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A Financialized Model for a Risk-Focused Sales and Operations Planning

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Abstract: Sales and Operations Planning (S&OP) is a business process that connects strategic plans of a company with its operational plans. However, achieving the objectives of S&OP becomes increasingly challenging facing the dynamic business environments. The paper proposes a Decision Support System (DSS) for S&OP, with an emphasis on uncertainty management and on the calculation of financial key performance indicators. This research contributes an original two-part proposal focusing on Tactical MRP Calculation, and Financial Valuation within S&OP processes. This paper has two contributions, a new Work-in-Progress calculation method that reflects a detailed financial calculation, and generating financialized scenarios for S&OP.

Keywords: S&OP, sales and operations planning, supply chain planning, tactical planning, risk management, uncertainties, decision support systems, working capital requirements, WIP, MRP II.

1. INTRODUCTION

Sales and Operations Planning (S&OP) serves as a bridge linking strategic plans with operational plans, facilitating the balance of product demand with supply capabilities (Grimson and Pyke, 2007). However, this process faces increasing challenges caused by the rapidly evolving and unpredictable nature of the modern business environment, characterized by incessant change (Tavares Thomé et al., 2012; Dittfeld et al., 2021). The value of scenario planning in addressing uncertainties in S&OP processes is well documented (Noroozi and Wikner, 2017). However, Oger et al. (2022) highlight significant limitations in current supply chain capacity systems, such as the lack of support for analyzing uncertainties and exploring "what-if" scenarios, along with a failure to account for the various sources of variability.

This paper aims to (1) assess how current S&OP literature and tools manage uncertainties and (2) propose an S&OP DSS that prioritizes uncertainty management and financialized scenario planning. Therefore, this research investigates the following industrial question: What DSS currently exist for incorporating uncertainty into the S&OP process? The work in this paper is inspired from the work previously done by Oger et al. (2022) on a Strategic Supply Chain Capacity Planning (SSCCP) DSS (Figure 1), which generates "what-if" scenarios to help strategic decision-making. However, the current SSCCP DSS—while effective for long-term strategic planning—has limitations when implemented in a tactical context. Its design does not account for the complexities of medium-term planning cycles, such as the integration of lead times in a more granular manner, or the integration of financialized Key Performance Indicators (KPIs) such as Working Capital Requirement (WCR). These limitations form the motivation for the development of the S&OP DSS proposed in this paper, which aims to transform the strategic tool into a tactical one, suitable for S&OP planning and decision-making. This paper proposes adjustments to this SSCCP DSS, which is composed of four blocks (Figure 1): Supply Web Modeler (SWM), Supply Chain Map Generator (SCMG), Assessment Model Generator, and What-if Scenario Generator and Assessor (WSGA). For more details about the functionalities of each block, readers are referred to Oger et al. (2022).

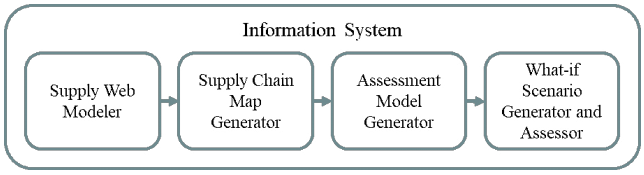

Fig. 1. SSCCP DSS overview adapted from Oger et al. (2022)

To enhance the tool's capacity to perform tactical planning, the enhanced S&OP DSS introduces additional calculations to the "Assessment Model Generator" block where all the calculations are done, that enables to consider shorter time horizons—shifting the planning granularity from an annual to a monthly scale. This modification allows for an alignment of supply chain activities with the dynamic nature of demand, allowing for a tactical planning from 6 to 24 months.

