



## TEACHING BRIEF

# A Simulation for Managing Complexity in Sales and Operations Planning Decisions

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## ABSTRACT

Within the classroom it is often difficult to convey the complexities and intricacies that go into making sales and operations planning decisions. This article describes an in-class simulation that allows students to gain hands-on experience with the complexities in making forecasting, inventory, and supplier selection decisions as part of the sales and operations planning process. The activity may be run during one class period and is flexible enough to accommodate almost any class size. During the simulation, students may apply forecasting techniques, inventory management concepts, and supplier selection processes, while experiencing the effects of supply chain disruptions. This simulation is recommended to be used after forecasting, inventory management, and supplier selection topics have been discussed. An overview of the exercise and evidence of its effectiveness is provided.

***Subject Areas: Approaches, Content Areas, Experiential Learning, Games and Simulations, Pedagogical Approaches, Pedagogical, Operations Management, Supply Chain Management.***

## INTRODUCTION

Sales and Operations Planning (S&OP) is an integrated business planning process in which managers gather and share information from different functional areas of the business, which can help lead to higher firm performance (Thomé, Sousa, & Scavarda do Carmo, 2014). S&OP provides an opportunity for an organization to match supply and demand, and it has been identified as an overlooked area of operations management texts (Maloni & Franza, 2009) and a major content area to which supply chain students are underexposed (Grandzol & Grandzol, 2011). Real-life business environments which explore complexity have been identified as valuable for reinforcing learned supply chain management (SCM) principles (Arora & Saxena Arora, 2015). This article reports the implementation of an S&OP

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simulation into supply chain courses to provide students with an opportunity to better understand and manage the complexities inherent in making the S&OP process. The Excel files associated with this simulation may be found on the following website, <http://wp.me/P8IPRP-y>, or by contacting one of the authors.

### **Learning Objectives of the Simulation**

There are three learning objectives of the S&OP simulation for students: (i) Understand the trade-offs inherent in the S&OP process; (ii) Apply forecasting, inventory management, and supplier selection techniques to develop a sales and operations plan to manage these trade-offs; and (iii) Test the robustness of the sales and operations plan under conditions of uncertainty. Overall, the exercise emphasizes greater connectivity among the different parts of the S&OP process through a simulation.

Trade-offs in SCM have been identified as an important decision criteria for managing a supply chain, especially in the presence of uncertainty (Prater, Biehl, & Smith, 2001). Previous research has highlighted the difficulties of imparting the complexities of SCM decisions through traditional teaching methods, since most students do not have much work experience and are not trained to see the entire supply chain of a firm (Feger & Thomas, 2011; Webb, Thomas, & Liao-Troth, 2014). This challenge is exacerbated by the traditional teaching methods that often present topics independently in a course, limiting the students' opportunities to understand and experience the interdependencies inherent in SCM.

In the simulation students are assigned to teams to manage decisions regarding the S&OP process over twelve periods. The simulation emphasizes the application of tools within a team-based setting to make effective decisions. Simulation-based learning environments enable students to generate relationships among the key components of the simulation as they engage in the role of decision makers to apply course concepts (Kang & Doerr, 2015; Zantow, Knowlton, & Sharp, 2005). Experiential learning enables illustrating "theoretical business and operations management concepts in practice by simulating the workings of an actual manufacturing organization" (Piercy, 2010).

The use of a simulation to connect complex content in business courses has been used to teach project management (Hartman, Watts, & Treleven, 2013), inventory decision making (Umble & Umble, 2013), and forecasting (Clark & Kent, 2013; Snider & Eliasson, 2013; Webb et al., 2014). Several other supply chain simulations exist, including Littlefield Technologies, which is a "factory simulator" (Responsive Learning Technologies, 2017a); The Supply Chain Game, which combines forecasting, production, and logistics (Responsive Learning Technologies, 2017b); the beer game (Sterman, 1989), which has been used extensively to teach about the bullwhip effect (Jacobs, 2000); and Harvard Business School's Global Supply Chain Management simulation, which emphasizes forecasting and supplier selection based on cost and capacity consideration (Harvard Business Publishing, 2016). While these simulations can be valuable learning tools, the lack of an available tool for addressing the S&OP process integrated with supplier selection was the primary motivation for developing this simulation. The simulation presented in this manuscript emphasizes the trade-offs inherent in the S&OP process and in supplier selection.

