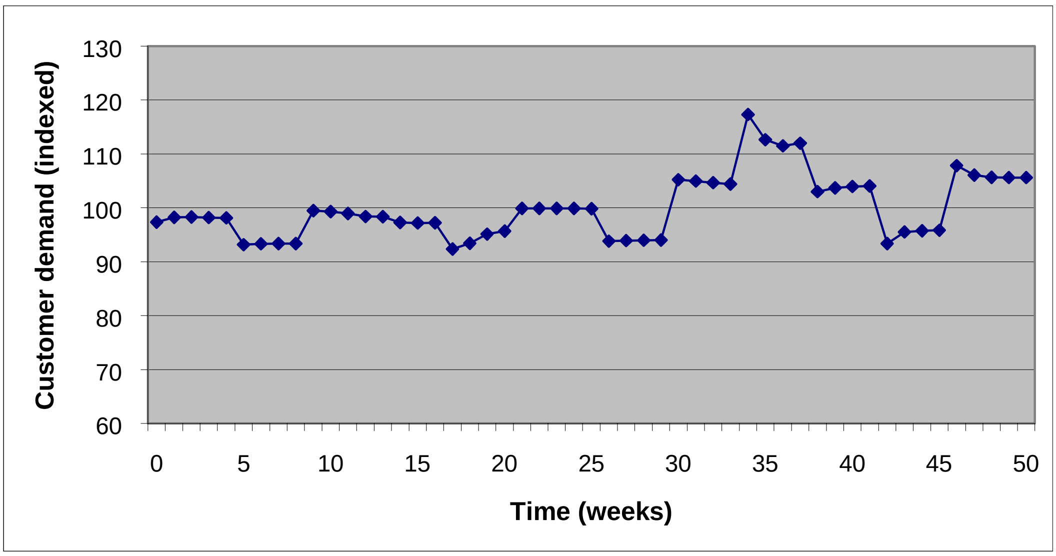

Figure 3: Forecasted, normalized customer demand for new telecom services

Some of the anecdotal evidence on earlier workload amplification incidents, could also be quantified. Figure 4 shows the estimated amplification effects on backlog and overtime as the result of the ''meltdown'' incident described earlier in this paper. This figure also shows that our simulation model fitted closely with historical events. The overall slopes of the simulated variables emerged out of the model structure. Fitting these values closely to the historical data was done by parameter calibration. In this sense, these historical time series data provided an opportunity for model validation.

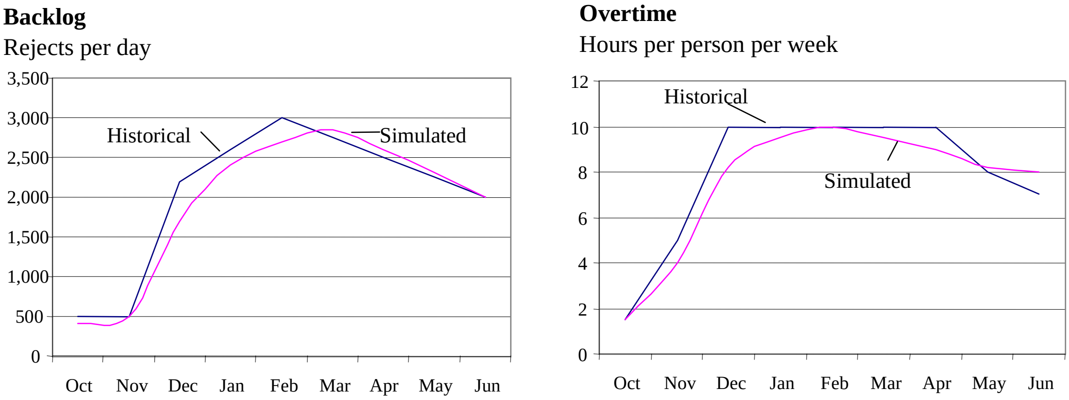

Figure 4: Amplification effects on backlog and overtime, historical and simulated

Exploring the potential of selected counter-measures

Evaluating the potential of selected counter-measures to reduce amplification effects in this telecom services supply chain happened in three different ways. Firstly, we could eliminate several alternatives by analytic reasoning, either because they were not applicable in a generic service context or because they were inappropriate or unacceptable in this particular case. One example of this was a counter-measure such as advance capacity reservations (see Lee et al. 1997b). Secondly, there were counter-measures that had been tried prior to or during our period of observation at the case company. These included such measures as lead-time reduction, every-day-low prices (EDLP) and joint forecasting. Finally, there were measures that had not yet been tried out in practice but that we simulated in the system dynamics model to evaluate their potential impact for this telecom company. In particular, we investigated the simulation scenario of maintaining strict quality controls on outgoing orders.