This paper introduces a two-part proposal to configure the SSCCP to S&OP DSS (Figure 2), focusing on the ultimate

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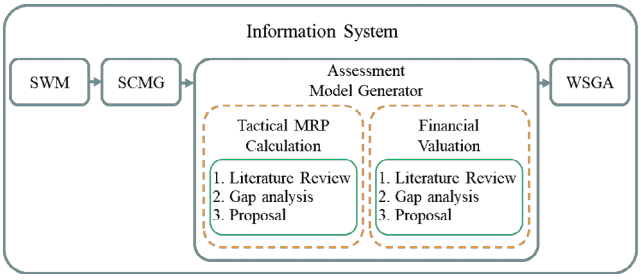

Fig. 2. S&OP DSS two-part proposal adopted in this paper, seen from the viewpoint proposed by Oger et al. (2022)

objective of generating automated "what-if" scenarios to manage uncertainties. The two parts are the "Tactical Material Requirements Planning (MRP) Calculation", and "Financial Valuation" for financial KPIs deduction (Figure 2). Each of these components represents a part of the S&OP DSS, designed to provide a tactical risk-focused S&OP process, which will be explained and developed in the later paragraphs. An "S&OP Tools" Literature Review is presented in Part 2, revealing insights gathered from existing S&OP literature. Part 3 outlines the proposal for the Risk-Focused S&OP DSS.

2. LITERATURE REVIEW

2.1 S&OP Tools

Neto et al. (2022) conducted a review of tools used in the S&OP process, concluding in the presentation of an S&OP framework evaluating various S&OP development scenarios. Their study highlights the important role of S&OP implementation maturity in guiding the selection and usage of tools for uncertainty management within the process. Particularly, during the initial stages of S&OP maturity, organizations predominantly rely on reactive planning strategies. As maturity levels develop, there is an increasing dependence on programming tools to manage demand uncertainty and help the formulation of viable delivery strategies (Neto et al., 2022). In highly matured S&OP processes, the integration of advanced simulation models becomes important, requiring efficient computational time management (De Ugarte et al., 2006; Feng et al., 2013-05/2013-06). These findings highlight the importance of aligning S&OP tools with the corresponding maturity level of the process.

The absence of tools capable of considering the diverse uncertainties and decision-making scenarios within S&OP is highlighted by Fakhry et al. (2022). A stochastic programming approach was presented by Almeida and Conceição (2021) with the objective of addressing uncertainties in the S&OP process. Comparative analysis against a baseline scenario included the evaluation of several key performance indicators (KPIs). This investigation enabled an assessment of the model's ability to capture the impact of uncertainty across various aspects of the S&OP process.

Nicolas et al. (2021) identified that information technology can significantly strengthen S&OP processes through the integration of analytical methodologies, including optimization strategies, to effectively address S&OP uncertainties. Furthermore, to better understand the impact of uncertainty in S&OP, using a stochastic programming model and examining multiple scenarios are proven to be beneficial (Sodhi and Tang, 2011; Feng et al., 2013-05/2013-06; Lim et al., 2017). To address the complexity of firm operations, Furlan de Assis et al. (2023) present a model based on system dynamics.

Gallego-García and García-García (2020) propose an approach that merges various methods, including scenario analysis, statistical analysis, forecasting, random number generation, and system dynamics, aimed at enhancing the precision and coherence of S&OP processes. Calfa et al. (2015) propose a data simulation and optimization approach to incorporate production variability into S&OP. Furthermore, Oger et al. (2022) highlighted from existing literature the limitations in supply chain capacity systems, including insufficient computer-aided support for opportunity and uncertainty analysis, particularly concerning "what-if" scenarios, and a limited consideration of uncertainties resulting from various sources of variability.

2.2 Tactical MRP Calculation

The MRP formulas adopted in this paper were calculated as per Chapman et al. (2017). As defined by Chapman et al. (2017), "Lead Time" is the span of time needed to perform a process, and "Offsetting" is the process of placing the exploded requirements in their proper periods based on lead time (LT).