## THE SIMULATION ACTIVITY

### Exercise Overview

The simulation provides an opportunity for students to experience a simulated S&OP process. Throughout the simulation, the students will make the following decisions:

- (1) *Forecasting*: Students are provided 24 periods of demand data for four different products. Using methods of their choice, students then develop a demand forecast for each of the products. In each period, students update the forecast as additional data is made available.
- (2) *Inventory Management*: Based on the generated forecasts, students must decide ordering times and quantities for each of the products and manage inventory levels throughout the simulation.
- (3) *Supplier Selection*: Students must decide between suppliers to cover all of the four products in each time period based on the supplier profiles provided in the simulation. They have the choice among four pieces of equipment and ten different suppliers, each with different profiles in terms of products offered, unit cost, startup costs, quality, disruption risk management, innovation, and timeliness.

The simulation is set up to run for 12 consecutive periods and engage in forecasting, inventory management, and supplier selection each period. Each decision is related and the teams must consider the full combination of information and choices together. Accurate forecasting is necessary for good inventory management, especially given the two-period lead time. Both forecasts and inventory levels can help to determine optimal supplier strategies due to costs associated with various suppliers, including upfront setup costs, variable, and fixed period costs.

The simulation is played in teams of three or four students. Each team uses the Student Excel File to enter their decisions for each period on the Decision Sheet. Based on the decisions that students make each period, the inventory levels, costs, and revenues are calculated automatically by the Student Excel File. The students may evaluate their performance by tracking their net profit both cumulatively and in each period. The overall performance metric for each team is the cumulative net profit (or loss) at the end of the twelve periods.

The primary objectives of the simulation are provided to the students on a single sheet within the Student Excel File. Figure 1 shows a screenshot of the Decision Sheet, which is the primary interface that students have with the simulation. It includes the following components: period instructions (i), a table to enter forecasts (ii), a table to enter actual demand provided by the instructor (iii), a table to enter and look up event codes (iv), a place to enter orders for every product in each time period (v), a table to select active suppliers for every product in each period (vi), supplier information (shown in Table 1), and performance scores (not shown).

The instructor has a dedicated Instructor Excel File that should be projected on the classroom screen. In each period, the instructor reveals the actual demand

**Figure 1: Decision sheet.**

Color Key		Period							
Generated by Forecasting Method	Forecast	Period -1	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Provided by Instructor	Product A			1000	1225	1250	870		
Decisions Required	Product B			500	650	550	667	ii	
General Information	Product C			300	325	500	435		
	Product D			200	200	225	145		
First Period	Actual Demand			Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Build Forecasting Models	Product A			1225	1250	870			
Select Suppliers	Product B			650	550	667		iii	
Place initial inventory orders for Products A-D	Product C			325	500	435			
	Product D			200	225	145			
Subsequent Periods	Event Information			Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Record Actual Data and Supplier Events	Code			7	12	3			
Update Forecasting Models with New Data									
Update Supplier Relationships	Event Lookup							iv	
Place inventory orders for Products A-D	Code			3					
	Event Type			Quality					
	Event Severity			Major					
	Event Description			You received a high quality reward for your organization.					
	Event Effects			Receive \$10,000 as a period adjustment for each applicable product					
	Condition			Every product supplied by a supplier with quality ≥ Very High					
	Instructions			Add 10,000 to the current period in column E on the Performance Sheet for each product impacted					
	Order Inventory	Period -1	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
	Product A	1000	1000	1000	1225	1250	870		
	Product B	500	500	500	650	550	667		
	Product C	300	300	300	325	500	435		v
	Product D	200	200	200	200	225	145		
	Active Suppliers*			Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
	Product A			Supplier 5	Supplier 5	Supplier 5	Supplier 5		
	Product B			Supplier 4	Supplier 4	Equipment 2	Equipment 2		
	Product C			Equipment 2	Equipment 2	Equipment 2	Equipment 2		
	Product D			Supplier 5	Supplier 5	Supplier 5	Supplier 5		vi

\*Leave active supplier selection blank if no order is placed in any given period for a specific part.

and any external events that impact the supply chains of the teams. In addition, the instructor can record team performance for each period on a sheet in the Instructor Excel File or on a classroom board. The demand information provided in the simulation consists of several components (trends, seasonal adjustments, seasonal events, and a random-walk stochastic component), and can be customized by the instructor for specific demand profiles as needed. In each time period, one random external event will be selected by the simulator from a pool of 32 possible events. Half of the events are positive and impact suppliers/equipment characterized by high scores for quality, high disruption risk management, high innovativeness, or high timeliness. The other half of the events are negative and impact suppliers/equipment which are characterized by low scores for each of the same characteristics. For every characteristic, there are four positive and four negative events, which include minor, medium, major, and critical events. A sample of events is provided in Table 2.

