Production capacity commitment approach for surface finishing manufacturers

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Abstract. Surface finishing manufacturers are faced with a plethora of problems concerning their workload visibility, delay and reactivity. Two of the main causes are variability and diversity of demand. In order to better plan the uses of their resources, manufacturers need to build more collaborative relationships with their customers. While many collaborative practices have been proposed in the literature, most of them are centered on the stock level and cannot be applied in the context of make-to-order operations. The purpose of this study is to evaluate the impact and feasibility of a new collaborative approach based on production capacity commitment. Elements of the model are discussed as well as execution mechanisms developed from a real case in the aerospace industry. The final goal of the proposed approach is to provide surface finishing manufacturers better visibility on future demand.

Keywords: Collaboration – Aerospace – Supply chain – Manufacturing – Collaborative contract – Production capacity commitment.

1 Introduction

The present study is drawn from an industrial case involving surface finishing manufacturers (SFMrs) in the aerospace industry. This group of manufacturers often operates at the end of the supply chain. Most of them are Small and Medium sized Enterprises (SME) that rarely have direct contact with main contractors despite the fact that the main contractors must certify their services. Instead, surface finishing manufacturers are solicited by different second and third tier suppliers within the aerospace supply chain. In practice, these customers often delay orders as long as possible to solicit the best SFMr with the best availability and the best price. As such, most SFMrs' customers place their orders at the last minute or with minimal delay between the order confirmation and the physical reception of the material needed treatment. The customer's due dates are very aggressive and subject to constant priority changes.

Consequently, SFMrs are directly affected by the bullwhip effect due to their position within the aerospace supply chain. At the opposite end, the main contractors' demand is fairly stable due to the long-term production program. That demand is known by most second and third tier suppliers. In turn, that knowledge is not passed down to SFMrs which suffer from a lack of visibility.

This lack of collaboration between aerospace supply chain stakeholders is deeply rooted. Fortunately, many initiatives have been launched to resolve this problem including the development of web portals and other data exchange practices. Nevertheless, these initiatives are not based on a rational evaluation of the production capacity of the SFMrs and focus on the short-term exchange of information. Finishing firms still continue to react to emergencies more than they plan their capacity utilization.

Recognizing this problem for SFMrs, this paper intends to contribute to supply chain collaboration and sharing practices with an innovative approach based on Production Capacity Commitment (PCC). The proposed practice attempts to prioritize job orders according to contracts signed off by collaborators. Note that this research project is at a preliminary stage and further validation will be conducted in the near future.

The remainder of the paper is organized as follows. First, a brief state of the art on business collaborative practices is presented with a focus on collaborative processes between organizations. Then, elements of the proposed model are discussed by presenting the general concept followed by a presentation of the proposed control execution and monitoring mechanisms. Finally, the paper ends with a general discussion on the possible use of the proposed model as well as covering its limitations and future research opportunities.

2 Collaborative practices: State of the art

There is obviously a lack of collaboration in regards to practices between SFM and their customers. However, many collaborative practices do exist and have been applied in other sectors such as manufacturing, transportation, and retail. Among these practices, some collaborative practices are based on an externalization of inventory, like Vendor Managed Inventory (VMI) or Third-party Logistics (3PL). According to Disney and Towill [1] VMI aims to give to the vendor or supplier the responsibility of the customer's stock level. It results in:

- a prompt information exchange about availability, quality, production output and demand through ERP, information systems, etc.; and
- a quick reaction with supply chain stakeholders to correct variance to the initial plan, like the bullwhip effect.

VMI is mostly used with retail whereas 3PL, another common practice, is specific to the transportation sector. 3PL allows firms to outsource logistics so they can focus on their main activities [2]. It, however, requires a high degree of collaboration between customers and 3PL service providers.

There are also practices based on information sharing and collaborative forecasting. The most common are Efficient Customer Response (ECR) and Collaborative Planning Forecasting and Replenishment (CPFR). CPFR is an extension of ECR and it aims to involve all supply chain's actors to reach better results. CPFR consists of three main stages [3]:

- Planning: specify objectives and resource requirements, stakeholders exchange strategies and develop a joint business plan;

- Forecast: collaborative sales forecast and order forecasts; and
- Replenishment inventory: replenishment process is initiated after acceptance of forecasting.

In other words: "CPFR allows contracting parties to avoid the difficulties of formal contracting while realizing the benefits that would be anticipated from vertical financial ownership" [4]. CPFR is a widely used practice but it is mainly performed between a retailer and a manufacturer, and is sometimes only based on collaborative forecasting without considering mutual commitment [5].

Other researchers suggest other form of commitment which goes further than collaborative forecasting. These approaches focus on supply contract with options [6 and 7]. For example, Wang and Liu [7] analyze the impact of an option contract between one retailer and one or several suppliers through simulation. Most of those approaches are based on a multi-stage process. The first stage is the collaborative forecast of expected demand. Then, stakeholders contract orders with options for the buyer, so the buyer can change the ordered quantity in case of demand variations. The supplier can receive compensation and the adjustment can be upward or downward [8]. The implementation of these practices allows the buyer to order the right quantity with optimal flexibility [9].