The integration of flow optimization and cost models for the enhancement of cost efficiency and customer satisfaction has been studied in recent research. In their paper, Belil et al. (2019) present a methodology that combines these aspects for tactical planning in a productive system characterized by a multi-site, multi-product supply chain structure. This structure includes finite capacities across production, storage, and transportation. The primary aim of their research is to concurrently optimize inventory cost efficiency and improve customer satisfaction levels, presenting a holistic approach to supply chain management. On the other hand, Bian et al. (2020) investigate the tactical planning of multi-level supply chains with a serial structure. Their approach incorporates various financial considerations, including the financing of the WCR, thereby offering a perspective on supply chain optimization.

2.3 WIP Valuation

Chapman et al. (2017) define the Cost of Goods Sold (COGS) as an accounting classification useful for determining the amount of direct materials, direct labor, and allocated overhead associated with the products sold during a given period of time. The COGS comprises two primary components: Raw Material (RM) and Value Added (VA). Raw Material refers to the cost of the initial materials and components used in the manufacturing process, representing the foundational input costs. VA, on the other hand, represents the additional value created during the production process, typically through labor and other operational activities, which increases during the whole LT duration. Therefore, the COGS is the sum of the Raw Material cost and the Value-Added cost, providing a measure of the expenses directly tied to the production of goods.

In cost accounting, the "Average Cost System" is a method of inventory valuation for accounting purposes, as per Chapman et al. (2017). A weighted average (based on quantity) of item cost is used to determine the COGS (income statement) and inventory valuation (balance sheet). Authors such as Belil et al. (2019) chose the Activity Based Costing (ABC) valuation method as a tool for their financial valuation model. As per Chapman et al. (2017), there are four methods accounting uses to cost inventory: first in first out, last in first out, average cost, and standard cost. Each has implications for the value placed on inventory. If there is little change in the price of an item, any of the four ways will produce about the same results.

2.4 Working Capital Requirement

The WCR is a financial metric defined as the current assets of a firm minus its current liabilities (Bian et al., 2020). The WCR formula is expressed as following:

$$WCR = \text{Inventory Value} + \text{Accounts Receivable} - \text{Accounts Payable} \quad (1)$$

The authors Bian et al. (2020) calculated the WCR considering the logistic costs. Such costs included purchasing, setup, production, and inventory holding.

3. GAP IDENTIFICATION AND RESEARCH QUESTION

While the literature highlights the importance of aligning S&OP tool maturity with the S&OP process level, there remains a notable deficiency in tools that can robustly accommodate the various uncertainties integrated in the S&OP process. Current tools primarily focus on managing uncertainties in highly mature S&OP processes through reactive planning strategies, programming tools, and advanced simulation models. However, these methods still lack in addressing the full range of uncertainties, particularly in the tactical scope of the S&OP process. This includes insufficient computer-aided support for opportunity and uncertainty analysis in "what-if" scenarios, as well as a limited scope in considering the various sources of variability that impact the supply chain (Fakhry et al., 2022).

In examining the existing literature, a gap emerges in financializing tactical planning within S&OP. While researchers like Belil et al. (2019) have integrated flow optimization and cost models to enhance inventory cost efficiency and customer satisfaction, their methodology does not explicitly address the calculation of the WIP inventory. Similarly, Bian et al. (2020) investigate the financial aspects of tactical planning across multi-level supply chains but their approach lacks consideration of WIP, and do not account for lead times in their assessments. Furthermore, none of the authors present an estimation of WIP at various stages of production that aligns the calculation with the actual progression of work within the LT. Moreover, existing literature does not model a behavior finer than the period, thereby neglecting the nuances of production within lead times shorter than the period. It is this gap that our research aims to fill by proposing a methodology that incorporates both the quantification of WIP and the influence of lead times, thus presenting a more financially sensitive S&OP DSS.

