AC 2009-1780: DEVELOPING A MANUFACTURING COST-OF-OWNERSHIP ALGORITHM FOR COMPARING GOODS FROM TRADITIONAL SUPPLIERS TO VENDOR MANAGEMENT

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Comparing the total cost of goods from traditional distributors to total costs under vendor management

Abstract

Vendor-managed inventories (VMI) are a great boon for manufacturers—when skillfully implemented—because they provide for lower inventories, lower overall costs, a multitude of risk management advantages, and improved service levels. Far-sighted manufacturers who have adopted VMI see cost savings and service improvements that belie the larger dollar figure shown on each product invoice.

As is usual in education, it is quite simple to issue this statement in a classroom and receive nodding heads in response, but it is quite a different situation when those students become purchasing managers themselves and are faced with the choice of paying more money up front under VMI or picking the lowest bid from any competitive supplier of reasonable quality and reputation. Typical business measures put in place to influence purchasing employees' behavior create negative incentives for employing VMI, since paying more money for supplies yields concrete negative numbers, even if the organization as a whole sees a cost reduction that is hidden in other areas of the organization. Conversely, measurements usually create incentives for purchasing managers to pick the lowest bid, even if the company as a whole loses.

This project, based on an ongoing study of the electric-utility industry, seeks to construct a solution for communicating the economic realities of separately sourcing materials for manufacturing versus creating a lasting relationship with one primary supplier through VMI. Moreover, the project will attempt to create an "argument" that arms students with knowledge of "total cost of ownership" philosophies, so that they can approach future manufacturing sourcing decisions with clear and convincing "experiential" knowledge. The result will be a clearly-defined economic difference between sourcing methodologies, complete with specific methods of quantifying (in terms of money) many of the benefits of VMI that impact the bottom line, but are not easily converted to a dollar figure.

Introduction

Vendor management of inventory (VMI) has a distinguished recent history of progress and success at the highest levels of industry.[1] From Procter and Gamble's 24-year-old partnership with Wal-Mart to the current environment of widespread big-box retailer adoption, VMI has grown up from its roots as a wishful thinking plan to combat the bullwhip effect to a legitimate and even dominant idea for optimization of a retail supply chain.[2]

Even so, VMI remains difficult to sell to some industries, and difficult to implement even if sold.[3] This is especially true when the nature of the industry means that freely sharing information is risky, or when operational compliance to regulation is enforced by means of a government order, subpoena, or criminal charge.

One such industry is the electric utilities industry, where a small handful of large national distributors compete with seemingly innumerable small regional distributors to serve hundreds of municipal, cooperative, and privately-owned electric utilities. Into these operations are annually hired graduates of STEM programs nationwide, some of whom, presumably, have had some education in supply chain management theory. This education may consist of a lecture on supply chain topics, and typically includes at least a small section on VMI and its benefits and pitfalls.

Consider the case of a student of one of these STEM programs who envisions a career in supply chain management, warehouse management, operations, or similar. Upon graduation the student receives offers and accepts a position as a purchaser for a large investor-owned utility. Move forward a few years and the student is now employed at the utility as a vice president in charge of warehouse operations and procurement. An enterprising distributor of electricity distribution products asks for a meeting with our former student—who is now a generous alumni-association donor—and tries very hard to sell the idea of a partnership through VMI. The former student remembers reading about VMI, and that it is supposed to be a good thing, but then balks when the distributor is obligated to reveal that up-front costs of distribution products will increase by 4%. Further, the possibility of VMI impacting labor relations in the warehouse is concerning, and then all notions of employing VMI are dashed by the idea of handing the fulfillment of regulatory stocking obligations over to a third party. Thus VMI and supply chain optimization are killed for another generation.

The problem statement within this story line is clear. The student, who became a decision-maker in industry, learned superficially about the subject of VMI: its definition, its basic premise and theoretical supply-chain benefits, but failed to gain a true understanding. The industry in which the former student is employed has a natural distrust of agency-based purchasing due to decades of regulatory oversight, inertia, and high risk averseness. The resulting lack of willingness to consider supply chain management best practices is obvious, unfortunate, and inevitable.