As can be seen from the description of the simulation, the students make decisions under conditions of uncertainty. The uncertainty arises from the trade-offs inherent in the S&OP process and supplier selection, unknown demand, and stochastic external events that occur every period. These trade-offs include:

- The typical trade-offs of Economic Order Quantity (EOQ) that exist between ordering costs, inventory carrying costs, and order quantities.
- The trade-offs between higher inventory carrying costs and unfulfilled demand (stock-outs).
- The trade-off between the cost structures of equipment/suppliers and their performance in terms of quality/disruption risk management/timeliness/innovativeness profiles.

**Table 1:** Supplier selection choices.

Supplier Choices		Upfront Setup Costs	Period Fixed Costs	Var Cost A	Var Cost B	Var Cost C	Var Cost D	Quality	Disruption Risk Management	Timeliness	Innovativeness
Make	Equipment 1	\$ (100,000)	\$ (1,000)	\$2	\$4	\$5	\$6	High	High	Very High	Low
	Equipment 2	\$ (40,000)	\$ (750)	\$4	\$5	\$5		Medium	Medium	Very High	Low
	Equipment 3	\$ (10,000)	\$ (500)	\$2				Medium	Medium	Medium	Low
	Equipment 4	\$ (20,000)	\$ (500)				\$5	Very High	Very High	Very High	Low
Buy	Supplier 1	\$ (500)	\$ (2,700)	\$3	\$4	\$5	\$8	Low	Low	Very Low	Low
	Supplier 2	\$ (8,000)	\$ (1,200)				\$6	High	High	Very High	High
	Supplier 3	\$ (4,500)	\$ (1,500)		\$3			Low	Medium	Low	Low
	Supplier 4	\$ (2,000)	\$ (3,000)		\$5	\$6		Very Low	Very High	Medium	Medium
	Supplier 5	\$ (5,000)	\$ (300)	\$5			\$9	Very High	Very High	Very High	Very High
	Supplier 6	\$ (9,000)	\$ (3,000)		\$5		\$8	Very Low	High	Low	Very High
	Supplier 7	\$ (5,000)	\$ (3,000)	\$4		\$6	\$7	High	Low	Medium	Very High
	Supplier 8	\$ (5,500)	\$ (3,000)	\$3		\$4		Low	Very High	Very Low	Very Low
	Supplier 9	\$ (3,000)	\$ (2,400)	\$4			\$7	Medium	High	Medium	High
	Supplier 10	\$ (2,500)	\$ (2,100)	\$3	\$4		\$6	Very Low	Very Low	High	Medium

**Table 2:** Selected event list.

Event Classification	Event Severity	+/-	Event Description	Effect
Quality	Medium	+	High quality product yielded more usable components than expected, increase inventory received for the period by +10%.	+ 10% inventory received for the period
Disruption Risk Management	Minor	+	There was some disruption due to storms, but your company was able to manage it effectively.	Gain 10% increased demand from customer appreciation for 1 period
Timeliness	Major	+	Effective inventory management has led to a reduction of \$10,000 of expenses in your warehouse.	Receive a one time \$10,000 period adjustment for each applicable product
Innovativeness	Critical	+	Your supplier's innovation has changed the way they manufacture their products making their products much cheaper.	Variable costs decrease by \$1 for the rest of the game for each applicable product
Quality	Medium	-	A review of your inventories found bad inventory.	20% of your held inventory must be discarded for the current period
Disruption Risk Management	Minor	-	The supplier had a disruption with their own supply network and can no longer provide all product types.	This supplier can no longer provide products A or B for three periods
Timeliness	Major	-	The shipment is late, but you are able to expedite the shipment at a cost of \$10,000.	Incur \$10,000 additional costs
Innovativeness	Critical	-	A new innovative change to Products A and D was released in the market, but your supplier cannot keep up with the change.	This supplier can no longer supply product A or product D

- The trade-offs between the fixed costs associated with acquiring and maintaining a piece of equipment or establishing a new supplier relationship, variable unit costs, and flexibility in terms of the products that the supplier can produce.

Students should be taught how to manage these trade-offs and should be given enough time to evaluate the information available to make better decisions. Student teams that understand the trade-offs above and use appropriate decision-making strategies will outperform student teams that do not rely on those techniques. A short, nonexhaustive list of techniques (in alphabetical order) students could apply for the different decisions are included below:

- *Forecasting*: linear regression, linear regressions with period adjustments, moving averages using simple, weighted, or exponential smoothing approaches, and seasonal adjustments.
- *Inventory management*: aggregate planning, continuous or periodic review systems, EOQ, least total/unit costs, lot-for-lot ordering, and safety stock calculations.
- *Supplier selection*: Analytical Hierarchical Process (AHP) decision making, breakeven analysis, total cost analysis, and weighted average comparisons.