In addition, the valuation of WIP within the WCR is absent. Methodologies such as those proposed by Bian et al. (2020), focus primarily on inventory valuation without including the WIP that is directly influenced by lead times. Moreover, methods of WIP valuation such as average costing, are tied to static periods and do not account for the complexities and disruptions that can result in fluctuating lead times. Consequently, they may not provide an accurate financial representation of WIP. This research introduces a WIP valuation calculation method that addresses these complexities without the necessity of transitioning to a more granular period modeling. When integrating lead times that may span less than the typical monthly tactical period, the proposed method offers a reflection of WIP value incrementation within any given period. Therefore, it allows for a monthly performance assessment while accepting a fraction of the month lead time variations, thereby presenting a finer behavior for the evaluation of the WIP.

The industrial question at the core of this research as mentioned above is: "What DSS currently exist for incorporating uncertainty into the S&OP process?" To answer this, we conducted a review of the literature to identify the current state and limitations of existing DSS. Notably, our review highlighted significant gaps in how these systems handle uncertainty as already mentioned above. Consequently, this research aims to address the following research question: How can a tool be designed to incorporate and financialize uncertainties and associated scenarios to support dynamic S&OP decision-making? This question leads to the exploration of the S&OP DSS that builds upon an existing strategic model by Oger et al. (2022), with the integration of financialized KPIs for medium-term planning horizons.

4. PROPOSAL

As explained in Figure 2 above, this paper proposes a two-block proposal for the transformation of SSCCP into an S&OP DSS. This proposal represents a shift towards a more granular and financially oriented S&OP DSS:

(1) Block 1: Tactical MRP Calculation: This involves the application of MRP for tactical planning.
(2) Block 2: Financial Valuation: This block presents a financial valuation methodology, integrating the WCR into the KPIs calculation for financialized scenario generation.

4.1 Tactical MRP Calculation

To be able to transform the original SSCCP into an S&OP DSS, we adopted the MRP calculation for our KPIs deductions. This paragraph will be a direct application of MRP with assumptions to make the calculations for the S&OP DSS. It is notable to specify that our calculations will be specific to an infinite capacity. All along the calculations, we assume having the reception of the products at the period of expedition. Given that the end goal is to calculate the WCR to financialize our KPIs and generate financial-

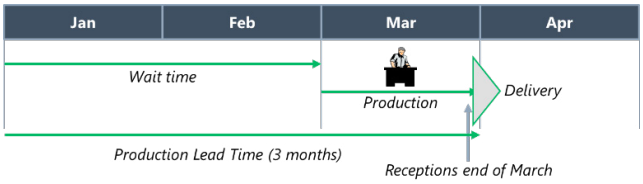

Fig. 3. Illustration of the resource allocation assumption

ized scenarios, we need to calculate the WIP quantity in the system at a certain period in the planning horizon.

Resource allocation: to incorporate lead times and allocate resources into the SSCCP, we introduced the following "Operation Number," "Operation LT," and "Operation Offset" to the input data model. The "Operation LT" is defined as the duration from when a production order is set up to its completion. The "Operation Offset" indicates the anticipation time for each operation. It is important to note that the longest "Operation Offset" within a set of operations determines the maximum LT. This will help enabling the representation of parallel operations, which is useful when creating macro-routing in the production planning.

One assumption that was made for the resource allocation is that the resources are utilized in the month preceding the delivery to account for production wait times in the production processes. To illustrate, we will take the following representation of only one operation (Figure 3): a product is scheduled for delivery in the first week of April, having an operation with a production LT of three months. Despite the operation production LT being three months, the actual utilization of resources occurs in the month of March due to waiting times in the production processes. This means that the allocation or usage of resources is anticipated in the month just preceding the scheduled delivery, specifically in March.

WIP calculation: calculating WIP involves considering the LT, which represents the time between launching a production order and its completion. To better illustrate this, let's consider an order required in April with a LT of two months. The order to be delivered in April will be included in the WIP of January and February. This allows the estimation of the WIP at various stages of production and aligns the calculation with the actual progression of work within the LT.

