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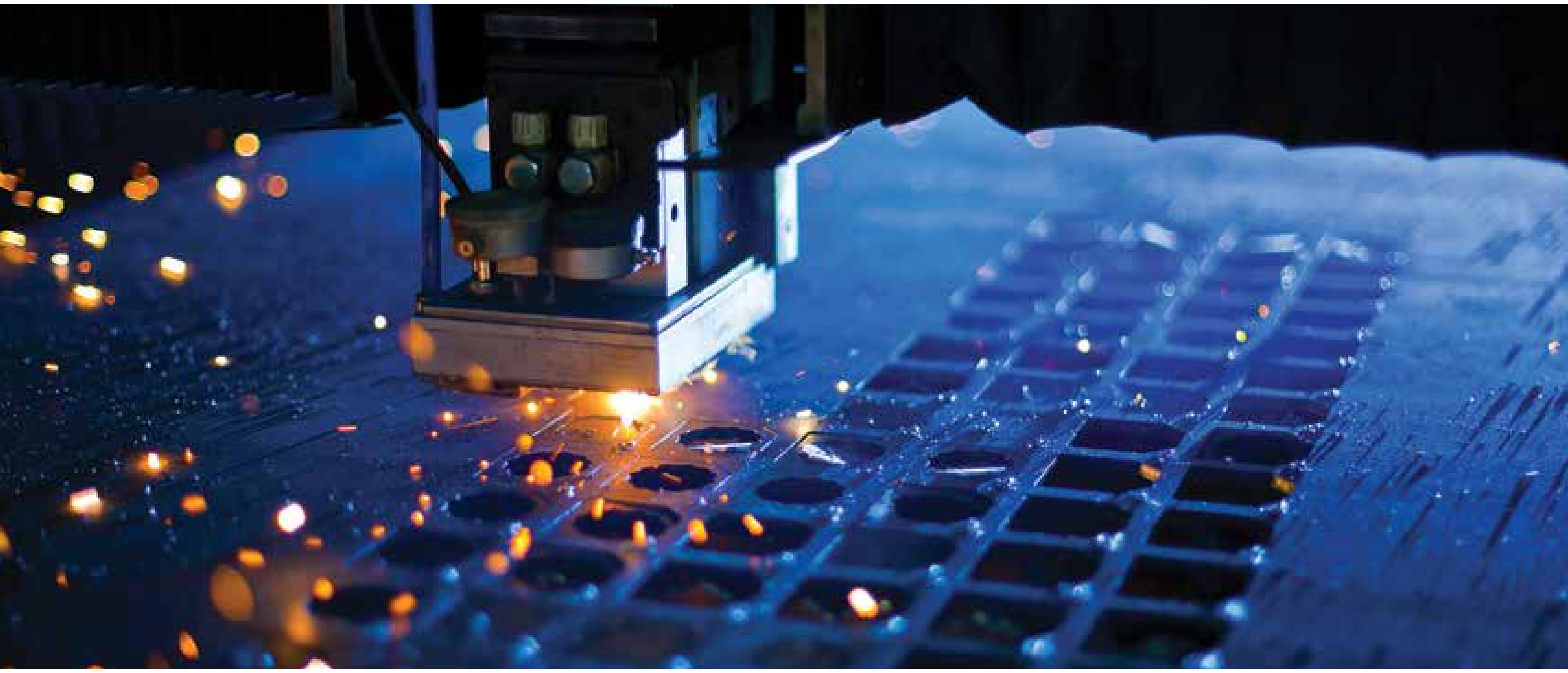

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This article evaluates the premise of demand adherence to normal distribution in inventory management models, showing that this can lead to significant distortions, mainly to stock control of very low and low consumption items. The article thus proposes a framework to help managers determine the best stock policy to be adopted given product demand characteristics. The article also presents the use of such a framework in a case study, in an attempt to illustrate the benefits of adopting probability density functions that are more adequate to product demand characteristics, in terms of total costs of stocks.

INTEGRATING FMEA WITH THE SUPPLY CHAIN RISK MANAGEMENT PROCESS TO FACILITATE SUPPLY CHAIN DESIGN DECISIONS

We present a novel approach of integrating failure mode and effect analysis (FMEA) with a supply chain risk management process (SCRMP). Focusing on the challenging task to assess and manage supply-side risks in global supply chains, the approach developed offers an effective and affordable way for firms to provide decision support for the selection of their most appropriate supply chain design. The aim of the integrated approach combining the strengths of FMEA and SCRMP is to gather as much pertinent information as possible, to structure it, and to comprehensively delineate all potential supply chain risk factors, offering valuable decision support. We illustrate the application of the approach at Michigan Ladder Company, where it was applied to two specific supply chains for the procurement of fiberglass ladders. Specifically, one supply chain spanned from China to the U.S. via Mexico (taking advantage of a Mexican maquiladora), and one spanned from China directly to the U.S. The combination of FMEA and the SCRMP enhanced the manufacturer's confidence in its supply chain design decision, and enabled the firm to proactively manage its supply-side risks. Overall, the article is meant to motivate practitioners to embark on the journey of active risk management. While some may perceive risk management as a daunting task or being primarily employed by larger firms, we provide guidance for firms of any size to apply the approach – it can be done, and does not have to consume an inordinate amount of resources.

OPERATIONS MANAGEMENT SALARY REPORT

APICS, in conjunction with the Cameron School of Business at the University of North Carolina Wilmington, is pleased to provide the results of the 2013 Operations Management Salary Report. The data are collected from a random sample of more than 30,000 operations management professionals worldwide.

Twice annually, approximately fifty percent of the APICS membership and customer base receives a request to complete an online survey collecting data concerning current salary and compensation by job function and title. The survey can be accessed at: http://csbapp.uncw.edu/apics/.

A TUTORIAL ON MANAGERIAL COST ACCOUNTING: YEAR-END REPORTING

Building on the companion article "A Tutorial on Managerial Cost Accounting: Living with Variances" by Fry and Fiedler (2011), this current paper picks up where the previous paper left off and illustrates how the management accounting system (MCA) is linked to financial accounting (FA) to generate the year-end financial reports required by shareholders, banks, and the IRS. The prior paper focused on the detailed use of information provided by the MCA throughout the year and walked through the development of the yearly budget, calculation of product costs, determination of budget variances, derivation of the periodic income and statement of cash flows reports, and provides possible examples of dysfunctional behavior at a fictitious company called Mandrake Manufacturing. This tutorial concentrates on the interaction of the MCA and FA systems and the production of year end FA statements. In addition to providing information such as cost of goods sold, inventory values, and operating standards to the FA, the year-end information provided by the MCA is also used to develop next year's budgets. In this present paper, the conversion of the MCA reports into the FA reports will be presented. Also, the impact of the MCA reports on future budgets will be discussed. As pointed out in F&F, it is vital that operations managers understand how the accounting systems used by their company function. Without such understanding, many of the problems associated with the improper use of the accounting systems will never be corrected.

A CONCEPTUAL FRAMEWORK FOR INVENTORY MANAGEMENT: FOCUSING ON LOW- CONSUMPTION ITEMS

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ABSTRACT
This article evaluates the premise of demand adherence to normal distribution in inventory management models, showing that this can lead to significant distortions, mainly to stock control of very low and low consumption items. The article thus proposes a framework to help managers determine the best stock policy to be adopted given product demand characteristics. The article also presents the use of such a framework in a case study, in an attempt to illustrate the benefits of adopting probability density functions that are more adequate to product demand characteristics, in terms of total costs of stocks.

Keywords: stock, lead-time demand, coefficient of variation, framework, costs

1. Introduction
Inventory management permeates decision-making in countless firms and has been extensively studied in the academic and corporate spheres (Rosa et al. 2010). The key questions – usually influenced by a variety of circumstances – which inventory management seeks to answer are: when to order, how much to order and how much stock to keep as safety stock (Namit and Chen 1999; Silva 2009). According to Wanke (2011a), inventory management involves a set of decisions that aim at matching existing demand with the supply of products and materials over space and time in order to achieve specified cost and service level objectives, observing product, operation, and demand characteristics.

These diverse circumstances that should be taken into account for an appropriate selection of inventory management models have contributed to the development of research and production of articles on possible qualitative conceptual schemes – also known as classification approaches – aimed at supporting decision-making (Huiskonen 2001). There are several examples of this kind throughout the years.

Williams (1984), for example, developed an analytical method to classify demand as regular (high consumption), low consumption, or intermittent, by decomposing the variability of lead-time demand into three parts: variability of the number of occurrences per unit of time, variability of demand size, and lead-time variability. Botter and Fortuin (2000) based their classification of items on three criteria: lead time, price, and consumption level, which underpin the development of eight different inventory management models. Eaves and Kingsman (2004) revisited Williams' (1984) model, reclassifying spare parts into five categories: smooth, erratic, low turnover, slightly sporadic, and strongly sporadic. Syntetos, Boylan and Croston (2005) classify items into four quadrants, divided by two axes: the average demand interval and the squared coefficient of demand variation. Years later Boylan, Syntetos, and Karakostas (2008) presented an application of this method in a software firm. The items' consumption pattern is classified as strongly sporadic, slightly sporadic, and non-sporadic.

The aim of this article is to analyze the pattern of demand as the main intervening factor in inventory management. It first of all discusses, in section 2, how the frequently adopted premises regarding the adherence of demand to Normal distribution may not be realistic and cause distortions, especially in the case of very low – when the annual demand is less than one – and low consumption items – when the annual demand ranges between one and a value sufficiently high, say three hundred or five hundred units per year, in order to characterize a daily demand close to one. Section 3 proposes a conceptual framework designed to support inventory management, which synthesizes those models that are most adequate for specific patterns of demand (mean and variability). Finally, sections 4 and 5 present a case study undertaken in a Brazilian company, which not only showed the practical application of the conceptual framework but also revealed the latter's impact in terms of shortage and excess costs.

2. Literature Review

Choosing the most adequate inventory management model is essentially an empirically-based decision that may involve the use of simulation, scenario analysis, incremental cost analyses (Silva 2009; Rosa et al. 2010; Rego and Mesquita, 2011; Wanke 2011b) or qualitative conceptual schemes also known as classification approaches (Huiskonen 2001). The latter usually considers that the impact of product, operation and demand characteristics constitute intervening variables in this choice (see, for example, Williams 1984; Hax and Candea 1984; Dekker, Kleijn, and De Rooij 1998; Botter and Fortuin 2000; Braglia, Grassi, and Montanari 2004; Eaves and Kingsman 2004; Wanke 2011b). An analysis of the literature dealing with inventory management model selection shows that it originally focused on production and distribution environments in which demand and lead time tend to be more predictable or, in other words, in which it is easier to answer the questions of "what" and “how much” to order (Wanke and Saliby, 2009; Wanke 2011b; Rosa et al. 2010). However, there is a growing literature related to the specific problems raised by low and very low consumption items such as spare parts (Botter and Fortuin 2000; Silva, 2009; Rego and Mesquita 2011; Syntetos et al. 2012).

The intrinsic characteristics of spare parts, which are typically low and very low consumption items, make the choice of inventory management models particularly critical under the following circumstances (Cohen and Lee 1990; Cohen, Zheng, and Agrawal 1997; Muckstadt 2004; Kumar 2005; Rego 2006): low stock turnover, difficult predictability, longer replenishment times, greater service level demands and higher acquisition costs.

Therefore, these special features of spare parts determine the selection of appropriate inventory management models. According to Botter and Fortuin (2000), there is a consensus that spare parts cannot be managed using traditional models (see, for example, those presented in Rosa et al. 2010). Basically, spare parts do not fit these models’ main premises such as, for example, the adherence of demand to symmetric and continuous probability density functions (Silva 2009).

The following subsections explore this issue at greater depth, linking demand characteristics (mean and variability) to inventory management models developed in the literature. In the case of average demand, the literature provides the basis for the segmentation of annual consumption according to three different levels – very low consumption, low consumption and mass consumption (Ward, 1978; Silva, 2009; Wanke, 2011a) – while the coefficient of variation (see for instance, Silver et al., 1998; Hopp and Spearman, 2008) and the probability distribution functions (see for instance, Yeh, 1997; Silver et al., 1998) form the basis for segmentation in the case of variability.

2.1 Very low consumption

According to Tavares and Almeida (1983), very low consumption parts are those whose average consumption is less than one unit per year. According to these authors, the stock control of these items should not be performed using the usual models because, due to their particular consumption characteristic, there are not enough previous occurrences to make a precise estimate of probability distribution (Croston 1972; Syntetos and Boylan 2001; Ghobbar and Friend 2003; Eaves and Kingsman 2004; Willemain, Smart, and Schwarz 2004; Regattieri et al. 2005; Hua et al. 2007; Gutierrez, Solis, and Mukhopadhyay 2008; Gomez 2008; Teunter and Duncan 2009).

In addition, following Tavares and Almeida (1983), it is the analysis of total shortage, excess and order placement costs, given a certain service level, that makes it possible to determine whether a part should, or should not, be kept in stock, and a replenishment request made solely against an order. Thus, a binary total cost model was developed to support decision-making regarding whether to keep one (1) or no (0) unit in stock based on two suppositions: adherence of demand to Poisson distribution and the possibility of placing an emergency order with a lower than usual lead time, whenever a shortage occurs. This model is presented in appendix 1.

2.2 Low consumption

For the purpose of this article, low cost items are those with a historical consumption of between 1 and 300~500 units per year, which leads to an average daily demand close to one, as suggested by Wanke (2005). As demand is not too small to use the model proposed by Tavares and Almeida (1983), service level-related decisions such as the order point and replenishment level assume greater importance. Thus, the model, which is widely used in the literature, was considered to be the most adequate (Rosa et al. 2010).
More precisely, the model involves a continuous review of stock levels and replenishment orders are always placed whenever the stock position reaches the order point s (Silver and Peterson 1985; Silver et al. 1998). In this case, a quantity of replenishment is used that is sufficient to raise the stock position to point S. That is, in practice, the lot size is . According to Hadley and Whitin (1961), the models result in unitary lot size orders when order placement costs are low. Thus, as Feeney and Sherbrooke (1966) conclude, the policy constitutes a particular case of models.

Various authors (Feeney and Sherbrooke 1966; Walker 1997; Porras and Decker 2008; Gomes and Wanke 2008) have used the model in spare part inventory management. Using this model, a replenishment order is requested as soon as a unit of stock is consumed in order to recompose the maximum level of stock. This model is appropriate for very costly components that are essential for business operations (Walker 1997).