In each period of the simulation, students will update their decisions for inventory management and supply selection to respond to the actual demand levels within the simulation and the various events which occur to suppliers that have been selected. Students are exposed to consequences from the choices that they make in terms of costs during the simulation and events that are connected to the attributes of selected suppliers.

### **Instructor Preparation**

The goal of this activity is to provide an opportunity for the students to utilize the tools they have learned in previous class sessions to make multiple decisions in the simulation, thus helping them to see the sequence of inter-related decisions that occur within a supply chain management process. During the simulation, the instructor manages the external factors that impact the teams during the simulation, including revealing actual demand information and the external event that occurs in each period.

The simulation instructions include an explanation of the simulation, recommendations of questions to ask the students, and an explanation of the Student Excel file that the students use to record their decisions throughout the simulation. Given the complexity of the simulation, it is important that the instructor takes an active role in seeking out student questions, such as asking each team individually if they have any planning and decision questions during the early part of the simulation. This is useful, as it provides an opportunity for the instructor to gauge the students' progress for timing each period, and students are more likely to ask questions of the instructor within their team rather than in front of the entire class.

Finally, the instructor collects data regarding each team's performance, both for individual periods and at the end of the simulation. This provides benchmarking results and creates a dynamic of competition among the teams. It also provides an opportunity to provide token rewards to teams for performance throughout the simulation and a larger prize at the end for the best performing team. While the reward process can add an enjoyable competitive dynamic to the simulation, care must be taken to identify how short-term performance does not always match with optimal decision making, and sometimes the best decision for the long-run might lead to short-term losses, such as investing in a new piece of equipment. The reward process also serves as an opportunity to reflect on the experience, as discussed in a later section of this article.

### **Class Preparation**

It is recommended that students are aware of the critical concepts related to S&OP prior to engaging in the simulation. These include understanding various forecasting techniques, supplier selection decisions and trade-offs, and inventory management for both S&OP and Master Production Scheduling (MPS). It is recommended that the simulation be used within the classroom after these topics are covered. To further assist with student preparation, instructors can provide students with materials prior to the simulation to allow them to practice the aforementioned concepts. This may aid them in preparation for any examination within the classroom, as well as provide them with experience using the tools necessary for making the types of decisions required during the simulation. To aid in this effort, the forecasting and supplier selection components of the simulation can be shared with students prior to the simulation activity to familiarize them with the data in the simulation.

Before the simulation begins, the students should be provided with the demand information from the simulation. The demand information included in the simulation has general trends, seasonal variation, and random variance. While students can use a variety of forecasting approaches, the most effective teams tend to use more advanced forecasting approaches, such as linear regression models or exponential smoothing models adjusted for seasonality.

Ideally, instructors would also share the supplier information with the students ahead of time to allow students more time to evaluate the different strengths and weaknesses of the suppliers. Higher quality suppliers have trade-offs of either higher costs per product, higher fixed or variable costs, or are able to supply fewer products. Students are asked to make trade-off decisions regarding supplier selections, but multiple strategies may be effective. Each team is encouraged to select a company strategy to help guide them in choosing the suppliers that best fit with their vision and mission. For example, a low-cost strategy would be more likely to choose lower cost suppliers that were less innovative, but more timely.

Inventory management analysis such as EOQ and the total inventory cost can be calculated with the data provided in the Student Excel File. However, time limitations of the simulation tend to limit these calculations to the initial planning time period only.

The simulation is designed in such a way that it can be used as a stand-alone single event using a single class period or broken into three individual segments

**Table 3:** Sample schedules for facilitating simulation for 80 minute classes.

One Class	Minutes
Introduction	5
Initial Analysis	10
Round 1	10
Discussion	5
Rounds 2–10	45
Conclusion	5
Total	80
<b>Multiple Classes</b>	
<i>First class - Forecasting</i>	
Assign Forecasting Module	5
<i>Second class - Supplier Selection</i>	
Assign Supplier Selection Module	
<i>Third class - Simulation Day</i>	
Introduction	5
Initial Analysis	5
Round 1	10
Discussion	5
Rounds 2–10	45
Conclusion	10
Total	80

(forecasting, supplier selection, and the simulation experience). The forecasting and supplier selection modules can be assigned via homework individually or in groups prior to the simulation experience, which might help to prepare students for the experience. This will make the simulation experience flow more smoothly and take less time, as the students will already be familiar with some of the modules. However, this simulation can also be done with no prior preparation beyond teaching the required concepts if sufficient time is allocated for planning. Sample schedules for this simulation are provided in Table 3.