Capacity reservations: Hardly feasible due to hiring and training delays

Advance capacity reservations would in this case mean making sure that sufficient employees would be present to deal with sudden increases in customer demand. With unexpected events such as extreme weather conditions or computer breakdowns this was practically impossible. But also for foreseen demand increases, such as those resulting from sales campaigns or seasonality effects, this counter-measure proved to be practically infeasible. By working overtime and holiday planning some capacity adjustments could be made, but hiring temporary workers remained a politically sensitive subject. The memory of recent layoffs as a result of the BPR effort was still fresh. Moreover, hiring and training skilled staff in all stages of this supply chain was a process that took time, far longer than the few weeks or months that this additional capacity was needed. And since these skills were fairly unique for a particular stage, capacity could not readily be reserved from other stages either.

Lead-time reduction: Many opportunities already exploited through BPR

One of the main purposes for this telecom company to restructure itself into a process-based organization, was lead-time reduction. This may well have helped in reducing amplification effects, but unfortunately we have no historical data to verify such effects. Nevertheless, the total processing times in periods of normal workloads were quite acceptable, i.e. 3-5 days, depending on the type of services requested. Shortening these lead-times even further would require more drastic process redesign efforts, which did not appear to be desirable for our case company at the time.

Every-day-low-prices: Incompatible with commercial strategy

According to most of the operations people we interviewed, refraining from sales campaigns might have eliminated the observed amplification effects. This would appear to hold at least for more complex, newer products, where order processing errors were quite likely. Nevertheless, the data from Figure 3 also suggest that some of the fluctuations were outside of the control of marketing, more determined by seasonal effects. Apart from this discussion, something in the nature of every-day-low-prices, as suggested by Lee et al (1997b), was unacceptable for the sales department. The case company's commercial strategy was precisely based on the aggressive use of sales campaigns to acquire market share in new telecom services as these were becoming rapidly available in an expanding market.

Information sharing: some limited successes

Sales forecast data were being shared with operations management, even more so after our research findings had been reported to management. This form of information sharing did indeed lead to somewhat better coordination. For instance, the timing of sales campaigns could be tuned in such a way that they would not coincide with seasonal demand peaks or holiday periods for staff. Still, given the limited opportunities to make processing capacity more flexible in the short term, this counter-measure could only yield modest benefits in this case.

Strict quality controls: potentially very promising

Our respondents had mentioned the interactions of quality and workload as a key driver behind amplification effects in their service supply chain. Therefore, we were especially interested in understanding the potential impact of strict quality management on the different stages of this "establish customer service" process. At the time of our research, quality management was not top on the list of management priorities. There were several bottom-up initiatives to make improvements in legacy systems and outdated procedures that were especially error-prone. One initiative, for example, was in the sales department. In that department, the order-capturing system was an outdated mainframe-application, the sales staff was insufficiently trained in dealing with new products and performance incentives were misaligned. Instead of rewarding an error-free order capturing process, sales agents were merely evaluated on the revenues they realized.

In evaluating the potential of these and other local quality improvements, we used our system dynamics simulation model. Figure 5 shows a result of our policy analyses. The left graph shows workload levels for the four process stages under the forecasted end customer demand and foreseen workforce changes. It replicates the amplification effects mentioned by our respondents, with higher workload levels for every subsequent process stage. Especially the behavior of the physical installation workload shows what must have seemed a doom scenario for company management

(although it should be noted that a 3-4 days period to install a new telecom service might still be acceptable for many customers.)