In relation to the probability distributions of demand and lead time in the context of models, Rosenshine et al. (1976 and Dhakar et al. 1993) initially assume that lead time is deterministic. However, various distributions, have been considered in the context of in order to represent the behavior of demand or lead time separately: Normal (Krupp 1997), Gama (Burgin 1975; Das 1976; Yeh 1997), Poisson (Hill, Omar, and Smith 1999) and empirical distribution with stochastic demands and lead times (Eppen and Martin 1988).
Another important point involves the determination of the probability distribution that results from the combination of lead-time demand results (Lau 1989; Silva 2009). According to Tyworth (1992), theNormal distribution constitutes a reasonable approximation for high consumption items, but not for low consumption ones. In the case of the latter items, distribution is typically asymmetric and possesses a high probability of demand equal to zero. Porras

and Decker (2008) adopted the Poisson distribution to estimate the lead-time demand of items with only one occurrence at each specific time interval.

It should be highlighted that when demand involves more than one occurrence per time interval, various authors have proposed compound models, such as the Stuttering Poisson (Ward 1978), the compound Poisson model (Williams 1984; Silver, Ho, and Deemer 1971) or the compound Bernoulli model (Janssen, Heuts, and Kok 1998; Strijbosch, Heuts, and Schoot 2000). More recently, Syntetos et al. (2012) conducted a comprehensive literature review on the distributional assumptions for spare-parts management, assessing the goodness-of-fit of various distributions and their stock-control implications in terms of inventories held and service levels achieved.

However, since most of the distributional assumptions are difficult to apply in practice – as the parameters of more than one distribution must be determined first so as to analyze the lead-time demand behavior – and in order to make the conceptual framework developed in this research operational to managers, readily to be implemented in Excel spreadsheets, we decided to narrow the decision regarding the most adequate lead-time demand distribution between Poisson and Gamma distributions. For examples on the practically of the implementation of these distributions in Excel, readers should refer, for instance, to Hopp and Spearman (2008) and Wanke (2011a) – for Poisson distribution – and Silver et al. (1998) and Tyworth and Ganeshan (2000) – for Gamma distribution. Besides, as detailed next, these distributions hold straightforward relations between their defining parameters and the mean and variance of the variable of interest.

2.2.1. Poisson Distribution

In the case of low consumption items, Silver et al. (1998) suggest adopting the Poisson distribution premise (cf. Appendix 2). According to Yeh (1997), however, it is first of all necessary to verify the practical applicability of the Poisson distribution. This is because, in the Poisson distribution, the mean and variance are numerically equal. Thus, if this distribution is to be used in practice, the variance of demand must be situated within an interval delimited by a variation of ten percent around its mean: $0.9ED<VarD<1.1E(D)$.

2.2.2. Gamma Distribution

The Gamma distribution premise (cf. Appendix 3) was adopted by Yeh (1997) in his study, in which more than fifty percent of the items considered in his sample had a consumption of less than ten units per year. The use of the Poisson distribution was originally rejected as it did not satisfy the condition previously expressed. According to Burgin (1975 and Yeh 1997), the

Gamma distribution adheres easily to real data and can be mathematically manipulated in inventory management.

Following Yeh et al. (1997), the Gamma distribution is adequate in cases where periods with null demand occur more frequently. Under these circumstances, it makes sense to consider the time interval that has elapsed between two consecutive demands different from zero as a variable of interest for modeling purposes, besides demand itself and lead time. Segerstedt (1994 and Yeh 1997), for example, developed an inventory management model assuming that the time interval between two consecutive non-zero demands (T_i), demand (λ) and lead time (*TR*) are adherent to the Gamma distribution.

It is worth noting that intermittent demand patterns – meaning that demand arrives infrequently and is interspersed by time periods with no demand at all – is a critical for choosing the most adequate distributional assumption (Eaves, 2002; Syntetos et al., 2012). Boylan and Syntetos (2007) used the average demand interval, that is the mean time between two consecutive demands greater than zero, to classify spare parts in conjunction with demand and lead-time uncertainty. Eaves and Kingsman (2004) developed similar concepts. The model used by Yeh (1997) uses the probability of not having a stock shortage during an order cycle, that is, during the interval of time between two consecutive replenishments, as a measure of the service level. The lowest and highest desired service levels for each item are defined according to the model. The service level for the remaining stock is calculated by *1-Ps(S)*, in which *Ps(S)*, given in Appendix 4, is the probability of stock shortage during the order cycle, given the level of stock *S*.

2.3 Mass consumption

Mass consumption items are frequently considered to be those with a historical consumption of over 300~500 units per year, roughly one unit/day (Wanke2005). According to Rosa et al. (2010), the classic lot size/reorder point model stands out among mass consumption item inventory management models. According to this model, units are requested whenever the stock position reaches reorder point (OP) (Love 1979; Silver et al. 1998; Muckstadt 2004; Sherbrooke 2004; Hopp and Spearman 2008). In practice, the size of lot *Q* is determined by the traditional Economic Order Quantity formula (Harris 1913) and the reorder point is defined so as to assure a specific service level measure (Eppen and Martin 1988; Rego et al. 2011).

It is necessary to know the format of the distribution of lead-time demand to determine the safety stock embedded within the reorder point (Keaton 1995). According to Porras and Decker (2008), this calculation requires specifying the distribution of lead-time demand so that the safety factor, *K*, can be determined. Traditionally, lead-time demand is modeled using a Normal distribution (Silver and Peterson 1985). Due to the properties of this distribution, the safety factor *K* for a specific service level is the same as of the standard normal distribution curve, *Z*, which can be found in several statistics and logistics textbooks such as, for example, Levine et al. (2005) and Ballou (2006). Various studies, however, criticize this approximation. According to Mentzer and Krishnan (1988), this approximation is only valid if the Normal distribution is defined between the interval of $-\infty$ and $+\infty$. Moreover, this creates the possibility of negative demand in many practical applications. For Moors and Strijbosch (2002), one of the main drawbacks of the Normal distribution is the symmetry assumption. Furthermore, according to Eppen and Martin (1988), items that present a Normal distribution of lead-time demand are found in only a few cases.

As an attempt to balance the advantages and disadvantages of choosing an specific premise, Silver et al. (1998) propose a general rule for approximating lead-time demand using the probability distribution of the coefficient of variation (*CV*), in the specific case of mass consumption items. If *CV* is greater than 0.5, the Gamma distribution should be used and, if it is not, a Normal distribution provides a good approximation for lead-time demand.

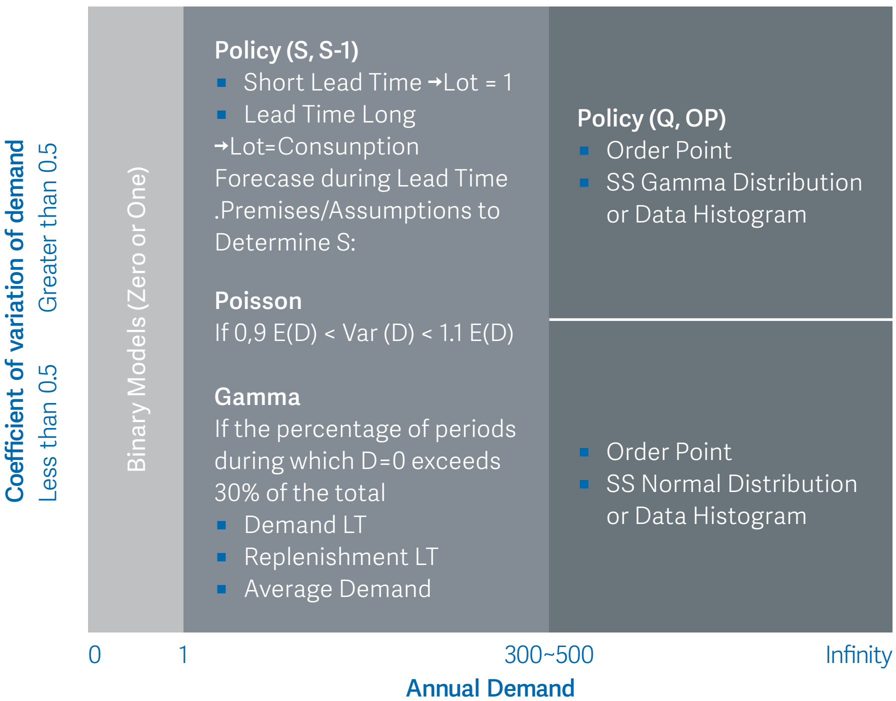
3. CONCEPTUAL FRAMEWORK FOR INVENTORY MANAGEMENT

Taking the theoretical framework presented in previous sections as a point of departure, the present article proposes a conceptual framework for inventory management based on the segmentation of annual demand into three categories – very low consumption, low consumption and mass consumption – and the coefficient of the variation of demand into two categories – high uncertainty and low uncertainty. Using these two demand pattern-associated variables, the conceptual framework indicates the most appropriate inventory management model for low, very low, and mass consumption items, thus supporting decision-making based on the most adherent premises to answer the questions of how much to order, when to order and how much stock to keep in safety stocks.

In the conceptual framework synthesized in figure 1, extremely low consumption items are considered to be those with an average historical demand of less than one unit per year. Low consumption items correspond to items whose average historical demand may vary between one and 300~500 units per year, or a maximum of one unit per day, while mass consumption items are those with a demand of over approximately 300~500 units per year, in accordance with Wanke (2005). The cut-off point for the coefficient of the variation of demand is 0.5, like in Silver et al. (1998).

More specifically, for each quadrant of annual demand and the item’s coefficient of variation of demand, the conceptual framework contains the most adherent probability distribution functions and the most appropriate inventory management model, incorporating all the theoretical considerations described in the previous sections.

FIGURE 1: CONCEPTUAL FRAMEWORK FOR INVENTORY MANAGEMENT



In addition to the development of conceptual frameworks, Rego et al. (2011) stress the need to conduct case studies focusing on their practical applicability in firms in order to overcome gaps between theory and practice. These case studies enable researchers to increase their practical knowledge given that aspects involving understanding about environment's complexity and the managerial efforts made by firms become evident. Examples can be found in Cohen et al. (1990), Botter and Fortuin (2000), Strijbosch, Heuts, and Schoot (2000), Trimp et al.(2004), Levén and Segerstedt (2004), Wanke (2005), Porras and Dekker (2008), Wagner and Lindemann (2008), Syntetos, Keyes, and Babai (2009), and Silva (2009). The following sections present and discuss the results of the practical application of the proposed conceptual framework in a large Brazilian company.

4. PRACTICAL APPLICATION: DESCRIPTION OF RESULTS

The conceptual framework presented in section 3 formed the basis for the development of a VBA tool for Excel to help segment inventory items using a database structured in an electronic spreadsheet. In addition, this tool makes it possible to obtain a quick answer to the questions of how much to order, when to order and how much stock to keep in a safety stock for a large number

of items, considering a given level of service that the firm wishes to offer customers and the previously identified segmentation. The tool was applied to real data from a Brazilian company in order to measure possible gains resulting from the proposed conceptual framework for inventory management.
The firm that was the object of this practical application is one of the world's leading manufacturers of agricultural and construction equipment. It has approximately one hundred sixty factories worldwide, of which three are located in Brazil. The Brazilian subsidiary has more than two thousand employees. In addition, the firm maintains a total of more than 20,833 different items in its Brazilian subsidiary's warehouses. The firm considers that this diversity of items is fundamental for providing support for technical assistance activities and post-sales services for the equipment it commercializes.

In order to perform a comparison between the inventory management actually verified in the firm and the policy suggested by the tool (conceptual framework), the study used consumption data of the previous forty-eight months for all 20,833 items. Besides consumption data, other data informed by the firm, which was important for modeling purposes, was also used: item's acquisition cost; replenishment/order placement cost; unavailability and penalty costs; average supplier lead time; variance of supplier lead time; opportunity cost of maintaining stocks for a year, for each of the different items.

The first step in the application of the conceptual framework was to use the Excel tool to segment the items according to the classification categories of very low consumption, low consumption and mass consumption, which resulted in the following respective percentages: 22 percent; 74.5 percent and 3.5 percent. In addition, based on the three demand categories and the two coefficients of variation, an analysis was undertaken of demand's degree of adherence to the Poisson and Gamma distributions, according to the discussion presented in sections 2.2.1 and 2.2.2.

Figure 2 shows one of the tool's output screens containing a sample of the first ten items analyzed, their respective classification (very low consumption, low consumption and massconsumption) and their adherence to the most adequate probability distribution (Poisson or Gamma). It should be highlighted that, as the adherence of demand to the Poisson or Gamma distribution was not verified, it was assumed that demand adhered to a Normal distribution in cases in which the coefficient of variation was lower than 0.5.

FIGURE 2: RESULTS OUTPUT SCREEN–SEGMENTATION AND ADHERENCE TO THE DISTRIBUTION

ID	Item Code	Classification	Poisson	Gama
1	A1304031	Low Turnover	no	yes
2	A162896	Very Low Turnover	no	no
3	BNHCMP0001	Low Turnover	no	yes
4	BNHCMP0002	Mass Consumption	no	no
5	BNHCMP0005	Mass Consumption	no	no
6	BNHCMP0007	Mass Consumption	no	no
7	BNHC0001	Low Turnover	no	yes
8	BNHC0002	Low Turnover	no	yes
9	BNHC0003	Low Turnover	no	yes
10	BNHC0004	Mass Consumption	no	no

All the analyses presented below relate to very low and low consumption items which represent 96.5 percent of total items.

As regards very low consumption items, it was observed that, in the case of 99.9 percent of the items classified in this group, the firm should keep a part in stock, totaling 4,586 stocked items (one for each item). The investment needed to form this stock exceeds BRL$2,540,000, if all parts have to be purchased initially at the same time, thus generating an annual opportunity cost of over BRL$563,000.

In the case of low consumption items that adhere to the Poisson or Gamma distributions, the study calculated the levels of stock needed to cater to three different service levels: a ninty percent, ninty-five percent, and ninty-eight percent probability of not having a shortage of the item in stock. For each level of service the study calculated the opportunity costs of keeping the parts in stock, as well the investment needed to purchase these items if they initially had to be purchased simultaneously.

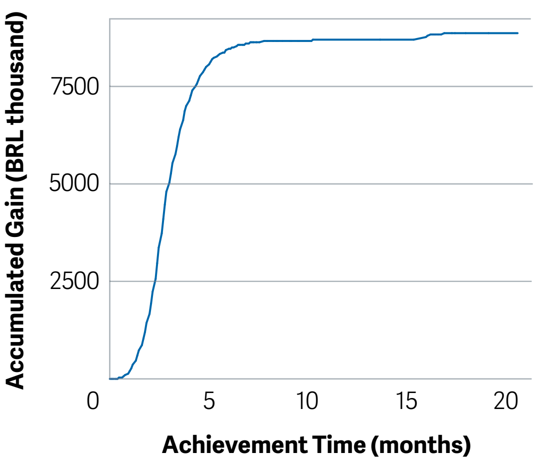
Specifically for the ninty percent level of service, an investment of over BRL$84,000,000 would be needed to form this stock if all parts initially had to be purchased simultaneously. This amount involves an annual opportunity cost of BRL$18,670,000.00. This opportunity cost of roughly twenty-two percent per year is basically financial: it relates to the high interest rates of the Brazilian economy. By the time the case study was conducted (2010), the Brazilian base interest rate, named SELIC, was around twelve percent per year. These additional ten percent points constitute the average spreads incurred by large companies when borrowing money to support working capital requirements, such as inventories. On average, ten parts are kept in stock for each low consumption item.