### Exercise Debrief

At the end of the simulation, it is important to help connect the students' experiences with their performance. This can be done by asking each team to report on their performance, including challenges and successes throughout the simulation. The different strategies that students select provide them with useful learning experiences as they reflect on optimal forecasting approaches, risk-taking decisions, managing forecast errors and order variance, and the trade-offs between fixed costs and variable costs for different supplier options. Typical responses include strategies focusing on one or two competitive dimensions from among cost, quality, timeliness, innovation, or disruption risk management. Students who choose to be the low-cost leaders and keep costs down will experience more negative events because their suppliers will have lower quality, timeliness, innovativeness, and/or disruption risk management scores. They may perform well for some of the periods, but they are at risk of having a poor event significantly affect them.

**Table 4:** Respondent Information

Respondents Profile	University 1 ( <i>n</i> = 32)	University 2 ( <i>n</i> = 69)
<b>Age (Years)</b>	21.5	24.0
<b>Gender</b>		
Female	40.6%	24.6%
Male	59.4%	75.4%
<b>Ethnicity</b>		
White	71.9%	30.4%
Hispanic or Latino	6.3%	18.8%
African American	0.0%	7.2%
Asian or Pacific Islander	21.9%	39.1%
Other	0.0%	4.3%
<b>Grade Level</b>		
Junior	43.8%	37.7%
Senior	56.3%	62.3%
<b>Major (% SCM)</b>	75.0%	71.0%
<b>Work Experience (Years)</b>	3.1	4.4

Students who choose to focus on quality may incur higher upfront costs for the suppliers/equipment they choose. Students are asked to create a strategy and then experience the complexities and outcomes tied to the decisions they make.

These post-simulation discussions can yield valuable learning opportunities to discuss short-term versus long-term performance as a team, which facilitates dialog about how decisions that are financially beneficial in the short term are not necessarily better in the long run. Recording team performance in each period enables both quantitative and qualitative discussions of team performance. Probing questions to explore challenges and successes also provide an opportunity to explain how to effectively apply different tools for managing the different components of the simulated business across multiple products. Finally, a written summary of what worked well, what didn't work well, and what the team would do differently may be assigned.

## ASSESSMENT OF EFFICACY

A version of this S&OP simulation has been used in three undergraduate courses at two different universities by two different professors. Anonymous survey data was collected during the last two semesters in which the simulation was used (data were collected Spring and Fall 2016). On average, about 60% of the respondents are seniors and 73% are supply chain management majors. Respondent ages ranged from 20 to 51. Specific respondent information is provided in Table 4.

The simulation activity was largely similar between both samples, though improvements were made to the simulation following the first iteration at Michigan State University (University 1 in Table 4) to help to better accomplish the learning objectives and increase the value of the simulation. Students responded positively to the simulation. Selected statements were collected from students who experienced the simulation at Michigan State University and are provided below:

**Table 5:** Survey results from Fall 2016 classes (n = 70).

Questions	Mean	SD
The SOP simulation was a worthwhile learning experience.	5.93	1.52
The SOP simulation was a more effective way to present the topic of SOP than the traditional lecture format.	5.71	1.65
The SOP simulation was a great way to learn about how my decisions would impact team and business process.	5.89	1.57
The SOP simulation improved my understanding of key concepts in SOP.	5.76	1.59
The SOP simulation improved my understanding of the importance of SOP.	5.90	1.56
The SOP simulation helped me learn about SOP.	5.88	1.61
The SOP simulation helped me apply course concepts.	5.96	1.53
The SOP simulation was an engaging classroom exercise.	6.03	1.42
The SOP simulation was fun.	5.97	1.49

\*7-point Likert scale was used. Strongly Disagree = 1; Strongly Agree = 7.

- *“It put us in a real world situation where we work with teams to use our skills learned in the classroom.”*
- *“The activity did benefit my classroom experience by putting the textbook knowledge we have covered into actual practical application.”*
- *“Engaged the classroom and gave us a visual experience of forecasting and ordering.”*
- *“By having a real-time simulation, it was easier to see how demand can affect inventory levels rather than just reading about case studies.”*
- *“It really put into perspective how much goes into every decision. There is a lot more than meets the eye when it comes to selecting suppliers.”*

The positive learning experiences of the students was further measured at Rutgers University (University 2 in Table 4) using modified questions based off the Hartman et al. (2013) perceptions of learning survey. The results are shown in Table 5. The results reveal that the activity was viewed as fun (5.97 out of 7.00 score on a balanced Likert scale) and as an engaging classroom exercise (6.03 out of 7.00). Additionally, the students agreed that the exercise improved their understanding of the importance of S&OP (5.90 out of 7.00) and its key concepts (5.76 out of 7.00).