This failure comes back to educators in engineering and technology. While system dynamics has done an excellent job creating deep experiential learning of the bullwhip effect through the use of The Beer Game and other similar activities[4], supply chain educators have not done as well creating deep experiential learning of the notions of total cost of ownership and VMI as responses to the bullwhip effect.

This paper seeks to take a step toward rectifying this oversight by proposing an interactive model for learning and understanding total cost of ownership, and thereby creating students who take quick advantage of opportunities to optimize supply chain performance. This model is designed to walk students through case studies in such a way that they can experience the decision-making process as information becomes available and is incorporated into the expected total cost of ownership. In this way students will be able to draw conclusions about supply chain integration that go beyond the basic definitions and understanding, and will lead, one hopes, to a lasting and powerful drive toward supply chain improvement.

Review of Literature

In STEM and business education, there is little available research specifically on the teaching of TCO or VMI through games, models and simulation. However, the use of these tools in business education in general is well-researched.

Keys and Wolfe suggested in 1990 that complex behavioral simulation can be used to create an environment that replicates decision making in a business environment, and provides measurable benefits for learning outcomes in education. The authors also note that games and behavioral simulation have the disadvantage of being highly married to a specific context, and are therefore not easily generalized to a larger organizational perspective. The specific context includes the rules governing the decision-making group, as well as the group dynamic itself and the nature of the group's environment.[5] Walters, Coalter, and Rasheed show that these tools are effective in educating students to make strategic business decisions. [6]

Proposed Model

Modeling total cost of ownership is an exercise in detecting and revealing relationships. It is easy for an educator to show that a utility will have costs of approximately X using a VMI agreement with distributor Y, but until that cost is shown relative to some alternative, there is no meaning.[7]

As a result, this paper will discuss the implementation of a proposed model that compares some existing traditional distributor/customer purchasing relationship with a comprehensive VMI alternative. This allows students to not only see total cost, but to view the makeup of the total cost, tweak elements to discover relationships between terms, and create new scenarios that enable extended learning opportunities.

To convey a broad sense of total cost of ownership, the model must be flexible enough to allow for large changes in scenarios, yet fixed enough that students find it accessible and useful as a learning tool. The model essentially consists of a complex set of mathematical relationships between base terms that are defined by the user. For example, a utility has a certain amount of money that it must spend on line products annually. This cannot be programmatically or mathematically deduced; it must be entered as a basic argument that describes the nature of an organization. Other elements may be deduced mathematically from the basic arguments entered. Given an average inventory level and a minimum attractive rate of return, one can derive much of the opportunity costs associated with the current inventory policy.

The proposed model was implemented as a Microsoft Excel-based application with Visual BASIC. This was chosen for the sake of ease of development and rollout of the final product, because, while the development environment is not particularly important to the model, Excel and VBA already hold a prominent place in education, business and sales, and are readily available to students of supply chain management and engineering. This platform also facilitates great ease of modification should the application be later required to model a very different industry.

The proposed model begins with a certain hierarchy of content. Namely, total cost of ownership for an organization must be broken down into the elements under consideration.[8] This paper and model will use the following cost breakdown:

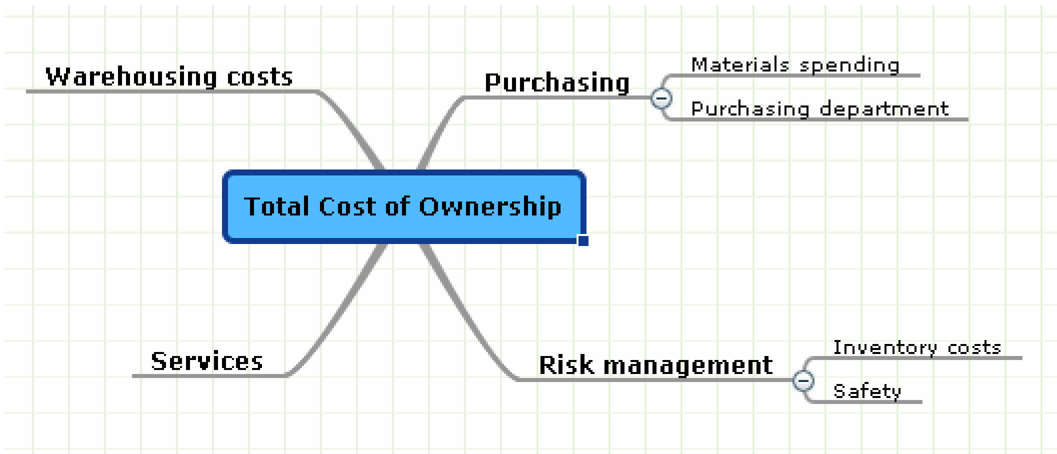

Figure 1: Total cost of ownership hierarchy

In most cases, the largest part of the total cost of ownership is the purchasing function, as this model defines it, because purchasing includes the cost of the materials purchased. Therefore, the model begins by gathering information about the amount spent under the current traditional buying scenario, the markup understood to dominate the relationship, and any shipping costs as a percentage of total money spent. From these pieces of information, the model as implemented is able to derive the original cost of goods sold from the manufacturer to the distributor, as shown in Table 1.

	Current	VMI	Savings
Spending			
Annual Inv. Spend	$5,000,000	$5,217,593	-$217,593
Markup	8%	15%	
Shipping rate	0%	0%	
Shipping costs	$0	$0	
Standardization gains		2.0%	
Cost of Goods	$4,629,630	$4,537,037	
Markup in dollars	$370,370	$587,963	

Table 1: Spending costs under traditional and VMI distribution models

In Table 1 and beyond, the input cells are bordered by a rectangle, while derived cells have no border and are not freely editable.

In this example, the utility currently spends five million dollars annually on distribution parts for its community's power lines. The utility believes that its distributor uses an average markup of 8%, which implies that the cost of goods to the distributor is $4,629,630.

In the case of electricity distribution, legacy systems and changing engineering requirements have created a patchwork effect of the transmission lines. This means that, while a single part number may technically fulfill its duties in many places throughout the system, a utility may order dozens of similar, yet incompatible, part numbers to fulfill niche obligations. In recent years, VMI distributors in the industry have stepped up promotion of standardization and substitution, which essentially means that utilities make active efforts to swap a unique part for a standard part whenever possible. Doing so is expected to decrease inventory requirements through risk pooling to the extent that one major distributor guarantees a 2% reduction in annual spending for utilities that are committed to standardization. The result of this is the "Standardization gains" entry, which defaults to 2% and reduces the cost of goods sold of the distributor by 2%.

Having used the current cost of goods and the standardization gains ratio to calculate the cost of goods sold under VMI, it is now trivial to calculate the total amount spent up front under the VMI scenario, given the assumptions listed. Note that in this case, as in many cases of VMI versus traditional distribution, the up-front cost is higher for VMI. Even though the extra charge is only a little over 4%, the cutthroat world of energy pricing and politics demands that the lowest cost option be pursued.

For the student, the overall result of walking through this section of the model is to note that VMI costs more than traditional distributor arrangements. The student wonders why VMI would be preferred at all, but may notice a hint of ancillary benefits to come from the standardization effort. Clearly a utility's interests are being actively watched under VMI, if nothing else.

The next section under purchasing follows the actual purchasing activity itself, including the employment of purchasing department personnel and their equipment, training, and benefits.

	Current	VMI	Savings
Annual Purchasing Labor			
# of employees	10	2	
Total purchasing dept. salaries	$450,000	$90,000	$360,000
Training costs	$2,500	$500	$2,000
Percent of total compensation as benefits	39%	39%	
Benefits	$287,705	$57,541	$230,164
IT systems	$65,000	$13,000	$52,000
Supplies & Equipment	$35,000	$7,000	$28,000
Purchasing dept. totals	$840,205	$168,041	$672,164

Table 2: Purchasing Labor Costs

Under VMI, it becomes possible to remove some of the costs of the purchasing function by offloading the responsibility to the vendor. This is a source of great cost savings to the utility, as seen here with a five- to-one reduction.