5. PRACTICAL APPLICATION: DISCUSSION OF RESULTS

As the company did not divulge its real inventory policy nor whether traditional inventory classification schemes, such as ABC, subsidized decision-making with respect to inventory model segmentation, the study made some working assumptions in order to be able to evaluate whether gains would occur in both financial and service level terms if the inventory models suggested by the conceptual framework were adopted. Some of these working assumptions considered the Normal distribution altogether with *(S, s)* inventory model and continuous review for low and very low consumption items.

For very low consumption items, the study analyzed the impact, in terms of total costs, of keeping no (*CT*0) or one (*CT*1) part in stock, as shown by eqs. (A1) and (A3), respectively. The results showed that the most appropriate policy was to keep a part corresponding to each item in stock as it led to a gain – given by the sum of the differences (*CT*0-*CT*1) for all items – of BRL$14,429,517.56. The gains that can be achieved by keeping a part in stock for all items are due mainly to the high unavailability and penalty costs, which thus constitute an extremely important part of the cost difference between the two policies. In the case of low consumption items, which represent 74.5 percent of the total, the study considered that the target-stock S for each item was equal to the mean of the three biggest demand spikes that had occurred during the previous forty-eight months. This is a common practice within Brazilian companies (cf. case study in Wanke 2011). Then, for each item, the study calculated the opportunity cost for the level of stock suggested by the tool and the one effectively practiced by the firm. When the resulting difference was positive, it was considered that the adoption of the conceptual framework would lead to a reduction in opportunity costs. In this case, this amounted to nearly BRL$8,870,000, due to lower levels of inventory. Similarly, when the difference was negative, the study assumed that there would be an increase in opportunity costs due to the framework's adoption which, in this case, totaled nearly BRL$2,230,000, on account of higher levels of inventory. It should be pointed out that, on most occasions, the increase in inventory levels can be attributed to the need to adjust customer service levels, stipulated, in this case, at ninty percent. With the aim of identifying the total time taken to achieve financial gains resulting from inventory demobilization, the study estimated the amount of time needed to consume excess inventory, based on average monthly consumption figures. The BRL$8,870,000 reduction in opportunity costs is achieved within a maximum timescale of 20.57 months, but in a maximum of six months it is possible to attain BRL$8,446,990.04, or 97.01 percent of the total, and in a little under a year, more precisely in 10.29 months, it is possible to achieve 97.89 percent of gains, amounting to BRL$8,676,001.41 (figure 3). The tool, which identified the adherence of the distributions of low turnover items to the Poisson and Gamma distributions, showed great efficiency, producing savings of BRL$2,321,674.55, to be achieved over a maximum period of 20.57 months.

FIGURE 3: Reduction Of The Opportunity Cost Of Maintaining Stocks Over Time.



6. CONCLUSIONS

A vast literature related to inventory theory has been developed over the past fifty years. However, many of the theoretical results achieved are not easily applicable in business practice, given that most are based on premises that are not verified in the corporate environment. With the aim of helping to fill this gap, this study proposes a conceptual framework designed to support the choice of the most adequate/appropriate inventory management model. Based on different demand characteristics, the proposed conceptual framework reveals that the premise that demand adheres to Normal distribution is not always valid and that other probability distributions, such as the Poisson and Gamma distributions, should be considered by managers. This study also explored issues related to the management of stocks of low and very low consumption items through the framework's practical application in a Brazilian agricultural and construction equipment company.

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APPENDIX 1 - DERIVATION FOR VERY LOW-CONSUMPTION ITEMS (TAVARES AND ALMEIDA 1983)

The authors demonstrated that the total cost associated with the policy of not keeping a spare part in stock ($CT0$) can be calculated as follows:

$$CT0=\lambda^{*}(CTR+Cip), \qquad \text{(A1)}$$

in which λ is the average historical consumption (parts/year), *CTR* is the total cost of item replenishment/order placement (BRL), and *Cip* is the cost of unavailability and penalty costs related to shortage (BRL).

In order to adopt the alternative policy, that is, the firm keeps a unit in stock until consumption occurs, an evaluation should be performed of the expected fraction of time in stock (*FTECE*), given by:

$$FTECE=\frac{1}{1+\lambda^{*}TR}, \qquad \text{(A2)}$$

in which *TR* is the replenishment lead-time.

The expected value of occurrences during the expected fraction of time out of stock is given by $\lambda^{*}(1-FTECE)$. Thus, one can obtain the total cost associated with the decision to always keep a part in stock ($CT1$), taking into account the possible occurrence of another request during the lead time, as well as its implications in terms of replenishment costs and unavailability and penalty costs, as given below:

$$CT1=\left[\frac{1}{1+\lambda TR}{}^{*}Caq^{*}i\right]+[CTR^{*}\lambda]+\left[Cip^{*}\lambda^{*}\left(\frac{1}{1+\lambda^{*}TR}\right)\right] \qquad \text{(A3)}$$

The parts of eq. (A3) represent, respectively, the opportunity cost of keeping a spare part in stock, the total replenishment cost and unavailability and penalty costs. In order to define the most advantageous policy, it is necessary to compare the magnitudes of $CT0$ and $CT1$, opting for the least-cost decision.

APPENDIX 2 - THE POISSON DISTRIBUTION

The Poisson distribution is given by:

$$P_x(t)=\frac{(\lambda^* t)^x e^{-\lambda t}}{x!} \qquad \text{(A4)}$$

in which, x is the consumption of spare parts per time interval whose probability is to be estimated, t is the time interval to be considered, λ is the historical rate of consumption per unit of time, and $P_x(t)$ - probability of occurring x requests during time interval t.

APPENDIX 3 - THE GAMMA DISTRIBUTION

The Gamma distribution is defined by two parameters and , which are, respectively, the form and scale parameter (Keaton 1995). The Gamma distribution's probability density function is given by:

$$f(x)=\frac{(\alpha x)^{\beta-1}}{\Gamma(\beta)}\alpha e^{-\alpha x}, 0\leq x<\infty, \qquad \text{(A5)}$$

in which $\Gamma(\beta)=(\beta-1)!$, when β is a whole number, $E(X)=\frac{\beta}{a}$, and $Var(X)=\frac{\beta}{a^2}$.

APPENDIX 4 - YEH'S MODEL (1997)

Considering that T_i, λ and TR adhere to the Gamma distribution, then:

$$Ps=\sum_{N-1}^{\infty}\frac{\gamma^\delta}{(\delta-1)!}\left\{\sum_{i=0}^{N\beta-1}a^i\frac{(i+\delta-1)!}{i!(\gamma+a)^{i+\delta}}-\sum_{i=0}^{(N-1)(\beta-1)}a^i\frac{(i+\delta-1)!}{i!(\gamma+a)^{i+\delta}}\right\}\times\mu^{N\sigma}e^{\mu\delta}\sum_{i=0}^{N\sigma-1}S^i\frac{1}{i!\mu^{N\sigma-1}} \qquad \text{(A6)}$$

in which (μ, σ) are the parameters of the Gamma distribution related to demand; (α, β), the parameters of the time interval between consecutive non-zero demands; and (γ, β),replenishment lead-time parameters.

INTEGRATING FMEA WITH THE SUPPLY CHAIN RISK MANAGEMENT PROCESS TO FACILITATE SUPPLY CHAIN DESIGN DECISIONS

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ABSTRACT

We present a novel approach of integrating failure mode and effect analysis (FMEA) with a supply chain risk management process (SCRMP). Focusing on the challenging task to assess and manage supply-side risks in global supply chains, the approach developed offers an effective and affordable way for firms to provide decision support for the selection of their most appropriate supply chain design. The aim of the integrated approach combining the strengths of FMEA and SCRMP is to gather as much pertinent information as possible, to structure it, and to comprehensively delineate all potential supply chain risk factors, offering valuable decision support. We illustrate the application of the approach at Michigan Ladder Company, where it was applied to two specific supply chains for the procurement of fiberglass ladders. Specifically, one supply chain spanned from China to the U.S. via Mexico (taking advantage of a Mexican maquiladora), and one spanned from China directly to the U.S. The combination of FMEA and the SCRMP enhanced the manufacturer's confidence in its supply chain design decision, and enabled the firm to proactively manage its supply-side risks. Overall, the article is meant to motivate practitioners to embark on the journey of active risk management. While some may perceive risk management as a daunting task or being primarily employed by larger firms, we provide guidance for firms of any size to apply the approach – it can be done, and does not have to consume an inordinate amount of resources.

Keywords: supply chain risk management, supply-side risks, failure mode and effect analysis (FMEA), supply chain management decisions, case study

Introduction

Globalization has enabled companies to take advantage of worldwide supply and demand markets, creating new opportunities and increasing their profit potential. However, with these enticing prospects have also come the dangers of associated longer and more complex supply chains (Tang 2006), which often span multiple countries or even continents. Especially in a time of increasing customer demands and requirements on quality, delivery lead time and responsiveness, managing these global supply chains has become a challenge. Ensuing risks are thus multifarious, and can manifest themselves in the form of supply disruptions or breakdowns (e.g., Hendricks and Singhal 2005; Stockes 2008; Tang and Musa 2011). This is especially heightened in times of companies focusing on their core competencies, and outsourcing the remaining tasks, inevitability increasing their vulnerability (Narasimhan and Talluri 2009). Evidence is provided for example by the catastrophes associated with super-storm Sandy on the East Coast of the U.S. in 2012, the floods in Thailand in 2012, and the Japanese tsunami in 2011. Besides the incomprehensible human tragedies, the latter event for example also resulted in companies such as Apple, Sony Ericsson, and many automobile manufacturers being unable to quickly adjust their supply chains; the firms were unable to compensate for the missed supplies from Japan, resulting in significant losses (BBC 2011). Further examples of imminent risks abound, such as the financial crisis affecting most companies and countries (Blome and Schoenherr 2011), as well as recent political instability and regime changes (Doukas et al. 2011).

Due to these realities, it has become an imperative for today's supply chain managers to identify possible risks affecting their supply chains, evaluate them, and develop appropriate risk mitigation strategies. However, this undertaking can be a daunting task (Kwak and Stoddard 2004), as was revealed in a survey by Snell (2010): while 90 percent of the responding firms felt threatened by supply chain risks, few felt confident and knowledgeable in managing these risks. This finding is consistent with our own anecdotal observations and recent interactions with supply chain professionals. As such, not many firms are employing a structured approach to assess and manage risks inherent in their global supply chains, which is especially the case for small- and medium-sized enterprises. This negligence can however have severe repercussions, since even smaller firms and their supply chains are now often interconnected globally and thus exposed to a multitude of risks.

It is therefore our objective in the present paper to illustrate a novel approach combining failure mode and effect analysis (FMEA) with a supply chain risk management process (SCRMP). This integrated methodology provides guidance for managers on how to better get a handle on risks associated with their existing or potential supply chain designs. The aim of the approach combining the strengths of FMEA and SCRMP is to gather as much pertinent information as possible, to structure it, and to comprehensively delineate all potential supply chain risk factors. We illustrate this application at Michigan Ladder Company (MLC), which utilized the integrative approach to provide decision support for its supply chain design. The methodology structured the decision problem and offered the firm more confidence in its final choice. The approach was applied to assess the supply-side related risks inherent in two alternate supply chain designs for the procurement of fiberglass ladders. While one supply chain design involved the procurement of the finished product from China, the other involved the procurement of parts from China, assembling them in a Mexican maquiladora, and then shipping them to the U.S. location of MLC. The risks associated with each were assessed relative to the firm's objectives of cost reduction and responsiveness. Within this context, supply chain risk was defined as the threat or probability of supply chain disruptions that adversely affect the smooth flow of products, impacting operational performance measures such as responsiveness and cost.

The development and illustration of the approach is important both from a practical and a theoretical perspective. From a practical angle, the value consists of the presentation of an effective, comprehensive, and integrated framework for risk management, consisting of both FMEA and the SCRMP, as well as an illustration of how it can be applied. The importance inherent in the latter is the demonstration that risk management does not have to be rocket science or hugely expensive, and that straightforward approaches can yield significant insight. It is thus our hope that the article provides an impetus, motivation and guidance for practicing managers to follow this framework, especially also for small- and medium-sized firms, which may have been hesitant to adopt risk management approaches in the past due to their potential associated expenses and effort. We are also directly addressing a shortcoming mentioned in Snell (2010), who found in their survey that respondents did not feel confident and knowledgeable in managing these risks. The approach presented herein is a means to increase confidence and knowledge in ris¬k management, and represents a ready-to-use tool to better manage global supply chain risks.

The study also contributes to literature and theory in supply chain risk management in that it proactively identifies and evaluates risk and mitigation strategies, instead of examining ex post scenarios (cf. Trkman and McCormack 2009); this leads to the further improvement of the firm's confidence in its supply chain design ex ante, anticipating potential failures and developing preventive and response action plans. The successful experiences made by Michigan Ladder Company demonstrate the usefulness of the approach and its significant potential in facilitating supply chain decisions focusing on risk assessment and management. We thus also answer the call for further insight into risk management approaches to facilitate and structure supply managers' strategic decision making on the optimal configuration of their supply chains (Zsidisin et al. 2004). In addition, we follow the example of Chan et al. (2012), who encouraged the integration of FMEA with risk analysis approaches. As such, overall, we make important contributions to both practice and theory/literature in production and operations management.

The next section provides a brief introduction into the general area of supply chain risk management. This is followed by a description of the integrative approach combining FMEA and the SCRMP. Michigan Ladder Company and the context in which the approach was implemented are presented next. This is followed by the application of our suggested approach at MLC. The ensuing section discusses the results, illustrates the derived value for MLC, and describes the actions resulting from the approach. A last section concludes the article.

Supply Chain Risk Management

We define supply chain risk as the threat or probability of supply chain disruptions that adversely affect the smooth flow of products, impacting operational performance measures such as responsiveness and cost. This definition was derived from extant literature, but was also specifically influenced by the context of MLC and how it viewed supply chain risk. Most definitions found in literature go back to the conceptualization offered by the British Standards Institute, which described risk as a "combination of probability or frequency of occurrence of a defined hazard and magnitude of occurrence" (BS 4778, 1991). Of particular relevance in the present study is the risk of interrupted supply. Within this context, supply risk has been defined as failures associated with inbound goods and services that affect the firm to meet customer demand (Zsidisin et al. 2004, 2005). Similarly, Harland et al. (2003), referring to Meulbrook (2000), described supply risk as adversely affecting inward flow of any resource that hinders scheduled operations. Our conceptualization is in line with these prior definitions.