To understand the changing aspects of production and model a behavior finer than the typical monthly period, without resorting to a more granular period modeling, we introduce a new calculation to the WIP estimation, that provides a balance between detail and manageability in our modeling. It reflects a refined performance within a period while still allowing for an aggregated monthly view. Therefore, the WIP calculation in the S&OP DSS considers the quantities launched in different parts of the month, but will present the results on a monthly basis. The following formula is structured to calculate the total WIP at the end of a period by adding the full or partial quantities of products in process across different time periods within the LT, that will be used in the S&OP DSS tool. We opted for Planned Order Receipts instead of Net Requirements in the WIP calculation to ensure the incorporation of batch size.

$$WIP_t = \sum_{i=1}^{\lceil LT_m \rceil} POR_{t+i} \times \min\left[LT_m - (i-1), 1\right] \quad (2)$$

Where:

- t is the current month for which we are calculating the WIP
- WIP (t) represents the total WIP at the end of month t
- POR (t) is the Planned Order Receipts for period t
- LTm is the Lead Time expressed in months, which could be a fraction
- i indicates the months within the LT window
- $\lceil LT_m \rceil$ is the mathematical ceiling function that rounds up LT_m to the nearest whole number, ensuring the entire LT is covered
- $\min\left[LT_m - (i-1), 1\right]$ calculates the proportion of the month's contribution to WIP, adjusting for fractions of a month in the Lead Time

Using this formula, we can illustrate the following example: if we have Planned Order Receipts of 800 for March and 2000 for April, with a LT of 0.75 months, the February WIP would only consider the portion of March's order that falls within this LT. This translates mathematically to 0.75 of the March receipts. Since February is t, March would be t+1 (or i=1) and April would be t+2 (or i=2). The LT of 0.75 months covers 0.75 of March. which will result into:

$$WIP(\text{Feb}) = 0.75 \times POR(\text{Mar}) = 600 \quad (3)$$

4.2 Financial Valuation

The second block of this research, titled "Financial Valuation", is dedicated to integrating and assessing financial indicators within the S&OP DSS (Figure 2). This block focuses on the valorization of WIP, and WCR calculation that represent financial aspects of S&OP. This aims to generate financialized scenarios that would better help with the decision-making process. The following KPIs are the ones that will be integrated into the S&OP DSS.

In order to calculate the value of the WIP at a certain period, certain assumptions were taken. Firstly, we assumed a linear progression for the cost of VA, and to progressively increase the value of WIP with each period. Monthly VA increase is a critical factor, especially when dealing with products having a LT of multiple periods. In such cases, the WIP valorization increases progressively each month, necessitating the calculation of the average for each individual period of the WIP rather than an overall average across the entire LT. The following formula is structured to value the WIP at a given period t based on the progression of costs within the associated lead times, will be used in the S&OP DSS. We opted for Planned Order Receipts instead of Net Requirements in the WIP valuation to ensure the incorporation of batch size and the scrap rate.

In the below formula, we calculated the WIP valuation for LT less than a period, and for lead times between periods one and two. We apply the same logic for lead times of two periods and above. It was not possible to simply use the above WIP formula and multiply by the average

WIP valuation cost that progresses within the LT. The valuation of WIP cannot be uniformly calculated across the entire LT by applying an average cost. This is because the value attributed to different segments of WIP varies throughout the LT, as the value of WIP parts changes depending on their respective stages within the LT. The below formula helps accurately reflect the varied valuation of WIP components at different points in the LT.

$$\text{WIP Value}_t = \begin{cases} POR_{t+1} \times LT \times \overline{\sum_{Ci}^{LT} C} & \text{if } LT < 1 \\ \left[POR_{t+1} \times \overline{\sum_{LT-1}^{LT} C}\right] + & \\ \left[POR_{t+2} \times (LT-1) \times \overline{\sum_{Ci}^{LT-1} C}\right] & \text{if } 1 \leq LT < 2 \end{cases} \quad (4)$$

Where:

- WIP (t) is the WIP valuation at period t
- LT is the Lead Time in months
- POR (t) is the Planned Order Receipts for month corresponding to the t period within the LT window
- C is the WIP valuation cost that progresses within the month
- Ci being the initial cost associated with the initial production month

To calculate the Accounts Receivable and the Accounts Payable, we will use the same logic as the formula for WIP calculation. The formulas are structured to calculate the total amounts in a period by adding the full or partial quantities of products across different time periods within the LT.