The VMI column inherits most of the assumptions from the Current column, and based on a ratio of headcount reduction calculates a savings. From the student point of view, the idea behind VMI starts to come into sharper focus. While the utility spent almost $220,000 more in materials costs, it saved over $650,000 in compensation and supplies, at least in this contrived example. Even if the actual reduction ratio were more like two-to-one, the utility easily recovers the extraneous expense of the VMI markup.

There are more labor savings in store as well. Because the VMI distributor has expertise in the areas of warehousing and logistics, it is often willing to take over the warehousing function of the utility, paid for by the unusually high markup employed.

	Current	VMI	Savings
Annual Warehousing Costs			
# of direct employees	25	5	
Total purchasing dept. salaries	$750,000	$150,000	$600,000
Training costs	$2,500	$500	$2,000
Benefits	$479,508	$95,902	$383,607
IT systems	$20,000	$20,000	$0
Supplies & Equipment	$50,000	$10,000	$40,000
Warehouse totals	$1,302,008	$276,402	$1,025,607

Table 3: Warehouse Labor Costs

Under the (again, contrived) example in Table 3, the utility is able to reduce direct warehouse labor by 80%, offering an additional savings of just over one million dollars.

At this point, if the student examines the total cost of ownership for the traditional distributor versus the VMI partner, this is the result:

	Current	VMI	Savings
Purchasing Total	$7,142,214	$5,662,036	$1,480,178

Table 4: Total Purchasing Costs

In terms of making a lasting case in the mind of the student about the power of supply chain partnership, communication, and optimization, the mission may be accomplished. But there is much more to say about the benefits of VMI.

Consider the case of risk management. For the purposes of this model, risk management refers to all issues surrounding inventory and safety. Inventory and safety are huge concerns for utilities for two important reasons: 1) service levels are related to the ability to repair line faults quickly, 2) line faults are highly variable due to external factors such as customer behavior, weather, wildlife, construction, and accidents, and 3) service level is usually mandated by a government entity, such as a city, country, state, or federal edict.

As a result, utilities in general hold far more safety stock than a less risk averse corporation. Common industry responses for inventory turnover range from 1.5 to a high of about 4. This means that the utilities industry, perhaps more than any other, stands to benefit greatly from the combination of VMI and consignment programs. If 90% of a 28-day supply of materials is moved off the books of the utility, the savings in holding costs is enormous even though the safety is unchanged.

In the case of the proposed model, the student is asked to supply an existing inventory turnover, a percentage of the inventory that regularly turns (defined as at least once annually), and a holding cost rate, which is typically between 15% and 33%. From these the model implementation derives the average inventory level and the holding costs. Benefits to the utility come in two forms. The first, and most obvious, is the reduction in holding costs associated with owning only the material in service or that is about to be installed. This is an annual savings that can be applied directly to the bottom line total cost of ownership, in this case $155,229.

	Current	VMI	Savings
Inventory Levels			
Inventory Turnover	3.50	38.65	+1104%
Percent Turning Regularly	85%	45%	
Turning Inventory	$607,143	$30,357	
Non-turning inventory	$107,143	$37,143	
Average Inventory level	$714,286	$67,500	$646,786
Holding Cost Rate	24.0%	24.0%	
Annual cost of required space	$0	$0	$0
Labor	$0	$0	$0
Utilities	$0	$0	$0
Security services	$0	$0	$0
Additional equipment	$0	$0	$0
Insurance	$0	$0	$0
Interest on amount invested	$0	$0	$0
Damage	$0	$0	$0
Shrinkage	$0	$0	$0
Inventory holding costs	$171,429	$16,200	$155,229
Days' safety stock	14	8	
Shipping lead time	9	3	
Cash freed from inventory	$0	$646,786	
Investment Hurdle Rate	10.0%	10.0%	
Annual cash investment income	$0	$65,029	$65,029
Total inventory costs	$171,429	($48,829)	$220,257