The criticality of ensuring the smooth flow of products through the supply chain and the impact of supply chain disruptions has been highlighted by recent events. For example, supply chains have been impacted by natural disasters, such as the super-storm Sandy on the U.S. East Coast in 2012, floods in Thailand in 2012, the Japanese tsunami in 2011 (Dawson 2011), the 2006 earthquake in Java, the hurricanes Katrina and Rita in 2005 (Devlin 2005), and the ongoing hijackings of vessels by pirates off the coast of Somalia (Bowman 2010). The immediate impact of announcements concerning such supply chain disruptions on shareholder value has been shown by Hendricks and Singhal (2005). It is therefore crucial for managers to identify and understand the associated risks with their supply chains, as well as to then develop risk-reduction strategies (Chopra and Sodhi 2004).

Responding to these realities, academic research into supply chain risk management has flourished. For example, Waters (2011) focused on supply chain risk management from the perspective of logistics, and Sodhi and Tang (2012) called for companies to more proactively manage the associated risks. Förstl et al. (2011) reported on what represents excellence in supply risk management across different industry sectors, and Olson (2012) offered analysis tools for supply chain risk management. Allen and Schuster (2000) examined risk management at Welch's, Inc., for their harvesting of grapes, and Manetti (2001) emphasized the importance of risk management for the choice and implementation of technologies in manufacturing. Risk management was described as an essential ingredient for project planning by De Reyck (2010). Pfohl et al. (2010) summarized extant literature in supply chain risk management, complementing earlier work by Tang (2006) who focused on the review of quantitative models for the management of supply chain risk. A review of recent studies in supply risk is also provided in Blome and Schoenherr (2011).

Various approaches have been suggested for the management and mitigation of supply chain risks. As such, Kilgore (2004) introduced an analytical risk mitigation framework consisting of five steps, Giannakis and Louis (2011) proposed a multi-agent decision support system for supply chain risk management, and Wagner and Neshat (2010) assessed supply chain vulnerability using graph theory. De Waart (2006) developed an informal assessment tool to implement risk mitigation strategies, Sheffi and Rice (2005) used the dimensions of disruption probability and consequences as categorization scheme, and Kleindorfer and Saad (2005) proposed a framework reflecting the activities of risk assessment and risk mitigation. Sinha et al. (2004) suggested a prescriptive risk methodology applied to the aerospace supply chain, Cucchiella and Gastaldi (2006) proposed a real options-based supply chain risk management approach, and Huhn and Kahn (2012) utilized robust optimization to manage supply chain risks. We build on and extend this stream of research and propose a novel and innovative supply chain risk management approach, which will be described next.

FMEA and SCRMP

In our integrated approach we combine the strengths of traditional FMEA (1995), and utilize it together with specific techniques such as the U.S. Military Standard 882C and the Hazard Totem Pole (Grose 1987), as part of the SCRMP. Within this context, FMEA enables the assessment of potential failures and their effects, together with the development of preventive action plans and associated implementation costs, effectively complementing the SCRMP. A recent study illustrated the power of integrating FMEA with general risk management approaches, noted the dearth of research in this area, and thus called for the further investigation of this area (Chan et al. 2011). Chan et al. (2011) specifically noted that there is a lack of practical guidance in the integration of risk and failure analysis, and stressed the significant potential of doing so. We answer this call in the present study.

The value of integrating FMEA with other approaches can be considerable, given extant research that reported on such integration efforts. For example, Shahin (2004) integrated FMEA with the Kano model, Chang and Paul (2009) combined FMEA with data envelopment analysis, and Chin et al. (2009) integrated it with the evidential reasoning approach. In the present study, we integrate FMEA with the supply chain risk management process and illustrate its combined application.

Failure Mode and Effect Analysis (FMEA)

Failure mode and effect analysis (FMEA) is a structured approach to identify and prevent product and process failures before they occur (McDermott et al. 2009). Having evolved from first applications in the aerospace industry in the 1960s, it has since then been widely employed for product and process improvement efforts and for the purpose of reducing the risk of failures (Stamatis 2003). In FMEA, every possible malfunction or breakdown is assessed in terms of the potential causes of the failure, the potential effects and consequences, preventive actions possible, and costs of these preventive actions (Tatikonda and Tatikonda 1994). FMEA has been applied for example to project risk management (Tummala and Mak 2001; Ng et al. 2003; Carbone and Tippet 2004) and to the implementation of enterprise resource planning systems (Shirouyehzad et al. 2011). It was also noted that benefits from FMEA are most fully realized if it is part of a quality management system (McDermott et al. 2009). Extending this idea, we forward the notion that the application of FMEA together with the SCRMP is most effective.

While most FMEA studies have focused on product and manufacturing process improvements, and not on supply chain management, the inherent interest of these prior studies was in reducing the risk of product or process failures (Stamatis 2003). What is therefore imminent is the applicability to supply chain risk management. With a few exceptions, however, extant research has not dealt with the application of FMEA to supply chain risk management, an observation which suggests to have left many opportunities on the table. Within the context of supply chain management, Elkins et al. (2005) proposed using FMEA to trace back the root cause of a failure and learn from the event, and Teng et al. (2006) provided guidance for implementing

FMEA in a collaborative supply chain environment. We extend these works by illustrating the combined application of FMEA with the SCRMP.

Supply Chain Risk Management Process (SCRMP)

The Supply Chain Risk Management Process (SCRMP) is a framework for the assessment of the risk profile associated with a specific supply chain, and was conceptually developed by Tummala and Schoenherr (2011). It offered a practical template to manage supply chain risks more effectively in a structured fashion. However, the authors failed to illustrate the approach in the real world, questioning its applicability and relevance for managerial practice. In the current research, we work towards alleviating this omission, and integrate it with FMEA.

The core of the SCRMP consists of three phases: (I) risk identification, risk measurement and risk assessment, (II) risk evaluation, risk mitigation and the development of contingency plans, and (III) risk control and monitoring (Tummala and Schoenherr 2011). The purpose of phase I is to enumerate all possible potential supply chain risks, and assess their severity and likelihood of occurrence. Phase II evaluates the identified risks to develop appropriate risk response strategies for risk reduction and management. Phase III develops a risk-based data management and analysis system to monitor the effectiveness of the implemented risk reduction plans.

In the current study we focus on phases I and II of the SCRMP, their inherent process steps, associated techniques and evaluation approaches. Specifically, the seven process steps that we consider are the following: (1) identify potential supply chain risk factors; (2) assess the severity of consequences of the identified risk factors; (3) assess the likelihood of occurrence of the identified risk factors; (4) classify the identified risk factors; (5) determine the cost of implementing risk response action plans; (6) determine risk priority scores; and (7) construct the Hazard Totem Pole chart. The last phase and remaining process steps not considered refer to actions taken after the risk mitigation and contingency plans have been implemented, and deal with ongoing risk control and monitoring. These steps are not considered since they are outside of the scope pertaining to the integration of FMEA; rather, they utilize results of the prior steps and FMEA to effectively manage risk.

CONTEXT AND BACKGROUND

We illustrate the application of our approach at Michigan Ladder Company (MLC), a small manufacturer and distributor of ladders, located in Ypsilanti, Michigan. The product spectrum of MLC is narrow but deep, including aluminum, fiberglass and wood ladders. The firm has been enjoying good financial health despite the economic downturn, providing evidence of its sound risk management approaches. Established in 1901, MLC is the oldest U.S. ladder manufacturing company, supplying ladders primarily for the commercial sector, including the military. The continued success of the company is attributed to its innovative and loyal workforce, as well as MLC's emphasis on and dedication to quality products. The firm was chosen to serve as an exemplar for the application of our approach, since it had been very proactive in its thoughts toward risk management.

An earlier approach to risk management that the company was taking, involving the analytic hierarchy process (AHP), was chronicled in Schoenherr et al. (2008). This evaluation was triggered by changes in the competitive landscape and the wish to move the sourcing of two of the firm's major product lines from a Mexican supplier to an alternate source. The five alternatives considered were (1) the sourcing of finished goods from Mexico, (2) the sourcing of finished goods from China, (3) the sourcing of parts from China and assembly in the U.S., (4) the sourcing of parts from China, assembling them in a maquiladora in Mexico with investment, and (5) the sourcing of parts from China, assembling them in a maquiladora in Mexico with no investment. These supply chain designs and associated sourcing locations were considered due to their appeal in terms of both quality and cost, which all alternatives demonstrated. A total of seventeen risk factors were identified as being relevant for the firm. Using AHP modeling, the risk factors were assessed across the five alternatives, yielding a preference score minimizing the risks for each alternative. As a result, the three alternatives with the least risk were implemented (alternatives (2), (5) and (1)). Three supply chain designs were pursued, so as to further diversify the risk inherent in each. This approach has been receiving great interest by practitioners, and was also featured at a dinner presentation held for the Greater Detroit Chapter of APICS. We therefore contacted MLC to solicit its participation for the present study.

Due to the dynamic environment, MLC was constantly re-evaluating its strategic choices regarding its outsourcing activities. At the time the study was conducted, the company had abandoned alternative (1), which was merely retained until the new supply chain designs were fully operational. As such, the company was operating with two supply chain designs: (A) the sourcing of finished goods from China, and (B) the sourcing of parts from China, assembling them in a Mexican maquiladora (with no investment taken in the venture), and then shipping them to the Midwest location of the firm. We will refer to option (A) as the China-Midwest supply chain, whereas option (B) is referred to as the China-Mexico-Midwest supply chain.

Although these two supply chains represented the least risk, based on the prior AHP analysis, quality problems began to emerge about a year after the commitment to the China-Midwest supply chain had been made. A more detailed investigation of the risk factors involved in this supply chain was therefore needed, offering a formidable context to apply FMEA integrated with the SCRMP. In order to provide a comparison benchmark, it was decided to also include the second least-risky alternative in the evaluation, the China-Mexico-Midwest supply chain, which had also been in operation. The design, structure and configuration of these two supply chains is quite diverse, involving a different set of supply chain risks and differing intensity levels for each. As such, a more rigorous assessment of these two scenarios was now warranted. In addition, in contrast to the earlier evaluations via AHP, the two supply chains were now fully operational, and actual experiences had been made to better gauge the risks. Therefore, in collaboration with the company, the approach presented herein was developed, combining FMEA and the SCRMP. The goal was to facilitate the decision on the optimal supply chain design, minimizing supply-side related risks. The overriding objectives of the assessment were to reduce costs along the supply chain, with however at the same time improving (or at least not deteriorating) service levels and responsiveness.

Differentiation to Prior Work

The current work builds on and extends prior studies, and we would like to highlight how the current paper differentiates itself. Specifically, above we noted that we are following up on a decision Michigan Ladder Company had made pertaining to five offshoring alternatives, which was facilitated with the Analytic Hierarchy Process and presented in Schoenherr et al. (2008). Our work differentiates itself in that we are not relying on AHP to offer decision support. While we conducted our research at the same company with the same risk factors (since these risk factors were still deemed valid by the company), the framework presented in the present paper is different in that we apply a novel approach integrating FMEA and the SCRMP.

In addition, the present paper describes an approach for decision support that was taken later on in the timeline of the company, once the decision chronicled in Schoenherr et al. (2008) had been made. As such, we are focusing on the two least risky alternatives identified in Schoenherr et al. (2008), and provide more enhanced and detailed decision support, building on and extending this prior work. Furthermore, we base the assessment on the actual operation of the two supply chains, for both of which experiences had now been made. Moreover, even though we consider the same seventeen risk factors as those identified by Schoenherr et al. (2008), the use of FMEA and the application of the principles inherent in the SCRMP, such as the U.S. Military Standard 882C and the Hazard Totem Pole, enabled us to provide a much more detailed analysis to assess the potential severity of risks and their probability indices, the preventive actions, and the associated implementation costs.

Further, while we utilize the SCRMP conceptually developed by Tummala and Schoenherr (2011), the work did not provide an illustration of the approach, failing to demonstrate its practical value. We thus build on their study and illustrate the practical application of the SCRMP. In addition, we extend their work in that we integrate the SCRMP with FMEA, which was not done in their paper. By doing so, we combine risk management assessments with FMEA, research which was called for by Chan et al. (2012).

Research Approach

With the objective of ensuring academic rigor, we conducted this study adhering to strict guidelines pertaining to action research (AR). This approach can be defined as a "grounded, iterative, [and] interventionist" method that ensures "closeness to the full range of variables in settings where those variables may not emerge all at once" (Westbrook 1995, 18). We deemed AR as especially appropriate for the current study, since, as was noted by Sheffi and Rice (2005, 47), "gauging the magnitude of a large disruption early requires a mindset that continuously questions prevailing wisdom and a culture that allows "maverick" information to be heard, understood and acted upon." As such, the AR approach enabled the capturing of unspoken important information, which is not possible to the same extent in alternate research methods. Methodological rigor of the action research approach was ensured by the application of Coughlan and Coghlan's (2002) AR cycle and their four process steps, and Eden and Huxham's (1996) twelve contentions.

Following AR methodology, two academics focusing on emerging risk management research worked closely with the owner and chief executive officer (CEO) of MLC, who is also an author of this manuscript. The CEO was the key decision maker and thus the primary informant. He had insight into all functional aspects of his company, and was in close contact with other administrative functions of the firm, ensuring insight into all departments within the company; due to the small size of the company this was possible (Lusch and Brown 1996). Regular meetings between the CEO, other administrative personnel, and the two academics were conducted to identify and assess supply-side risks, and to ultimately facilitate the risk assessment of the two alternatives to provide decision support for the firm's supply chain design. The final identification of failure modes and preventive actions, as well as the assignment of numeric values in the SCRMP, were conducted in joint meetings of the academics and the CEO.

INTEGRATING FMEA WITH THE SCRMP: AN APPLICATION AT MLC

This section describes the integration of FMEA with the SCRMP, as well as how it was applied at MLC. Table 1 provides a summary of this integration. Overall, this exposé provides a valuable application and template for other firms facing similar problem scenarios and decisions.