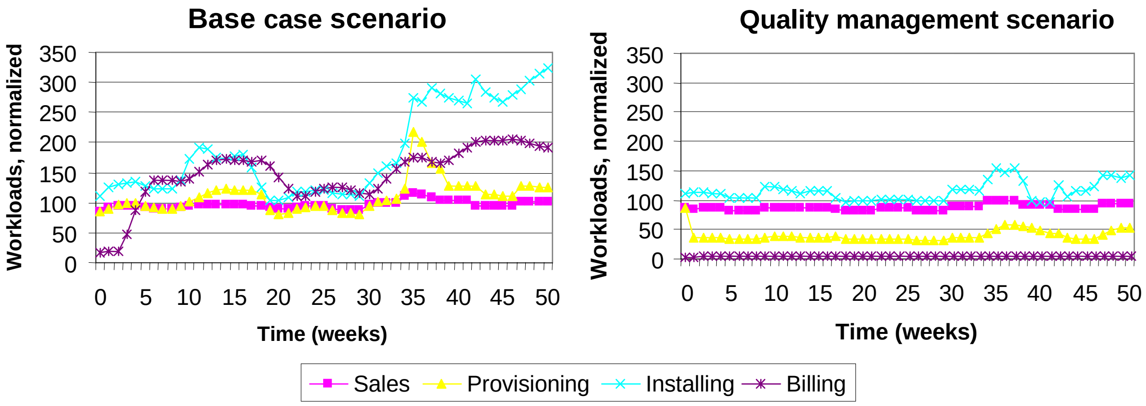

Figure 5: Workload per process stage under forecasted demand for base case (left graph) and with strict quality control measures (right graph)

The right graph in Figure 5 shows the behavior under a strict quality management scenario. This implies that process quality remains at its high base level, regardless of workload increases from campaigns or skill level decreases through new hires. Improvements in performance are impressive: amplification effects are minimal. Although the sales and installing stages show considerably lower workload levels throughout, the most spectacular workload decreases are with provisioning and billing. This is illustrative of the fact that these were designed as highly automated processes, so in the case of correct incoming orders, workload impact for human operators should be minimal. Management of the telecom company agreed that this particular counter-measure was promising enough to justify further investigation and used this insight to prioritize its list of local improvement projects.

Discussion

In this section we return to our original research questions and, based upon the findings from our telecom case study, suggest propositions as preliminary answers to these questions and possible starting points for follow-up research.

Amplification phenomenon in service supply chains

The amplification phenomenon has been well-documented in manufacturing supply chains but not in service contexts. Does a similar phenomenon occur in service supply chain and, if so, how does it manifest itself? The manifestation question is relevant since it is plausible to assume that services are inherently different from physical transformation processes. Based upon our research, the following proposition seems appropriate:

Proposition 1. Amplification effects also occur in service supply chains, but they manifest themselves in order backlogs and workloads

Our telecom case findings clearly confirmed the existence of amplification effects here, which was more or less to be expected. Perhaps more interestingly, though also not completely unexpected, the amplification effect manifested itself in a different way. Whereas in manufacturing supply chains it is inventory levels that fluctuate, it is backlogs and workloads that display increasing variances in service supply chains. This finding is in line with the results presented by Anderson and Morrice (2000). They also use backlogs as the measure for amplification effects.

We would like to stress that both order backlogs and workloads point to a common underlying problem, being that capacity is not sufficient to meet customer demand. The concept of workload (order backlog divided by available capacity formulated in the number of orders per time unit) has the advantage of being theoretically more to the point. Order backlogs, on the other hand, are easier to measure in practice.

Root causes for amplification effects in service supply chains

Some known root causes (see Table 1) were also present in our telecom case study, but for others we could not find any supporting evidence. More specifically, we found no empirical support for the root causes batch ordering and shortage gaming, mainly due the specific, intangible nature of the telecom services. The evidence on demand signaling was mixed. The problem in the telecom company was not so much the exchange of demand information since this was already done periodically. The issue was rather that it proved to be extremely difficult to tear down the functional walls between operations and sales. It was likely that the poor coordination between these two departments did indeed contribute to the occurrence of amplification effects in this telecom services supply chain.

An interesting finding is that our case data suggest an emerging root cause of amplification effects in supply chains, one that is particularly relevant in service operations. This root cause relates to the vicious cycle of workload, quality and rework (see Figure 2). The mechanics of this vicious cycle are that higher workloads deteriorate process quality, leading to more rework and hence even higher workloads, both in the same process stage as well as in downstream and upstream stages. Based upon workshops with the respondents in the telecom company, we could clearly establish a causal relation between process quality and fluctuations in workloads and backlogs.

Based upon our exploratory case research, the following propositions seem appropriate:

Proposition 2a. Due to the specific, intangible nature of services, none of the root causes identified in previous research can automatically be applied to service supply chains.