Many other collaborative practices have also been developed based on capacity reservation contracts. There are at least five types of capacity-reservation contracts, which will be presented from the simplest to the most complicated. First, reservation capacity can be useful for buyers. Based on a selection of possible suppliers, one collaborative scenario involves equal allocation of capacity among the selection. Hazra and Mahadevan [10] propose some practices to contract the capacity depending on the demand and its variability. That model shows that increasing the number of suppliers is irrelevant and that capacity heterogeneity is good for buyers.

Deductible reservations (DR) is another reservation capacity strategy in which the buyer pays to reserve capacity. This fee is deductible from the purchasing price [11, 12, and 13]. It encourages stakeholders to share risks and DR is compared to take-or-pay and others supply contracts. However, this strategy has only been applied in high-tech industries on a limited number of products [14].

The third group of capacity reservation approaches consists in dividing the procurement into two strategies: one for the short term based on spot market and random price and one for the long term which is based on a multi-period capacity reservation with fixed price [15, 16, 17, and 18]. Spot market provides flexibility for the purchaser whereas the reservation brings assurance for the main supply.

The next approach involves two procurement strategies. It first proposes a strategy based on postponing excess needs of capacity. The second one is based on outsourcing. De Kok [19] proposes an optimal policy using both strategies. The case study is a packaging facility dealing with one type of product with several sizes of packages for different amounts of items. However, this research focuses on transportation capacity and not on production capacity.

Finally, the last group of reservation strategy deals with a multi-period reservation contract between customer and long-term supplier under uncertainty [20]. The buyer pays a specific fee each period and the supplier guarantees a committed number of product orders. Such practice can improve the supplier's capacity utilization. The buyer benefits from flexibility on the commitment and information and demand can be updated [21]. This article also proposes a heuristic to reach the optimal commitment and purchasing quantities.

All these collaborative practices can bring some benefits to many organizations. However, they can be difficult to apply with surface finishing firms. Indeed, CPFR concerns more retailing activity than manufacturing [3]. The manufacturing sector adopted all of the collaborative practices developed for logistics and mass distribution without considering the question of production capacity sizing. Also, these practices are not based on resource and production capacity planning. In addition, surface finishing manufacturing (SFM) is a service delivery and not a Make-To-Order (MTO) production. Job orders are diversified, uncertain and require a delay for analyzing specifications and required processes. Above all, customers do not buy parts or material items but rather pay for using production capacity.

Regarding contract-by options, all the studies show that such practice clearly favours the buyer or the retailer more than the suppliers. Most of them involve money compensation [6, and 8], which is not satisfactory because compensation can be less of a priority than better visibility for SFMrs. In fact, the compensation fees do not overcome the problems generated by the lack of visibility. In addition, most studies analyze the case of one retailer that orders a few items to several suppliers which is not the usual case for SFM.

Finally, the DR approach is limited to a single period case. Multiple period cases are excluded as well as asymmetric cost information cases [11, 12, and 13]. Furthermore, most of the case studies deal with only one type of product and same production lead-time. SFMrs deal with more constraints and complexity caused by the diversity of the production mix. This is the same for periodic commitments [21] as it does not take into account several types of products. Globally, the literature has mostly focused on buyers than suppliers [10] and the proposed approaches rarely end up with a profit increase for the suppliers [20].

3 Elements of model

Recognizing the limitations of current collaborative practices, this study aims at proposing a solution that can bring visibility not only to customers but to SFMrs as well. The proposed model was developed as part of a larger research project aiming at improving the productivity of SFM within the Canadian aerospace industry. In this project, meetings were first conducted with one surface manufacturer to analyze its business processes. This step aimed at identifying their main weaknesses and to propose concrete solutions. Among potential solutions, the reengineering of the production planning processes was judged as the top priority. The model exposed in this section is one element of the proposed approach and is currently under validation. Therefore, the feasibility and efficiency of the proposed model are not discussed in this paper.

Elements of the proposed collaborative practice are detailed as follows:

1. First, the nature of the proposed contract is discussed;
2. Secondly, the elements monitoring its execution are presented.

3.1 General contract characteristics

First, the production capacity of the manufacturer has to be defined. This committed capacity is a subset of the total production capacity. This block of hours consists of a reserved number of hours allocated to a specific contract. While this information gives an idea of the SFMr capacity, the total capacity is kept private as it has a strategic dimension [10]. We also propose to use hours to define the amount of work for each order. In some cases, hours may be detailed per types of processes or resources.