## ACADEMIC AND MANAGERIAL IMPLICATIONS

For instructors teaching operations and supply chain management courses, this simulation provides an opportunity to integrate many concepts into one class exercise. Students find it fun and stimulating. It is important to expose students to real-life scenarios. This is often hard to do with the limited number of interactive class periods during a typical semester. This simulation provides the opportunity to expose students to situations that may occur at their current and future employers. It may provide them confidence to address future tasks assigned to them at their

jobs and to better understand the potential pitfalls of various decisions. Finally, it helps to expand their thinking beyond the linear processes that the curriculum often contains by having them consider decision scenarios from multiple angles.

There is a need in industry for individuals to understand all the working parts of an organization and to realize how their decisions affect others. This simulation allows for students to better understand the steps and outcomes of their decisions on a supply chain. As one industry contact stated after learning of this simulation, “I wish my team could participate.” Another individual that works for a major construction equipment manufacturer stated,

“We still use Excel for much of our analyses. However, many of our analyses rely on qualitative reasoning, rather than textbook methods. It would be helpful to know how to test and implement various forecasting techniques and create better inventory management policies.”

These statements help lead to the conclusion that the concepts and tools being taught are useful and set students up for success. While many of the concepts in the classes may have been taught for decades, businesses are still in need of these ideas and tools. This simulation helps students practice their techniques and develop strategies to integrate several areas of a business.

## **CONCLUSION**

Educators are facing pressure to provide opportunities to students to take learning beyond the classroom. By using simulations, one can achieve this in a low-cost, engaging manner. This simulation helps to prepare students for positions within the field of SCM by providing them with a greater appreciation of the complexities and trade-offs that are involved in the decision-making processes within S&OP. Specifically, it requires a sequence of decisions to be made for a supply chain, so that value is maximized across the supply chain and not optimized locally.

Often in class exercises, assigned homework, and exams, the process to find the correct answer is linear and involves following the correct process for solving the problem. By participating in this exercise, students learn that determining an optimal strategy is not a simple process, and one must make trade-offs to complete the task to the best of their abilities within the time frame provided. These insights are highly valuable for students to experience. It is valuable for them to understand and experience the trade-offs involved in managing complexity and making decisions using limited information, resources, and time. This S&OP simulation provides a meaningful experience that enhances student learning, in addition to providing a fun, engaging classroom opportunity to students, while reinforcing the concepts from the classroom instruction, so students are better prepared for their future careers.

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## APPENDIX A: SUPPLIER SELECTION SIMULATION STUDENT INSTRUCTIONS

Your team has been assigned the task of making sure demand for the next year is met for your company’s key product lines. In years past, production has been outsourced overseas, but the company recently decided to start producing the products themselves. You have been tasked with selecting the suppliers and managing the ordering process over the next year to make sure you can meet customer demand and be as profitable as possible. To do that, you will need to select the right equipment or suppliers to meet demand. You have four different products to manage: Product A, Product B, Product C, and Product D.

The company has provided you with some information to help you make the decisions in an Excel file. *In the Excel file, you will find the following sheets:*

- (1) “Decision Sheet” – Primary sheet for all decisions and data input. Includes quick reference of useful data at the bottom.

**Forecast** – Area to include updated forecasts for each part as the simulation progresses.

Forecast	Period -1	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Product A			1000	1225	1250	970		
Product B			500	650	550	667		
Product C			300	325	500	435		
Product D			200	200	225	145		

**Actual Demand** – Area to include actual order information as provided by the instructor in each period.

Actual Demand	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Product A	1225	1250	870			
Product B	650	550	667			
Product C	325	500	435			
Product D	200	225	145			

**Event Information** – Area to report event codes for each period and to look up a specific event.

Event Information	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
Code	7	12	3				
<b>Event Lookup</b>							
Code	3						
Event Type	Quality						
Event Severity	Major						
Event Description	You received a high quality reward for your organization.						
Condition	Every product supplied by a supplier with quality ≥ Very High						
Event Effects	Receive \$10,000 as a period adjustment for each applicable product						
Instructions	Add 10,000 to the current period in column E on the Performance Sheet for each product impacted						

**Order Inventory** – Area to indicate orders placed in that time period to arrive two periods later.

Order Inventory	Period -1	Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Product A	1000	1000	1000	1225	1250	870		
Product B	500	500	500	650	550	667		
Product C	300	300	300	325	500	435		
Product D	200	200	200	200	225	145		

**Active Suppliers** – Area to indicate suppliers selected for each product in every time period.

Active Suppliers*	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Product A	Supplier 5	Supplier 5	Supplier 5	Supplier 5		
Product B	Supplier 4	Supplier 4	Equipment 2	Equipment 2		
Product C	Equipment 2	Equipment 2	Equipment 2	Equipment 2		
Product D	Supplier 5	Supplier 5	Supplier 5	Supplier 5		

\*Leave active supplier selection blank if no order is placed in any given period for a specific part.