Proposition 2b. The vicious cycle of workloads, process quality, and rework is an emerging root cause of amplification effects in service supply chains.

Counter measures to mitigate amplification in service supply chains

In line with our findings on the root causes of amplification effects, not all known management practices to mitigate such effects are likely to be effective in service supply chains. In the case we did find supporting evidence for the positive *potential* effect of counter-measures such as lead time reduction, every day low prices and sharing sales forecasting information. Still, we have shown that, for various reasons, these measures were not sufficient to achieve a substantial and sustainable effect in reducing the negative impact of amplification effects on supply chain performance.

A very powerful counter-measure in this setting was to enforce strict process quality controls throughout the service supply chain, starting with the reduction of errors in the sales process of capturing customer orders. Our analyses clearly revealed that such strict quality management policies would indeed be very effective in reducing workload fluctuations in all stages of this telecom services supply chain (see Figure 5).

Based upon our research, the following propositions seem appropriate:

Proposition 3a. Counter-measures identified in previous research on manufacturing supply chains, will only be partly effective in mitigating the amplification effect in service operations.

Proposition 3b. A powerful measure to achieve a sustainable reduction of amplification effects in service operations is quality improvement throughout all stages of the supply chain.

The quality related counter-measures referred to in proposition 3b can be highly instrumental in turning a vicious cycle of high workloads and poor process quality into a virtuous one of modest loads and minimal amounts of rework. This emphasis on process quality in countering amplification effects also fits well within the overall research directions of service OM. Based upon a survey among OM scholars, Nie and Kellogg (1999) put quality on top of the list of critically needed research areas in the field of service operations. They also conclude that researchers already seem to be aware of the importance of quality in services, given the amount of publications on this topic. Still, we have not found any research findings in the existing body of OM knowledge specifically focused on the relation between service process quality and amplification effects. Moreover, it is observed that improving quality of services did indeed receive a lot of attention among both practitioners and academics in the last decade, but modeling approaches toward achieving such improvement have been almost nonexistent in the literature (Soteriou and Hadjinicola 1999).

We did find some support for our proposed relation between process quality and workload fluctuations in a study on the banking industry (Roth and Jackson, 1995). In that study it was concluded that increasingly higher levels of factor productivity were negatively correlated with service quality. This implies that becoming “lean” may have the hidden cost of reduced service quality. The experiences of our telecom case company with its BPR effort illustrate this point. The layoffs resulting from this BPR initiative made the company less flexible in dealing with fluctuations in sales. Since adjusting capacity levels was not feasible in the short run, the company had to deal with a vicious cycle of increased rework levels and reduced service levels.

Conclusions

Services are becoming a dominant part of our economy, especially in industrialized countries. Yet it appears that the performance in the services sector improved only modestly in the past decades. Effective design of service operations is an important condition for performance increases in this sector. In designing effective service supply chains, operations managers frequently look for guidance to manufacturing supply chains. In manufacturing contexts, deep and extensive experience on designing effective chains of operations has accumulated over the past decades.

However, one of the problems associated with such a "best practice" approach is that not everything that is successful for physical products can automatically be assumed to be effective in service environments. One example of such a potentially problematic area is the impact of demand and workload amplification effects in service supply chains. Such amplification effects are known to be very harmful for operations performance and therefore sound operations design should limit or even eliminate their impact. There is a well-established body of knowledge on amplification effects in manufacturing supply chains covering over forty years of research. Root causes and promising counter-measures are known and tested. Still, to what extent all these apply to service supply chains is not immediately evident.

This paper contains results from an exploratory study evaluating the applicability of the existing body of knowledge on amplification effects to service supply chains. It shows that part of the existing knowledge can be applied to a service context as well, with some notable exceptions and additions. The exceptions are primarily caused by the fact that services can not be made-to-stock, but are by definition made-to-order. One result of this is that amplification effects do not manifest themselves in inventory levels, but rather in backlog and workload levels. A second result is that those known counter-measures that work by way of inventory do not apply, notably consolidation of flows and reduction of batch sizes.

One emerging insight from this exploratory research to the knowledge on root causes for amplification effects is the importance of quality, and its interactions with workload levels, on amplification effects in service supply chains. We show that such chains often get caught in a vicious cycle of high workloads and, as a result of this, low quality levels, which further increase workloads. This finding confirms the importance that is currently being attached to service quality in the service management literature.

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