As the aerospace industry has different seasons and customers might be interested in medium or short-term period, contracts may assign different amounts of reserved capacity per period as proposed by Serel [16]. This brings flexibility to handle differences between programs demand. Indeed, demand for a product depends directly on the lifecycle of the aircraft programs (unstable demand for new products versus stable or declining demand for end-of-life aircraft). Because our contract can deal with many periods, the contract has to be reviewed periodically with each customer. We propose to define a contract horizon with several periods that are not automatically identical as proposed in the CPFR literature [3, 4, 5, and 21]. The frequency of revision can be different from one customer to the next and has to be determined through negotiations.

We also propose that contracts may be negotiated per product family as the SFM demand is too diversified to be quantified globally. Planning the required resources by product family is also easier and more precise for SFM.

Regarding the quantity ordered, a maximum and a minimum can also be negotiated in order to provide some flexibility to the customer. Below the maximum reserved capacity, new orders have no impact on the SFM processing ability. However, a quantity lower than expected minimum would result in resource underutilization. Indeed, customers may demonstrate three kinds of behaviours as regards to the negotiated reserve capacity. Firstly, the customer might respect the initial commitment with the contract tolerance. Secondly, the customer might not respect the tolerance and order less than the minimum. In this case, we propose that the customer pays for the resources mobilized by SFM, even though they were not used. Thirdly, the customers might order more than the maximum. In this case, the literature proposes to outsource the excess demand or to use overtime [19]. In either case, the customer has to pay a superior price to access these additional resources.

Due to the high diversity of the mix of products, it appears more relevant to use a payment per order than a fixed payment per period. This strategy is more adapted to retail or any activity involving only one product [11, and 20].

3.2 Contract execution and monitoring

Executing and monitoring the proposed reservation contract is particularly difficult due to the diversity of the demand. In addition, production sequences can be complex. Furthermore, the capacity required for some orders may be quantified only after analyzing the required surfacing process. Therefore, a contract monitoring process must be put in place in order to control the exact resources and/or number of hours used by the customer. In a similar manner, such collaborative contract may allow for customers to define and change their order priority dynamically. Priorities setting and order monitoring mechanisms must therefore be determined within the contract.

Regarding capacity allocation, we propose to proceed in 2 steps:

- First, the customer agrees to give specifications to the surface finishing manufacturer so as he can analyze the demand and the capacity required;
- Then, the SFMr proposes a due date based on its current workload and capacity. Order processing time must be faster than conventional orders in order to translate the long term customer engagement into concrete benefits.

Note that for any product that has been processed previously, the SFM knows the required capacity utilization required by exploiting former data. The first step is not required in this case.

Regarding priorities, SFMrs have to deal with two kinds of orders: those that are linked to reservation contract and those that are negotiated in the traditional way. We propose three levels of priorities:

- Low: this level is intended for classic orders originated for conventional contracts.
- Medium: this level is for orders under the reservation contract. This way, we can be sure the orders are globally processed more rapidly than conventional orders.
- High: this level of priority is given when the job orders reach a critical date. There are many studies about critical ratio scheduling, notably, one led by Berry and Rao [22] that shows that critical ratio gives relevant priority index when processing times are known.

In all cases, SFM need to give feedback about order status. The reservation contract may specify some productivity commitments and how to measure it. One obvious indicator is due date: if the SFMr executes each orders before the committed due dates, the reservation contract is respected. The effective number of used hours must be communicated to the customer. In order to eliminate a steep increase of job orders at the end of a contract negotiated period, we recommend to monitor and evaluate the determined capacity usage per contract with completed orders only.

3.3 Potential benefits

SFMs have obviously better interest in engaging themselves into contract reservation strategy. These contracts would give them better visibility on future demand and in turn, be proactive in addressing workload variations. Such strategy may even end with dedicated resources to contracts if the negotiated reserved capacity is high enough. In this case, the order process may be optimized and result in shorter lead time and cost reduction. They could also plan mitigation measures if they encounter underutilization of their plant. They can also better anticipate augmentation of their workload. This is a major benefit for SFM as it is difficult to quickly recruit and train a workforce with the required skills.

On the customer side, they can expect from these contracts a lead time reduction and possibly a price reduction. One more attractive point is flexibility on priorities. If suppliers want to accelerate the processing of one of their orders, they can change their priority and still expect a better priority compared to classic orders.

4 Conclusion

The literature shows that a plethora of collaborative practices are used in practice even in uncertain environments. However, most of these practices are difficult to apply within SFM or in other industries coping with a high number of products and with variable manufacturing processes.

The model developed in this paper gives an overview of a potential solution to one of the major concerns of SFMrs, the lack of visibility on future demand. Although the study concerns SFM specifically, it may also provide a solution to other kinds of suppliers within the aerospace industry. Indeed, one of the biggest challenges for manufacturers is to plan the use of their resources in the mid and long term.

However, this paper presents some limitations. The presentation of the elements of the model do not permit one to conclude at this stage on its feasibility. Potential benefits also need to be quantified. As such, we propose to pursue this research by first developing performance criteria to be used for monitoring the engagements of both parties within the capacity reservation contract. Then, the implementation of the complete model within a discrete event simulation model will be tested using real data obtained from our industrial partners.

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