TABLE 1: INTEGRATION OF SCRMP AND FMEA

Step	Step in the SCRMP	Integration with FMEA
1	Identify risk factors	Define the potential failure mode (i.e. how the specific risk manifests itself in terms of failures or breakdowns for MLC), potential causes of the failure or breakdown, potential effects or consequences of the failure or breakdown, preventive actions that could be done, and the cost of such actions
2	Assess the severities of consequences	Update (add or modify) the FMEA framework by more detailed information having emerged through this SCRMP step
3	Assess the likelihood of occurrence	Refer to information collected in the FMEA to make more informed decisions on the assignment of individual likelihood values
4	Classify the identified risk factors	Refer to information collected in the FMEA to substantiate classification; if necessary, make adjustments to better reflect reality
5	Determine the cost of implementing risk response action plans	Provide more detail in the FMEA framework pertaining to specific costs, as well as substantiation for specific cost estimates
6	Determine risk priority scores	Substantiate the classification into risk priority scores with qualitative information recorded in the FMEA, combining the strengths of both approaches
7	Construct the Hazard Totem Pole chart	Utilize information from the FMEA framework to substantiate classifications and overall structure of the Hazard Totem Pole, refuting the criticism that SCRMP scores can be subjective; this can be especially useful in the presentation to others affected by the decision

Step 1: Identify Risk Factors

We commenced with the first step of the SCRMP, i.e. the identification of supply chain management risk factors. Useful approaches at this stage include brainstorming or the nominal group technique. All feasible risks should be identified that could potentially influence the desired outcomes. The overriding objectives of the risk assessment in the case of MLC were to reduce costs along the supply chain, with however at the same time improving (or at least not deteriorating) service levels and responsiveness. These objectives were kept in mind when considering potential supply-side risk factors for MLC. After a review of potential risks, the research team deemed the seventeen risk factors as identified earlier (Schoenherr et al. 2008) as still representing the current situation. Further discussions and feedback obtained from colleagues not involved in the research and in other functions did not lead to any additional applicable factors. These seventeen risk factors, as well as their definitions and corresponding abbreviations used in the ensuing discussion, are summarized in Table 2.

TABLE 2: IDENTIFIED RISK FACTORS

Risk Factor Code	Risk Factors Label	Risk Factor Definitions
ACR	ANSI Compliance	Minimum requirements that the company's products must at least fulfill, and the risk that the supplier fails to meet these requirements.
PQR	Product Quality	Likelihood of the supplier not providing an excellent product in terms of quality (measured in terms of the number of defective products).
PCR	Product Cost	Price that the company pays for the product, and the risk associated with a price increase.
CCR	Competitor Cost	A measure of how the price that the company receives from its suppliers compares to the price competitors are likely to pay for comparable input. It represents the risk of the competitor having a relative cost advantage.
DMR	Demand Risk	Measures the likelihood of severe swings in demand, and the responsiveness the respective supply chain would exhibit in accommodating these swings.
SFR	Supplier Fulfillment Risk	Estimates how accurate suppliers are fulfilling the orders, both in terms of quality, quantity and punctuality.
LGR	Logistics Risk	Risks due to organizational aspects of logistics, such as paperwork involved, scheduling routes, determining what to ship with what mode and at what time, selection of ports and carriers, etc.
TBR	On-Time and On-Budget Risk	Deals directly with the ability of the supplier to deliver the product to the company on-time and on-budget, i.e. without delays and without any higher costs.
OFR	Order Fulfillment Risk	Addresses the risk that products ordered are not delivered in the quantity and quality demanded.

TABLE 2: IDENTIFIED RISK FACTORS CONTINUED

Risk Factor Code	Risk Factors Label	Risk Factor Definitions
WPR	Wrong Partner Risk	Risk of engaging with the wrong partner, and thus, due to their potential poor performance, not being able to meet customer needs and/or demand requirements.
OSR	Overseas Risk	Considers the possibility that relationships overseas are more difficult to manage, due to for example cultural and political factors, but also distance and language barriers.
SUR	Supplier Risk	Concerned with the chance that the supplier goes out of business / goes bankrupt as a result of poor management capability.
SSM	Supplier's Supplier Risk	Deals with how the immediate (or Tier 1) supplier manages its sources of supply and the associated risk, i.e. the buying company's second and possibly also third and fourth tier suppliers.
EIR	Engineering and Innovation Risk	Concerned with the supplier's capability to collaborate on design, the potential for joint innovations, as well as the potential for the leakage of confidential information shared.
TPR	Transportation Risk	Measures the extent to which carriers can have problems in the physical movement of goods.
SVR	Sovereign Risk	Assesses the risk associated with giving up control when going overseas, including potential political instability, strikes, and stringent government regulations
NTR	Natural Disasters/ Terrorism	Likelihood that the supply chain can fall victim to natural disasters and terrorism attacks.

Instrumental at this stage, pertaining to the integration of FMEA with the SCRMP, was that as much detail as possible for each risk factor was collected. The opportunity to gather this information at this stage is given, since there is usually an underlying rationale for a team member to suggest a particular risk as being important. Specifically, for each identified risk factor, we aimed to define the potential failure mode (i.e. how the specific risk manifests itself in terms of supply chain failures or breakdowns for MLC), potential causes of the failure or breakdown, potential effects or consequences, possible preventive actions, and the cost of such action. These categories were revised and/or complemented with additional information that was triggered in the ensuing stages of the SCRMP. For example, for the "on-time and on-budget risk" (risk factor code TBR; this risk factor will be used as an illustrative example throughout), which addresses the ability of the supplier to deliver the product without delays and without any higher costs, the potential failure mode for MLC was identified as not having what is needed and when it is needed. Potential causes were attributed to the lack of manufacturing capability and transportation flexibility on the part of the supplier. Effects of this failure were lower safety stock levels, lost sales, and higher replacement costs. Preventive actions that were identified included a closer working relationship with logistics personnel and suppliers, the provision of help to the supplier for improving their processes and capabilities, and more effective communication. The implementation of these initiatives was estimated to cost $60,000. The FMEA analysis for all risk factors pertaining to the China-Midwest supply chain is presented in Appendix A.

Step 2: Assess the Severities of Consequences

In the second step of the SCRMP we utilized Military Standard 882C (1993) to define the categories of consequence severities into catastrophic, critical, marginal or negligible (yielding the Risk Consequence Index). The four-level standard was adapted to MLC in a cross-functional fashion involving the academics and the CEO of the company. As such, a catastrophic consequence (risk severity index = 4) was described as the plant being shut down, equivalent also to no delivery occurring for more than one month due to lack of components and zero safety stock levels. The consequence was described as critical (risk severity index = 3) if the process slowed down or if no delivery was received for more than one week due to lack of components and zero safety stock levels. A situation with decreasing service levels and depleting safety stock was described as marginal (risk severity index = 2), while an instance with service levels not being impacted due to sufficient safety stock levels was considered negligible (risk severity index = 1). These degrees of magnitude can be adapted based on the individual company's assessment of what would represent a catastrophic, critical, marginal or negligible event; according to the military standard, the worst possible event is considered in each category. With these definitions in place, we evaluated each of the seventeen risk factors along their respective consequence severity on the objectives of (a) cost reduction and (b) responsiveness (service levels). Since it was our intent to assess the current offshoring strategy (the "China-Midwest" supply chain) and to compare it to an alternate design (the "China-Mexico-Midwest" supply chain), the evaluation of consequence severities was conducted for both objectives and both alternatives. The results are shown in Table 3. For example, the consequence severity of the "on-time and on-budget risk" on MLC's cost reduction objective for the China-Midwest supply chain was judged to be critical, and was thus assigned a value of 3. The rationale behind this assessment was that if deliveries are delayed, while some demand could be initially accommodated by safety stock, most might be lost due to the unavailability of the product. This would yield not only a loss of immediate business, but also potentially future business if the goodwill of customers is damaged by the unfilled order. Thus, the risk was evaluated to be critical.

TABLE 3: ASSESSMENT OF CONSEQUENCE SEVERITY

Risk Code	China-Midwest Supply Chain		China-Mexico-Midwest Supply Chain	
	Cost Reduction	Responsiveness	Cost Reduction	Responsiveness
ACR	4	3	4	3
PQR	4	3	4	3
PCR	4	3	3	3
CCR	3	3	3	3
DMR	4	3	4	3
SFR	4	3	4	3
LGR	3	3	3	3
TBR	3	4	3	4
OFR	3	3	3	3
WPR	3	3	3	3
OSR	2	2	2	2
SUR	3	3	3	3
SSM	2	3	2	3
EIR	1	1	1	1
TPR	3	3	3	3
SVR	4	1	3	1
NTR	4	1	2	1

While the assignment of a numerical value is a powerful approach due to the development of a final score for comparison purposes, it also has its limitations, since any qualitative information that may have led to this assessment is lost. This is where the value of integrating FMEA comes in, in that it provides a structured template to document this information. As such, the FMEA framework created with step 1 above was now revisited, and additions and modifications were made. Adjustments were made especially to the potential effects or consequences of a failure, as well as the ensuing preventive actions; the additional detail and rationale behind the assessment gathered in step 2 also helped put risk factors into perspective. This was done concurrently, to not lose any pertinent information that played into the assignment of certain values.

Step 3: Assess the Likelihood of Occurrence

In the third step of the SCRMP, U.S. Military Standard 882C (1993) was further adapted to define the risk probability categories and the corresponding risk probability indices. Depending on the likelihood of occurrence, risk probability indices of 4, 3, 2 or 1 were assigned, which correspond to the risk probability of often, infrequent, rare and extremely rare. The research team defined these occurrences as potentially happening once per week, once per month, once per year, or once per decade, respectively. Using this scale, the seventeen risk factors were evaluated; the results are summarized in Table 4. Continuing with the "on-time and on-budget risk" example from above, its likelihood of occurrence for the China-Midwest supply chain was judged to be "often," and a value of 4 was thus assigned.

Here again, FMEA enabled decision support in that it provided additional information already gathered previously. As such, rather than relying on one's recollection of what had been discussed, the FMEA framework offered a structured template that was referred to when deciding on the individual values. In the "on-time and on-budget risk" example, the potential of the supplier lacking manufacturing capability and transportation flexibility as a cause for failure was especially considered in assessing the likelihood occurrence as being "often." This assessment was made based on the actual experiences of MLC, and the consideration of eventualities that could affect an on-time and on-budget delivery.

The value of such an integrated approach is especially given when many risk factors and supply chain designs are evaluated, as was the situation in our case. As such, the FMEA framework provided a convenient way to record additional information that emerged, especially for preventive actions. For the "on-time and on-budget risk" example, this led to the suggestion of better communication protocols and helping the supplier to improve their processes.

TABLE 4: ASSESSMENT OF LIKELIHOOD OF OCCURRENCE

Risk Code	China-Midwest Supply Chain	China-Mexico-Midwest Supply Chain
ACR	3	3
PQR	3	3
PCR	3	3
CCR	3	3
DMR	3	3
SFR	3	3
LGR	3	3
TBR	4	4
OFR	2	2
WPR	2	2
OSR	2	2
SUR	2	2
SSM	2	2
EIR	2	2
TPR	3	3
SVR	1	1
NTR	1	1

Step 4: Classify the Identified Risk Factors

As a fourth step in the SCRMP we rank ordered the risks, which is based on the determination of a risk exposure value (REV) for each identified supply chain risk, defined as follows:

Risk Exposure Value = Risk Consequence Index × Risk Probability Index

The equation uses the indices defined earlier to find the risk exposure values of the corresponding supply chain risk. For the “on-time and on-budget risk” example, which received values of 3 and 4 for consequence severity and occurrence likelihood, respectively, the risk exposure value is 3×4=12. In this fashion we found the risk exposure values for each identified supply chain risk and for both company objectives (Table 5).

TABLE 5: RISK EXPOSURE VALUES

Risk Code	China-Midwest Supply Chain		China-Mexico-Midwest Supply Chain	
	Cost Reduction	Responsiveness	Cost Reduction	Responsiveness
ACR	12	9	12	9
PQR	12	9	12	9
PCR	12	9	9	9
CCR	9	9	9	9
DMR	12	9	12	9
SFR	12	9	12	9
LGR	9	9	9	9
TBR	12	16	12	16
OFR	6	6	6	6
WPR	6	6	6	6
OSR	4	4	4	4
SUR	6	6	6	6
SSM	4	6	4	6
EIR	2	2	2	2
TPR	9	9	9	9
SVR	4	1	3	1
NTR	4	1	2	1

The risk exposure values were then used to classify the identified risk factors into classes. The highest risk exposure class (risk exposure class index 4, risk exposure class code A) included risks that had REVs between 16 and 11, the second highest risk exposure class (risk exposure class index 3, risk exposure class code B) contained risks that had REVs between 10 and 6, the third highest risk exposure class (risk exposure class index 2, risk exposure class code C) included risks that had REVs between 5 and 3, and the fourth highest risk exposure class (risk exposure class index 1, risk exposure class code D) included risks that had REVs of 2 or 1.

These class indices and the class codes were assigned with respect to the cost objective. Corresponding risk exposure class codes of J, K, L and M and class indices of 4, 3, 2, and 1, respectively, were assigned for the responsiveness objective. Table 6 presents in its four panels the result of this analysis. Since the "on-time and on-budget risk" had an REV of 12, it was assigned a risk exposure class code of A and a risk exposure class index of 4. Five additional risk factors were placed in the same exposure class, based on their consequence severity and occurrence likelihood. This information will be used in a later step to construct the Hazard Totem Pole chart to visualize the risks.

The integration of FMEA at this stage substantiated the classification of the seventeen risk factors into their respective risk exposure class index. As such, rather than blindly calculating the values, we referred back and forth when classifying the risks to substantiate their allocation to a particular risk exposure index. In the example noted, the relative severity, the likelihood of potential causes and associated preventive actions substantiated the "on-time and on-budget risk" to be classified in the highest risk exposure class. This served as a confirmation for the appropriate classification of the risks, which can be overwhelming and thus lead to mistakes, especially when a multitude of risks are considered. Since the assignment of values is inherently subjective, the integration of FMEA at this and other stages served yet again as a further check for the integrity of the evaluation.