2 “Historical Demand” – Shows the demand for the last 24 periods for all products and will update automatically based on new information. Revealed demand below does not match that in the simulation.

Period	Date	Product A	Product B	Product C	Product D
Period -23	January, 2015	384	232	80	0
...					
Period -2	October, 2016	1250	550	500	225
Period -1	November, 2016	870	667	435	145
Period 0	December, 2016	1026	648	432	351
Period 1	January, 2017	1225	650	325	200
Period 2	February, 2017	1250	550	500	225
Period 3	March, 2017	870	667	435	145
Period 4	April, 2017				
Period 5	May, 2017				
Period 6	June, 2017				

3 “Performance Sheet” – Tracks costs per period and net profits by product. Also includes detailed information and cost calculations by product.

Period	Total	Supplier	Supplier	Period	Product A	Product B	Product C	Product D
		Fixed Costs	Period Costs	Adjustments	Net	Net	Net	Net
1	(35,050)	(\$47,000)	(\$4,050)	\$0	\$5,875	\$2,750	\$1,975	\$5,400
2	12,925	\$0	(\$4,050)	\$0	\$7,525	\$3,100	\$1,075	\$5,275
3	13,512	\$0	(\$1,050)	\$0	\$7,320	\$2,465	\$1,200	\$3,577
4		\$0	(\$1,050)	\$0				
5		\$0	\$0	\$0				
6		\$0	\$0	\$0				
7		\$0	\$0	\$0				
8		\$0	\$0	\$0				
9		\$0	\$0	\$0				
10		\$0	\$0	\$0				
11		\$0	\$0	\$0				
12		\$0	\$0	\$0				
<b>Total</b>	<b>(8,614)</b>							

4 Inventory Sheets (one for each Product A - D) – Simple S&OP chart for managing current and incoming inventory levels. Has some columns which will be modified as needed by events which occur in the simulation.

Event	Fill in if an event occurs with a supplier for this product									
Decision	Decided Each Period (imported from Decision Sheet) Calculated Automatically									
Inventory Sheet										
Period	Beginning Inventory	Inventory Modifier	Inventory Scheduled to Arrive	Inventory Received Modifier	Demand	Demand Modifier	Fulfilled Demand	Unfulfilled Demand	Ending Inventory	Orders Placed (Arrives T+2)
Period -1	0									1000
Period 0	0									1000
Period 1	0		1000		1225		1000	225	0	1000
Period 2	0		1000		1250		1000	250	0	1225
Period 3	0		1000		870		870	0	130	1250
Period 4	130		1225							870
Period 5			1250							
Period 6			870							
Period 7										

5 “Supplier Management Sheet” – Provides information for selecting suppliers and shows supplier costs for every period.

Supplier	Choices	Setup Costs	Period Fixed Costs	Var Cost A	Var Cost B	Var Cost C	Var Cost D	Quality	Disruption Risk	Management	Timeliness	Innovativeness
Make	Equipment 1	\$ (100,000)	\$ (1,000)	\$ 2	\$ 4	\$ 5	\$ 6	High	High	Very High	Low	Low
	Equipment 2	\$ (40,000)	\$ (750)	\$ 4	\$ 5	\$ 5		Medium	Medium	Very High	Low	Low
	Equipment 3	\$ (10,000)	\$ (500)	\$ 2				Medium	Medium	Medium	Medium	Low
	Equipment 4	\$ (20,000)	\$ (500)		\$ 5	\$ 5	\$ 5	Very High	Very High	Very High	Very High	Low
Buy	Supplier 1	\$ (500)	\$ (2,700)	\$ 3	\$ 4	\$ 5	\$ 8	Low	Low	Low	Very Low	Low
	Supplier 2	\$ (8,000)	\$ (3,200)				\$ 6	High	High	Very High	Very High	High
	Supplier 3	\$ (4,500)	\$ (5,500)	\$ 5	\$ 3			Low	Medium	Low	Low	Low
	Supplier 4	\$ (2,000)	\$ (3,000)	\$ -	\$ 5	\$ 5	\$ 6	Very Low	Very High	Medium	Medium	Medium
	Supplier 5	\$ (5,000)	\$ (300)	\$ 5	\$ 5		\$ 9	Very High	Very High	Very High	Very High	Very High
	Supplier 6	\$ (9,000)	\$ (3,000)	\$ 5	\$ 5		\$ 8	Very Low	High	Low	Low	Very High
	Supplier 7	\$ (5,000)	\$ (3,000)	\$ 4		\$ 6	\$ 7	High	High	Low	Medium	Very High
	Supplier 8	\$ (5,500)	\$ (3,000)	\$ 3	\$ 5	\$ 4	\$ -	Low	Very High	Very Low	Very Low	Very Low
	Supplier 9	\$ (3,000)	\$ (2,400)	\$ 4		\$ 5	\$ 7	Medium	High	Medium	High	High
	Supplier 10	\$ (2,500)	\$ (2,100)	\$ 3	\$ 4	\$ 6		Very Low	Very Low	High	Medium	Medium