Table 5: Inventory Costs

The second form of savings is more difficult to apply to the total cost of ownership. Because the use of consignment removes much of the inventory from the books of the utility, the utility experiences a one-time freeing of cash from inventory. In this example, inventory dropped from just over $700,000 to just under $70,000, which freed almost $650,000 of cash. Since this windfall is a one-time event, to add it to the total cost of ownership model one must convert it to an annual cash flow. To that end, the student (acting as the utility) provides a minimum attractive rate of return (MARR), or investment hurdle rate, which is then used to calculate the annual return on the cash freed from inventory. In the example case, the utility has a MARR of 10%, which translates to an annual investment income of $65,029. This amount is slightly more than 10% of the reduction in inventory due to services that are described later.

Overall, the value proposition of the VMI relationship has improved by more than $220,000, further cementing the advantages of advanced supply chain cooperation and optimization in the mind of the student.

The final category of VMI costs involves the services provided by the VMI partner. Services are a great advantage of supply chain partnership, and are often difficult to quantify.

In the case of the utilities distribution market, services include technical support, IT services, inventory management services, and services that help utilities find a buyer for old inventory that still has useful life.

	Current	VMI	Savings
Technical support costs	$100,000	$0	$100,000
IT Services	$0	$0	$0
Inventory Management			
Old product on hand	$70,000	$0	
Sale/Trade Old Product	$0	$3,500	$3,500

Table 6: Services

In Table 6 it is assumed by the model implementation that technical support services offered for no additional charge beyond the markup would cost the utility $100,000 if purchased separately under the current traditional relationship. This is merely an assumption for the sake of example, and should not be taken as a typical industry figure. Regardless, it is not a meaningful amount of money in the larger picture. Neither is the cash freed from the sale of old inventory, which in this case was originally valued at $70,000 and has an expected salvage value of $3,500. However, it is these services, in part, that make up the total picture of value to a customer, and can similarly make an impression on students.

The model implementation uses the provided and calculated numbers to arrive at a total cost of ownership for the utility, as shown in Table 7.

	Current	VMI	Savings
Total cost of ownership	$9,063,642	$7,287,357	$1,776,285

Table 7: Total Cost of Ownership

The admittedly contrived example utility saves over 1.7 million annually under VMI, even though the initial cost of goods is greater than the traditional distributor cost. The model implementation, as mentioned previously, allows for a very flexible re-imagination of new examples and wildly varying scenarios. The skeptical student may create scenario after scenario that approaches and then exceeds the limits of VMI to provide additional value. However, the mere activity of pushing and then breaking the VMI model advantage is an educational experience beyond that of most supply chain students. Additionally, finding the limits of VMI advantage may provide students with better tools for knowing when to seek supply chain partnership within their organizations as they turn from students to graduates, and then decision makers.

Model Implications and Possible Uses

Students today will be making decisions about the world's supply chains tomorrow. It is incumbent upon the educators of today to create future supply chain improvements through well-educated graduates. To that end, a model that helps educators illustrate the benefits of supply chain partnership and cooperation may serve the same educational function that The Beer Game serves for educating students about the bullwhip effect.

The model proposed in this paper is not radical, but is instead a basic approach to "simulating" the process of learning about VMI experientially through the eyes of an industry insider, with an eye toward an industry still very much in need of supply chain improvements.

This model can be used alone, as a primary educational tool for conveying the depth, stochastic nature, and difficult-to-quantify content of a thorough TCO evaluation model. Alternatively, the model can be used as a supplemental tool for reinforcing a traditional book and lecture learning environment. Finally, the model may best serve students by application within a series of business cases that highlight TCO. This application will provide the most exposure to the different outcomes possible when the full weight of non-purchasing costs are considered.

Future Research Opportunities

The next steps in this research are to put this proposed model in front of a class of students to conduct experiments that illuminate its level of usefulness. This might be against only a control of traditional book/lecture learning, or also against another proposed TCO model, such as a personalized approach. A personalized approach might encourage student learning and involvement by creating a model that allowed students to examine the total cost of ownership of some aspect of their own lives, such as car ownership or a purchase decision between consumer electronics choices.

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