TABLE 6: RISK EXPOSURE CLASSES

Panel A: Risk exposure class, China-Midwest supply chain, cost objective

Risk Exposure Values Classification	Risk Factor Codes	No. of Risk Factors in the Class	Cumulative Number of Risk Factors	Risk Exposure Class Code	Risk Exposure Class Index
16 – 11	ACR, PQR, PCR, DMR, SFR, TBR	6	6	A	4
10 – 6	CCR, LGR, OFR, WPR, SUR, TPR	6	12	B	3
5 – 3	OSR, SSM SVR, NTR	4	16	C	2
2 – 1	EIR	1	17	D	1

Panel B: Risk exposure class, China-Midwest supply chain, responsiveness objective

Risk Exposure Values Classification	Risk Factor Codes	No. of Risk Factors in the Class	Cumulative Number of Risk Factors	Risk Exposure Class Code	Risk Exposure Class Index
16 – 11	TBR	1	1	J	4
10 – 6	ACR, PQR, PCR, CCR, DMR, SFR, LGR, OFR, WPR, SUR, SSM, TPR	12	13	K	3
6 – 3	OSR	1	14	L	2
2 – 1	EIR, NTR	3	17	M	1

Panel B: Risk exposure class, China-Midwest supply chain, responsiveness objective

Risk Exposure Values Classification	Risk Factor Codes	No. of Risk Factors in the Class	Cumulative Number of Risk Factors	Risk Exposure Class Code	Risk Exposure Class Index
16 – 11	ACR, PQR, DMR, SFR, TBR	5	5	A	4
10 – 6	PCR, CCR LGR, OFR, WPR, SUR, TPR	7	12	B	3
5 – 3	OSR, SSM SVR,	3	15	C	2
2 – 1	EIR, NTR	2	17	D	1

Panel D: Risk exposure class, China-Mexico-Midwest supply chain, responsiveness objective

Risk Exposure Values Classification	Risk Factor Codes	No. of Risk Factors in the Class	Cumulative Number of Risk Factors	Risk Exposure Class Code	Risk Exposure Class Index
16 – 11	TBR	1	1	J	4
10 – 6	ACR, PQR, PCR, CCR, DMR, SFR, LGR, OFR, WPR, SUR, SSM, TPR	12	13	K	3
5 – 3	OSR	1	14	L	2
2 – 1	EIR, SVR, NTR	3	17	M	1

Step 5: Determine the Cost of Implementing Risk Response Action Plans

The phase of risk mitigation and contingency planning includes the development of risk response action plans to contain and control the identified supply chain risks. This important activity involves risk planning, which begins with examining the costs required to implement each response action, along with the determination of the respective consequence-severity and risk-probability index levels. As such, in the fifth step of the SCRMP, a four-level cost category system was adopted to facilitate this process.

The research team determined plans with an implementation cost of more than $100,000 to be in the "substantial" cost category (cost index = 1, cost code = S), plans with implementation costs between $10,000 and $100,000 to be in the "high" cost category (cost index = 2, cost code = R), plans with implementation costs between $1,000 and $9,999 to be in the "low" cost category (cost index = 3, cost code = Q), and plans with an implementation cost of less than $1,000 to be in the "trivial" cost category (cost index = 4, cost code = P). Table 7 summarizes the cost indices for our seventeen risk factors across the two supply chains. For the "on-time and on-budget risk," the implementation cost of risk mitigation plans for both supply chains was estimated to be $60,000, thus being allocated a cost index of 2 and the cost code R. The choice of such a four-level system is similar to the number of levels used in classifying supply chain risks based on the REVs.

TABLE 7: IMPLEMENTATION COST INDICES

Risk Code	China-Midwest Supply Chain	China-Mexico-Midwest Supply Chain
ACR	2	2
PQR	2	2
PCR	2	2
CCR	2	2
DMR	2	2
SFR	2	2
LGR	2	2
TBR	2	2
OFR	2	2
WPR	2	2
OSR	2	2
SUR	2	2
SSM	3	2
EIR	3	2
TPR	3	2
SVR	2	2
NTR	1	2

The link between the SCRMP and FMEA exists also here, in that the FMEA framework specifically considers the cost of mitigating the risk. As such, similar as above, it offered an opportunity to provide more detailed information than with a mere categorization into the four classes. In this way, FMEA provided additional insight and aided in a more informed decision. In addition, substantiation for cost figures was provided in the FMEA, and their derivation was facilitated. This is especially valuable in situations with a multitude of risk factors. In the "on-time and on-budget risk" example discussed, the potential effects of lower safety stock and lost sales were considered, together with potential actions aimed at preventing the failures. Actions included more intense collaboration with logistics personnel and suppliers, and potentially also visiting the supplier to help improve their processes. Due to these initiatives involved, the cost was substantiated at the specified level.

Step 6: Determining Risk Priority Scores

Using the risk severity, risk probability and implementation cost classes, as well as their corresponding indices, we determined the risk priority scores to assess the relative importance of the identified supply chain risks. This represents the sixth step of the SCRMP. The prioritization assisted us in using our resources most efficiently. Based on the three coding levels, each risk factor was assigned a three-letter code. For example, a risk factor with a code of AJP (or 4, 4, 4) possessed a consequence severity of "catastrophic," an occurrence probability of "often," and was associated with prevention plans that would cost less than $1,000. As suggested by Grose (1987), the corresponding risk index was determined as 12 (=4+4+4). In this fashion, each identified supply chain risk was assigned a hazard code and a Hazard Totem Pole (HTP) score. Table 8 presents this analysis for our two supply chain designs.

TABLE 8: HAZARD CODES AND HTP SCORES

Panel A: China-Midwest supply chain

Risk Factor Code	Hazard Code (Class Code)	Numerical Level No.	HTP Score	Cost of Preventative Actions
ACR	A K R	4 3 2	9	75,000
PQR	A K R	4 3 2	9	85,000
PCR	A K R	4 3 2	9	25,000
CCR	B K R	3 3 2	8	50,000
DMR	A K R	4 3 2	9	50,000
SFR	A K R	4 3 2	9	60,000
LGR	B K R	3 3 2	8	60,000
TBR	A J R	4 4 2	10	60,000
OFR	B K R	3 3 2	8	25,000
WPR	B K R	3 3 2	8	30,000
OSR	C L R	2 2 2	6	30,000
SUR	B K R	3 3 2	8	30,000
SSM	C K Q	2 3 3	8	10,000
EIR	D M Q	1 1 3	5	10,000
TPR	B K Q	3 3 3	9	10,000
SVR	C M R	2 1 2	5	20,000
NTR	C M P	2 1 2	5	20,000

Panel B: China-Mexico-Midwest supply chain

Risk Factor Code	Hazard Code (Class Code)	Numerical Level No.	HTP Score	Cost of Preventative Actions
ACR	A K R	4 3 2	9	25,000
PQR	A K R	4 3 2	9	50,000
PCR	B K R	3 3 2	8	25,000
CCR	B K R	3 3 2	8	25,000
DMR	A K R	4 3 2	9	50,000
SFR	A K R	4 3 2	9	40,000
LGR	B K R	3 3 2	8	20,000
TBR	A J R	4 4 2	10	20,000
OFR	B K R	3 3 2	8	25,000
WPR	B K R	3 3 2	8	30,000
OSR	C L R	2 2 2	6	25,000
SUR	B K R	3 3 2	8	30,000
SSM	C K R	2 3 2	7	15,000
EIR	D M R	1 1 2	4	15,000
TPR	B K R	3 3 2	8	15,000
SVR	C M R	2 1 2	5	20,000
NTR	D M R	1 1 2	4	20,000

Let us consider, for illustrative purposes, the values received for the "on-time and on-budget risk" example. We labeled this risk with the abbreviation "TBR," which received the overall Hazard Code AJR (corresponding to the numerical levels of 4, 4, and 2, respectively), yielding a final HTP score of 10. The first letter of the Hazard Code represents the corresponding Risk Exposure Value for the cost objective, and the second letter represents the Risk Exposure Value for the responsiveness objective. These values and the corresponding letter classification were computed and derived in step 4, taking into account the Risk Consequence Index and the Risk Probability Index, which were determined in step 2 and step 3, respectively. If more objectives are considered in a decision, additional letter codes can be added. The last letter code represents the cost category associated with the estimated dollar amount needed to implement risk mitigation strategies for the particular risk considered, which was determined in step 5. Since a cost of $60,000 was estimated, the "on-time and on-budget risk" received a cost code of R. Overall, the three-letter Hazard Code provides a concise way to summarize the outcome of prior evaluations. The numerical level of 4-4-2 represents the values corresponding to the letter codes above. These are now added together, to constitute the overall HTP score (10), which will be utilized in the next step to construct the Hazard Totem Pole.

At this time it was prudent to go back to the FMEA framework and ensure that the scores derived with this fashion were consistent with the more qualitative information in the FMEA. Here again our integrated approach highlights its benefits, in that it combines the strengths of numerical analysis in the SCRMP with the strengths of the more qualitative assessment in FMEA. The evaluation of the seventeen risks should be consistent, yielding decision support that can be relied on. As such, the HTP score of 10 for the "on-time and on-budget risk" was consistent with the potential causes of the failure, its potential effects, and possible preventive actions. This information, gathered in the FMEA framework, will now also be useful in substantiating the HTP score derived to executive management or other stakeholders that were not intricately involved in the exercise.

Step 7: Construct the Hazard Totem Pole Chart

In the seventh step of the SCRMP, we utilized the risk scores shown in table 8 to construct the Hazard Totem Pole (Grose 1987). We first prioritized the supply chain risks by sorting the table according to the HTP score in descending order, placing the most critical risk on top. As such, the supply chain risk of TBR (on-time and on-budget risk) received the highest HTP score for the China-Midwest supply chain. Similarly, the risks of TPR (transportation risk), PCR (product cost), DMR (demand risk), SFR (supplier fulfillment risk), ACR (ANSI compliance), and PQR (product quality) received the next highest HTP scores. In this fashion, all identified supply chain risks were prioritized and incorporated in the Hazard Totem Pole. For risks with the same HTP score, the ordering within can be based on the relative implementation cost for the risk mitigation plans, in ascending order.

In the Hazard Totem Pole, the risks with the highest scores are on top (sharply pointed for management attention). The numerical values of the HTP scores are provided in the third column of the chart, and the corresponding risk factor code is noted in the second column. The first column in the HTP chart represents the cumulative risk factor count, and the last columns represent the cumulative risk control cost as well as the resources allocated.

Figure 1a provides the HTP analysis for the China-Midwest supply chain, whereas Figure 1b summarizes the analysis for the China-Mexico-Midwest supply chain. This visual representation in the HTP was especially useful in presenting the information to others at MLC that were going to be affected by the potential change in supply chain design. As such, the graph presented a concise and simple way to visualize the output of the process.

FIGURE 1A: HAZARD TOTEM POLE, CHINA-MIDWEST SUPPLY CHAIN

Cumulative Risk FactorCount	Risk Factor Code	HTP Score	Cumulative Risk Control Cost ($)	Allocated Resources
1	TBR	10	60,000	
2	TPR	9	70,000	
3	PCR	9	95,000	
4	DMR	9	145,000	
5	SFR	9	205,000	
6	ACR	9	280,000	
7	PQR	9	365,000	
8	SSM	8	375,000	Allocated Resources
9	OFR	8	400,000	
10	WPR	8	430,000	
11	SUR	8	460,000	
12	CCR	8	510,000	
13	LGR	8	570,000	
14	OSR	6	600,000	
15	EIR	5	610,000	
16	SVR	5	630,000	
17	NTR	5	650,000	

Considering the China-Midwest supply chain, the risk of on-time and on-budget risk (TBR) needed to be considered first in the development and implementation of risk reduction action plans. The cost of developing and implementing such a risk reduction plan would cost $60,000. Similarly, the supply chain risk of transportation (TPR) with a hazard code of BKQ and a HTP score of 9 needs to be considered next. The cost of developing and implementing an appropriate risk reduction plan would be $10,000. Therefore,

FIGURE 1B: HAZARD TOTEM POLE, CHINA-MEXICO-MIDWEST SUPPLY CHAIN

Cumulative Risk FactorCount	Risk Factor Code	HTP Score	Cumulative Risk Control Cost ($)	Allocated Resources
1	TBR	10	20,000	
2	TPR	9	45,000	
3	PCR	9	85,000	
4	DMR	9	135,000	
5	SFR	9	185,000	
6	ACR	8	200,000	
7	PQR	8	220,000	
8	SSM	8	245,000	
9	OFR	8	270,000	Allocated Resources
10	WPR	8	295,000	
11	SUR	8	325,000	
12	CCR	8	355,000	
13	LGR	8	370,000	
14	OSR	6	395,000	
15	EIR	5	415,000	
16	SVR	4	430,000	
17	NTR	4	450,000	

the cumulative cost of implementing risk response action plans to reduce the risks due to TBR and TPR for the firm is $70,000. In this fashion, the HTP chart provides useful information for supply chain planners and senior management to develop and implement appropriate risk reduction action plans.

For illustrative purposes, let us consider another example, and demonstrate how we derived the relative positioning of the supplier fulfillment risk, which is abbreviated with the code SFR (Table 2). This risk factor received an HTP score of 9, which was derived as follows. In step 2 of the SCRMP the risk was associated with a consequence severity of catastrophic and critical for the cost reduction and responsiveness objectives, respectively, and thus received numerical values of 4 and 3, respectively (Table 3). The likelihood with which the risk is to manifest itself was assessed as infrequent in step 3 of the SCRMP, and thus received a value of 3 (Table 4). Step 4 put these values together, and computed the Risk Exposure Value, which was 12 (4 3) and 9 (3 3) for the two objectives (Table 5). Based on this value, the risk is classified into a Risk Exposure Class, which received the class code A for the cost objective, and the class code K for the responsiveness objective (Table 6, panels A and B). The cost of implementing risk response action plans was determined in step 5 of the SCRMP, which resulted in an index of 2 for the risk considered (Table 7); thus, a cost code of R was assigned to the risk. Table 8 summarizes the outcome of the steps: the risk with risk factor code SFR received a Hazard Code of AKR, with corresponding numerical values of 4, 3, and 2. The sum of these values yields the HTP score, which is 9. When ordering all the risks based on their HTP score and their costs associated with the implementation of risk mitigation plans, SFR is placed at rank five for the China-Midwest supply chain (Figure 1a), and at rank three for the China-Mexico-Midwest supply chain (Figure 1b). This represents an effective priority in terms of it being addressed by management.

If a certain budget is available for risk management, this can be indicated as well, as is done in Figures 1a and 1b. The availability of resources can then indicate which risks can be addressed (indicated by the range covered by "allocated resources"). For example, if a budget of $280,000 was available, as indicated in Figure 1a, the risk of SFR could be addressed (together with the risks TBR, TPR, PCR, DMR, and ACR).

The additional information provided with the FMEA framework proved to be invaluable to substantiate the classification of risks and the overall structure of the Hazard Totem Pole. With this information as a back-up, criticisms were refuted pertaining to the SCRMP scores being overly subjective. In addition, when objective information was not or not sufficiently available, methods associated with FMEA (e.g., decision analysis techniques based on experience, beliefs, and judgments of supply chain managers) were found to be very useful to assess severity and probability indices. The FMEA framework accompanied the results from the SCRMP in a final document, to ensure that individuals not familiar with the construction of the HTP can obtain additional insight into why the HTP was constructed the way it was.

DISCUSSION, VALUE TO MLC, AND ENSUING ACTIONS

Having conducted the SCRMP integrated with FMEA, as presented in the preceding section, we performed a comparative analysis between the two supply chain designs under consideration. It was revealing to identify which supply-side risks seemed to be most prevalent with each supply chain design, illustrating the power of the suggested approach. Specifically, with the structured procedure requiring great detail at each process step, it was ensured that no feature of the individual risk factors was missed, and that their characteristics were accurately described and classified. The benefit of applying the approach to two supply chain designs was in the comparative benchmarking that was now possible. However, such a comparative approach does not have to be conducted in all instances, and a single application of the integrated approach presented in this paper will also yield significant decision support. For the case of MLC, the comparison led to the identification of the China-Midwest supply chain design to be more robust, which the company thus focused on primarily.