6 “Product Pricing Sheet” – Shows breakdown for product costs and revenues.

Product A							
Period	Material Costs	Event Modifier	Variable Labor Costs	Sell Price	ICC (Per Period)		
Period 1		5		\$5	\$15		20%
Period 2		5		\$5	\$15		20%
Period 3		5		\$5	\$15		20%
Period 4		5		\$5	\$15		20%
Period 5				\$5	\$15		20%
Period 6				\$5	\$15		20%

***Your job is three-fold:***

- (1) Analyze historic demand and use a forecasting approach for ordering quantities for products A-D.
- (2) Select the equipment or supplier to manufacture or supply products A-D in each time period.
- (3) Manage inventory levels for products A-D.

***In every period, you will have to make the following decisions:***

- (1) Select the supplier to use for each product.
- (2) Place orders for each product.
- (3) Update demand information and forecasts.
- (4) Enter event number and follow event instructions, if applicable.

Your performance will be evaluated based on the total net income of the team's inventory management plan over the course of the year. Here are some hints:

- During the simulation, good and bad events will occur which will impact different suppliers based on their qualifications. Selecting suppliers or equipment that are good or bad in an area will expose you to these positive or negative events.
- Products A, B, C, and D are all different. Consider looking at their demand patterns separately. They also have different carrying costs, profit margins, and costs to manufacture. This might change your strategies for ordering each product. More information is provided on the Product Pricing Sheet for the breakdown between products.
- Watch what is happening and be ready to adjust plans as necessary. But remember, you have two periods of lead time that slow down your reaction for any decisions that you do make.

## **APPENDIX B: SUPPLIER SELECTION SIMULATION INSTRUCTOR INSTRUCTIONS**

***The Learning Objectives***

- (1) Understand the trade-offs inherent in the S&OP process.
- (2) Apply forecasting, inventory management, and supplier selection techniques to develop an S&OP to manage these trade-offs
- (3) Test the robustness of the S&OP in conditions of uncertainty.

***Simulation Outline***

- (1) Provide simulation materials (assign pre-simulation modules, distribute the Student Excel file and student instructions).
- (2) Assign teams of 3 or 4 individuals.

- (3) Introduce the simulation by discussing student responsibilities of forecasting, inventory management, and supplier selection.
- (4) Run through a small hypothetical example where you do the following steps:
  - a. Generate a simple forecast:
    - i. Insert a line graph for a single product number.
    - ii. Generate a simple forecast (naïve forecast, lifetime average)
  - b. Place an order for that product on the Decision Sheet.
  - c. Select a supplier that can produce that product.
  - d. Announce an actual demand scenario.
  - e. Show updated inventory sheet on product table and final costs for the period for that product on the performance tab.
- (5) Have students play period 1:
  - a. Tell students to develop a forecasting methodology and forecast for the first time periods, select suppliers, and place orders for the four products for the periods that occur prior to period 1 to pre-order inventory for periods 1 and 2.
  - b. Visit each team to observe behavior and answer questions during period 1.
  - c. After students have placed all orders, reveal actual demand and the event which occurs in period 1.
- (6) Play periods 2–12. In each period, students' primary responsibilities include:
  - a. Select the supplier they are using for each product
  - b. Place orders for each product
  - c. Update demand information and forecasts
  - d. Follow event instructions if applicable
- (7) Report final scores.
- (8) Lead classroom discussion:
  - a. Teams that performed well, what worked for you?
  - b. Teams that did not end up as top performers, what happened? Why was it difficult?
  - c. What challenges did you run into?
  - d. If you adjusted your strategy, how difficult was it to adjust strategies in the middle of the simulation?
  - e. What additional information did you wish you had available? Did you have enough/too much information?
  - f. What tools did you use in making decisions at the start of the simulation? At the end?

The entire simulation can be done in an 80-minute class. It can be shortened in many ways to adjust to specific schedules (faster periods, fewer products, or fewer time periods) as necessary. Sample simulation schedules are provided in Table 3.

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