5. EXPERIMENT

This study was conducted in partnership with a leading French aerospace manufacturer known for its expertise in mechanical welding and machining of large aeronautical parts, as well as the production of aluminum structural components. The studied company has a tactical planning process undertaken from 2 to 3 times a year. This process is led by the finance department and performs analysis over a time horizon of 4 years. Within this context, numerous scenarios are discussed, but only a few precisely assessed. The objective of this experiment is to test the first version of the S&OP DSS, which includes the lead time consideration as detailed in a previous section.

5.1 Methodology

The methodology followed for experimenting the S&OP DSS went through the following steps: Data Gathering, Data Preparation, and S&OP DSS Software Run. We first obtained the necessary business data from the company's S&OP process manager. This included demand forecasts for a time horizon of 12 months for 10 final products within the product families A and B. The resulting input data are summarized in Table 1.

*The number of elements is to multiply by the number of periods (i.e., 12) to get the number of associated states when it applies (based on the supply web metamodel).

5.2 Results

When running the first version of the S&OP DSS software with the provided data, it generated scenario assessment results files that included the KPIs. Table 2 provides a summary of the model's runtime, with a total of 100 scenarios assessed. In this initial test, we were able to look at the saturation levels of resources on a monthly basis, offering insights on the utilization rates and potential bottlenecks within the production process. This indicates that the transformation of the initial SSCCP into a tactical S&OP DSS, with a specific emphasis on the integration of lead times, has been successful.

The outcomes from this initial testing phase highlight the feasibility of further integrating the mathematical formulas and WIP valuation methods discussed throughout this paper into the S&OP DSS. These additions are planned for the following testing and experimentation, as it is ongoing development for a complete S&OP DSS.

6. CONCLUSION AND RESEARCH AVENUES

This research has two contributions. Firstly, we introduced a new WIP calculation method that reflects a detailed financial calculation within a period while still allowing for an aggregated monthly view, thereby improving the precision of WCR estimations. This offers an understanding of the capital needed in production at any given time. Secondly, the research contributes a global vision by generating financialized scenarios for S&OP. This global vision covers the integration of risk management and uncertainties into the S&OP process by generating multiple scenarios, helping organizations mitigate the impact of

Table 1. Supply web metamodel characteristics

Supply web metamodel node	Number of node instances*	Additional details
Periods	12	12 months in 2024
Organization	1	Production site
Product category (PC)	10	10 finished products
Demand forecast	10	Number of PC with demand forecast
Resources	13	13 resources with associated operation LT and offsets
Decision option	2	Options include purchasing new equipment to increase resource capacity
Uncertainty source	1	20% demand increase for "Family A" in October 2024

Table 2. Breakdown of the S&OP DSS processing time

SSCCP software module	Computing time
Computing time per scenario	0s 35.599ms
Program duration	5s 419.971ms
Number of scenarios assessed	100

variability in their operations. Our proposed S&OP DSS demonstrated its effectiveness in an industrial experiment with a French aerospace company, with a first version including lead times.

However, there are still a number of limitations to be addressed for future research: enriching the S&OP DSS with a wider array of financial KPIs, such as revenue, EBITDA, and CAPEX. While the current experiment serves as a proof of concept in an illustrative use case, expanding and including multiple real-world scenarios will be critical in evaluating the model's applicability and scalability. Furthermore, exploring alternative methodologies for calculating and generating scenarios is also a research avenue. When addressing the above, we can move closer to a DSS that navigates the complexities of today's production environments.

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