The integrated approach of using both SCRMP and FMEA has been invaluable for MLC in providing the company a rigorous and structured approach to assess supply chain risks. What was especially valuable was the qualitative substantiation via FMEA of the quantitative classifications via the SCRMP, and vice versa. As such, implementing the approach provided greatest confidence for the company in their ensuing decisions and actions. The documentation generated provided also an excellent tool to communicate to others the rationale for the decisions. In addition, the company was able to use information, derived via the FMEA, to now readily implement response action plans. For example, for both supply chains the highest ranked risk factor was "on-time and on-budget risk." A preventive action pursued by MLC was close collaboration with logistics personnel and suppliers to prevent late shipments. To do so, MLC's CEO travelled to China on several occasions to visit with suppliers, to stress the importance of timely delivery, and to identify opportunities for preventing future delays from occurring.

A further critical risk that was identified via the integrative approach applying FMEA and SCRMP included poor quality. Despite frequent communication and feedback from the company to the supplier, quality problems continued to transpire. As a response to reduce the risk from occurring again in the future, the CEO travelled to China again, and actively worked with the suppliers to improve their processes for incoming materials and outgoing product inspections, so that no faulty products would be shipped. In instances where the supplier was unwilling or unable to improve their processes, the relationship was ended, and alternate sources were sought.

In addition, most recently, in an effort to further decrease the supply chain risks associated with a global supply chain design, as identified in this study, MLC decided to primarily source parts from suppliers, rather than the finished product. At the same time, the supply base was diversified; while it had been one supplier in the past, the current structure involves multiple suppliers in multiple locations, including not only China, but also Canada and the U.S., effectively spreading the risk. This strategy was derived via the approach presented herein, and was deemed as a suitable method to minimize supply chain risks. This new configuration provided added flexibility for MLC, since it now directly controlled the assembly of ladders, being able to ensure highest quality standards. It further enabled the company to better react to swings in demand, reducing an additional risk as identified in this study. A further significant benefit was the bringing back of jobs to the U.S., since the company was now doing the assembly itself.

As the company continues to operate in an environment prone to worldwide supply chain management risks, it needs to be vigilant and monitor current and future developments. One alternative that the company is contemplating and that would facilitate this objective is to develop a working database and knowledge management system in which new information is added pertaining to the risks associated with each supply chain design. The FMEA framework can serve as a starting point – information in this template can be updated as situations change (each update should be accompanied by substantiation for doing so). Accordingly, scores assigned in the SCRMP can be revised, to reflect the new reality, so that the most risky issues stay current at all times. Ideally, such a knowledge management portal pertaining to the assessment of risks should be made available to everyone in the firm. Entries could then be reviewed on a regular basis, and changes to the HTP could be finalized by the management team. The central database system thus also serves as a vital hub for this crucial information, and can generate valuable managerial reports to facilitate decision making.

As change is the only constant in today's environment, the approach presented herein, combining the SCRMP with FMEA, should be continuously reviewed and updated. The approach described is therefore not a linear process with a beginning and an end, but rather a continuous cycle, characterized by constant and continuous improvement. It is also important that the risk monitoring and control step in the overall process must be seen as a means to determine possible preventive measures and to provide guidelines for further improvement, as part of FMEA, rather than to search for a scapegoat.

CONCLUSION

This article chronicled the approach Michigan Ladder Company was taking to assess the vulnerability of different supply chain designs and their associated supply-side risks. Pursuing the overall objectives of cost reduction and responsiveness, two supply chain design choices were considered. Inherent to both supply chain designs were important risks, which were however too complex to be evaluated just by mere contemplation. Therefore, to facilitate the management, a structured approach was employed, integrating and combining the strengths of the SCRMP with FMEA. With this process, all possible risks involved with each alternative were identified and evaluated, in an attempt to facilitate the decision on the least risky supply chain design, also considering associated costs to mitigate such risks. The overall aim of the integrated approach was to gather as much pertinent information as possible, to structure it, and to comprehensively delineate all potential supply chain risk factors, in order to provide decision support. This paper presented this novel approach, and illustrated its application at Michigan Ladder Company. Supply chain risk management does not have to be rocket science, and is not reserved for larger companies. We have provided a template, illustration, and motivation for other firms to apply this approach to better manage their supply chain risks.

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APPENDIX A. FMEA FRAMEWORK CHINA-MIDWEST SUPPLY CHAIN

Risk Factor Code	Risk Factor	Potential Failure Mode	Potential Causes of Failure	Potential Effects or Consequences of Failure	Preventive Action	Cost of Preventative Action
ACR	ANSI Compliance	Frequent non-conformance to specifications	Supplier not following the ANSI guidelines	▪ Product related accidents ▪ Can't sell products ▪ Loss of image / reputation	▪ Contact supplier and inform them of the criticality of ANSI compliance ▪ Replace defective ladders for customers ▪ Communicate with customers pertaining to the actions taken ▪ Possible visit to supplier for corrective actions ▪ Seek alternate sources ▪ Diversify supply base	$75,000
PQR	Product Quality	Frequent shipments of defective products	Breakdown in the supplier's process leading to defective/ damaged products	▪ Product related accidents ▪ Can't sell products ▪ Loss of image	▪ Contact supplier and inform them of the criticality of product quality ▪ Replace defective ladders for customers ▪ Communicate with customers pertaining to the actions take ▪ Inspection and testing ▪ Possible visit to supplier ▪ Seek alternate sources ▪ Diversify supply base	$85,000

APPENDIX A. FMEA FRAMEWORK CHINA-MIDWEST SUPPLY CHAIN CONTINUED

Risk Factor Code	Risk Factor	Potential Failure Mode	Potential Causes of Failure	Potential Effects or Consequences of Failure	Preventive Action	Cost of Preventative Action
PCR	Product Cost	Product cost charged by the supplier is increasing	Supplier charges more for materials used in producing the product due to for example sub-optimal sourcing practices or inefficient operations management	▪ Price increases by the supplier	▪ Continue to work with the supplier and support them in improving processes pertaining to engineering and manufacturing; use of alternative second-tier suppliers/components/ materials without compromising on quality ▪ Possible visit to supplier	$25,000
CCR	Competitor Cost	Loss of customers and loss of business to competitor	Competitor has a lower price of the product than the buying customer's product, which leaves the firm at a disadvantage	▪ Lost sales ▪ Lost market share	▪ Continue to work with the suppliers to support their cost reduction efforts, e.g. with value engineering / value analysis ▪ Possible visit to supplier	$50,000

APPENDIX A. FMEA FRAMEWORK CHINA-MIDWEST SUPPLY CHAIN CONTINUED

Risk Factor Code	Risk Factor	Potential Failure Mode	Potential Causes of Failure	Potential Effects or Consequences of Failure	Preventive Action	Cost of Preventative Action
DMR	Demand Riskw	Too much or too little inventory	Longer lead times due to outsourcing to China, yielding greater difficulties in forecasting	▪ Higher inventory cost ▪ Lost business	▪ Improve forecasting ability with reduced forecast errors ▪ Revise forecasts based on POS data ▪ Examine the actual sales swings with forecasts	$50,000
SFR	Supplier Fulfillment Risk	Do not have what you need when you need it	Supplier is prone to perform less than optimal in adhering to quality, cost and delivery performance measures; this risk is amplified as more players become involved in the supply chain and as it becomes longer (since wider distances have to be covered and lead times are likely to increase)	▪ Lower safety stock levels ▪ Not enough quantity to support business ▪ Lost business	▪ Reexamine safety stock levels ▪ Work with suppliers to improve delivery time ▪ Expedite to secure products to serve important customers ▪ Possible visit to supplier ▪ Development of alternate/back-up sources	$60,000
LGR	Logistics Risk	Late shipments	Delays due to paperwork involved, scheduling routes, determining what to ship with what mode at what time, selection of ports and carriers, etc.	▪ Lower safety stock levels ▪ Lost sales ▪ Replacement cost of stocking products purchased from other suppliers	▪ Work with logistics personnel and suppliers to prevent late shipments	$60,000

APPENDIX A. FMEA FRAMEWORK CHINA-MIDWEST SUPPLY CHAIN CONTINUED

Risk Factor Code	Risk Factor	Potential Failure Mode	Potential Causes of Failure	Potential Effects or Consequences of Failure	Preventive Action	Cost of Preventative Action
TBR	On-Time and On-Budget Risk	Do not have what you need when you need it, and late shipments	Lack of manufacturing capability and transportation flexibility, negatively impacting the supplier to accommodate changes in production quantities, transportation modes and order quantities, expedited and rush orders, etc.; causing delays and higher costs in delivering the products to the end customer	▪ Lower safety stock levels ▪ Lost sales ▪ Higher cost by having to stock/purchase products from other suppliers as backup	▪ Work with logistics personnel and suppliers to prevent late shipments ▪ Help them improve their processes ▪ Communicate what dimensions are most important	$60,000
OFR	Order Fulfillment Risk	Discrepancies when shipments are received	Delays due to order processing, production scheduling and transportation errors, impacting the right quantity delivered	▪ Lower safety stocks ▪ Higher inventory costs ▪ Capital tied up due to the warehousing of products purchased from other suppliers	▪ Reexamine safety stocks ▪ Train/develop supplier	$25,000

APPENDIX A. FMEA FRAMEWORK CHINA-MIDWEST SUPPLY CHAIN CONTINUED

Risk Factor Code	Risk Factor	Potential Failure Mode	Potential Causes of Failure	Potential Effects or Consequences of Failure	Preventive Action	Cost of Preventative Action
WPR	Wrong Partner Risk	Repeatedly not delivering what we need and when we need it	Not following rigorous selection and evaluation criteria in selecting the most suitable supply and logistics partner	▪ Lost sales and market share ▪ Loss of image due to poor quality products	▪ Continue working with supplier to improve performance in the short-term ▪ Find a new supplier in the long-term ▪ Have multiple suppliers to diversify risk	$30,000
OSR	Overseas Risk	Difficulty in maintaining relationships	Failed understanding and tracking of current events and trends regarding cultural and political factors; distance and language barriers to manage effective relationships	▪ Continued loss of sales	▪ Work with supplier ▪ Change foreign country location ▪ Come back to the U.S.	$30,000
SUR	Supplier Risk	Supplier getting into financial problems	Supplier bankruptcy due to poor management	▪ Higher inventory costs ▪ Higher cost of purchasing products from other suppliers on short notice	▪ Monitor supplier's financial health ▪ Finding multiple suppliers for products (backup suppliers) ▪ Diversify supply base/seek alternate sources	$30,000
SSM	Supplier's Supplier Risk	Tier1 supplier having problems with Tier 2+ suppliers	Supplier not selecting and evaluating well their sources of supply to meet their production schedules, not getting quality materials, etc.	▪ Higher cost of purchasing products from other suppliers on short notice	▪ Continue working with the Tier 1 supplier to resolve problems ▪ Reach out to Tier 2+ suppliers to develop them	$10,000

APPENDIX A. FMEA FRAMEWORK CHINA-MIDWEST SUPPLY CHAIN CONTINUED

Risk Factor Code	Risk Factor	Potential Failure Mode	Potential Causes of Failure	Potential Effects or Consequences of Failure	Preventive Action	Cost of Preventative Action
EIR	Engineering and Innovation Risk	No engineering abilities to design and develop new products; leakage of confidential information	Not following a formal process of collaborative product and process development with the objective for continuous improvement with the help of suppliers	▪ No new or improved products	▪ Continue working with the supplier to improve design process ▪ Establishment and enforcement of non-disclosure and confidentiality agreements	$10,000
TPR	Transportation Risk	Delays in deliveries	Lack of an efficient infrastructure in the host country, port capacities, cranes and other material handling equipment, and qualified human resources available; also, lack of understanding of possible delays due to bad weather (storms), containers going overboard, truck accidents, and delays at ports (due to capacity, loading/unloading capabilities, and/or delays at customs)	▪ Impacted safety stocks	▪ Work with transportation provider to improve delivery performance	$10,000

APPENDIX A. FMEA FRAMEWORK CHINA-MIDWEST SUPPLY CHAIN CONTINUED

Risk Factor Code	Risk Factor	Potential Failure Mode	Potential Causes of Failure	Potential Effects or Consequences of Failure	Preventive Action	Cost of Preventative Action
SVR	Sovereign Risk	Inability to control/predict environment; hampering of smooth business operations	Giving up control when going overseas, including potential political instability, strikes, and stringent government regulations	▪ Higher duties ▪ Higher tariffs	▪ Plan to go to another country	$20,000
NTR	Natural Disasters/ Terrorism	Inability to receive products; delays; impact on quality	No contingency plans in place; lack of foresight	▪ Safety stock depletion ▪ Higher costs of purchasing products from other suppliers on short notice	▪ Purchase products form other suppliers to serve customers until the disaster is resolved ▪ Develop contingency plans and strategies up-front	$20,000

OPERATIONS MANAGEMENT SALARY REPORT

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ABSTRACT
APICS, in conjunction with the Cameron School of Business at the University of North Carolina Wilmington, is pleased to provide the results of the 2013 Operations Management Salary Report. The data are collected from a random sample of more than 30,000 operations management professionals worldwide. Twice annually, approximately 50 percent of the APICS membership and customer base receives a request to complete an online survey collecting data concerning current salary and compensation by job function and title. The survey can be accessed at: http://csbapp.uncw.edu/apics/.

Keywords: operations management, salary

Salary/Compensation:
The results of the 2013 salary and employment survey continue to be optimistic for salaries in the operations management profession. The salary component of the survey tracks compensation in over thirty different job titles in the operations management field. Respondents were asked to report not only current salary but also any other cash compensation received. For reporting purposes, respondents were grouped into five recognized categories (execution and control of operations, purchasing/CRM, quality, resource planning, and supply chain management) rather than by individual job titles to illustrate the variability of income between job categories.

Table 1 shows salary and other compensation by job category. Table 1 reports that the average annual compensation across all operations management job categories was $97,398. Average compensation ranged from a high of $110,405 for the "other" category, with the execution and control of operations and the supply chain job classification next with combined salaries of $101,367 and $100,962 respectively, to a low of $69,792 for the resource planning job classification. The resource planning job classification continues to report the lowest or second lowest total compensation in all year-end reporting periods. (The salary data for the quality job description is based on fewer than 25 responses and therefore not significant).

TABLE 1: Average Compensation by Job Category (in USD)

Job Category	Average Salary	Average Bonus	Average Total Compensation
Execution and Control of Operations	$88,983	$7,553	$96,536
Purchasing/CRM	$71,497	$9,032	$80,528
Quality*	$106,500	$1,500	$108,000
Resource Planning	$69,142	$4,405	$73,547
Supply Chain	$91,272	$13,242	$104,514
Other	$90,582	$16,488	$107,070
Overall Weighted Average*	**$87,811**	**$11,874**	**$99,685**

* Fewer than 25 responses for this category

**Average salary across all respondents (salaries weighted by number of respondents in each job category)

To support the usefulness of the data, survey respondents were also asked to provide demographic information including age, gender, education, years of industry experience, certifications achieved, geographic location and industry. The results in Tables 2 to 6 illustrate how compensation averages vary across the above factors.

General Observations

Table 2 shows how average compensation levels varied across the seven geographic areas of North America (illustrated in Figure 2) and Canada.

TABLE 2: Average Total Compensation by Geographic Area

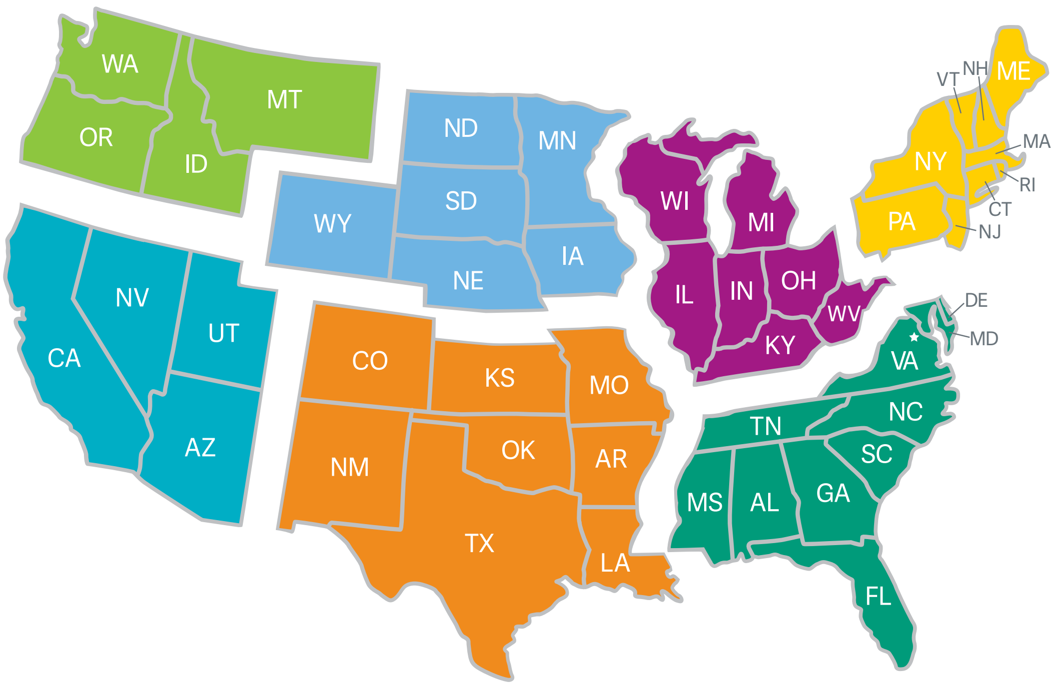
Geographic Area	Gender		Average*
	Female	Male	
Northwest**	$71,256	$103,617	$92,830
Southwest	$85,195	$124,628	$113,446
North Central	$77,561	$96,098	$87,447
Midwest	$91,768	$106,630	$102,150
South Central	$86,902	$115,581	$106,902
Northeast	$97,695	$112,386	$106,472
Southeast	$87,065	$110,504	$103,066
Canada**	$67,231	$85,080	$79,555

*Average weighted by number of respondents in each category

**Fewer than 25 responses for this category

Note: No valid data from Alaska or Hawaii; Canadian salaries have been adjusted for currency differences

FIGURE 2: Geographic Regions in the United States



On average, practitioners in the Southwest, South Central and Northeast earned more than those in any of the other geographic regions in North America ($113,446, $106,902 and $106,472), while operations professionals in the North Central U.S. once again earned the least ($87,447). It is promising to note that all salaries have been steadily rising over the course of this project. Canadian salaries continue to lag average U.S. salaries.

It is not surprising that the data shown in Table 2 suggests that gender plays a role in total compensation. There have been numerous research studies looking at gender bias in salary compensation. Our results indicate that gender bias may also exist for operations management professionals. Since the inception of this study regional salaries have fluctuated, but men's salaries have consistently outpaced women's salaries in all regions. In the current report, the most striking disparities can be found in the Southwest, Northwest and South Central, where women earn 31.6%, 31.2% and 24.8% less than their male counterparts on average. Canada shows gender bias as well, with females earning on average 21% less than their male counterparts. Once again, this male female salary disparity has been consistent across all data collection periods.

To gain further insight into possible gender bias, Table 3 and Figure 3 show average total compensation by job category and gender. Across all respondents, the average total compensation for females is $85,844 compared to $105,569 for males. The gender gap in compensation is most pronounced in the purchasing/CRM area, with males making approximately 40% more than their female counterparts, with the Resource Planning area also showing a great dispersion with males making on average 31% more than females in the same job classification. For all job areas, compensation for males is approximately 23% higher than that of females in equivalent job categories.

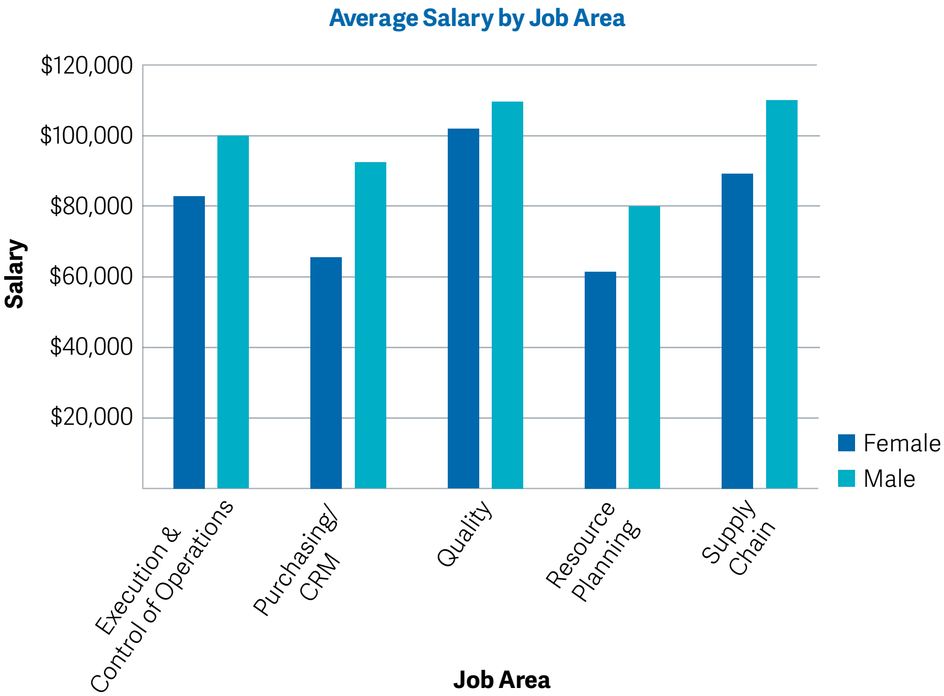
TABLE 3: Average Total Compensation by Job Category and Gender

Job Category	Gender		Average*
	Female	Male	
Execution & Control of Operations	$82,959	$100,270	$96,536
Purchasing/CRM	$65,324	$91,283	$80,528
Quality**	$102,000	$110,000	$108,000
Resource Planning	$61,761	$80,722	$73,547
Supply Chain	$89,740	$110,342	$104,514
Other	$103,689	$108,819	$107,070
***Overall Weighted Average**	**$85,844**	**$105,569**	**$99,685**

*Average salary across all respondents (salaries weighted by number of respondents in each job category)

** Fewer than 25 responses for this category

FIGURE 3



Note: Average salary includes base salary and bonus compensation

Considering age in combination with gender makes salary discrepancies even more pronounced. As industry strives to reduce gender bias in salary compensation, it is promising to note that pay scales are more consistent for younger employees. Table 4 and Figure 4 indicate that the difference in compensation between genders tends to narrow with younger hires. In fact, for all employees under 31 years of age, compensation disparities are less than the overall average shown in Table 3, with women's salaries higher (12.3%) than men's salaries in the under–25 age range, and within 5% in the 26 to 30 age range. This may suggest new policies are being put in place at companies to correct for compensation discrepancy by gender. Again, this is consistent with prior reporting periods.

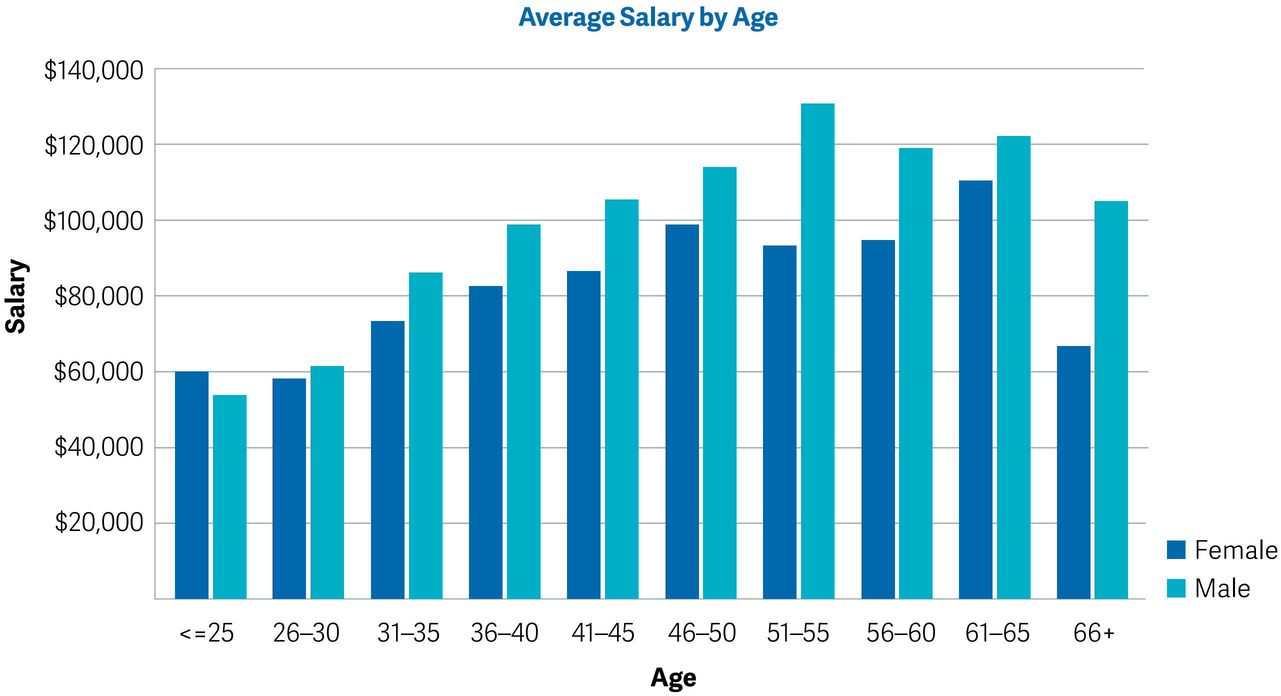
TABLE 4: Average Total Compensation by Age and Gender

Age Range	Gender		Average*
	Female	Male	
<=25	$59,051	$52,600	$54,751
26–30	$57,347	$60,417	$59,301
31–35	$72,353	$84,949	$80,517
36–40	$81,533	$99,497	$96,036
41–45	$85,220	$103,944	$96,811
46–50	$99,537	$112,200	$108,391
51–55	$91,564	$128,867	$118,505
56–60	$93,357	$117,042	$110,134
61–65	$108,883	$120,065	$116,819
66+**	$65,587	$103,443	$98,711

*Average weighted by number of respondents in each category
**Fewer than 25 responses for this category

Including "years in industry" along with gender (table 5, figure 5) supports the compensation gap shown in tables 3 and 4. For all age ranges, female salaries are approximately 22 percent less than males.

FIGURE 4



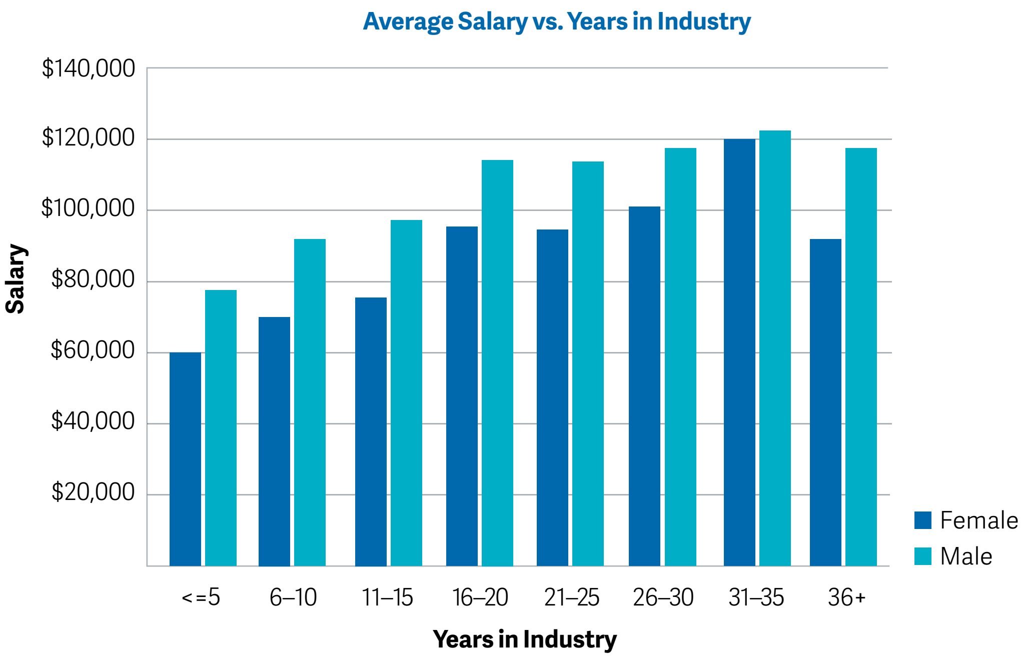
Note: Average salary includes base salary and bonus compensation

TABLE 5: Average Total Compensation by Years in Industry and Gender

Years Range	Gender		Average*
	Female	Male	
<=5	$60,842	$75,290	$70,425
6–10	$69,717	$91,393	$84,042
11–15	$76,311	$99,652	$93,068
16–20	$97,211	$116,199	$110,502
21–25	$96,557	$115,410	$109,865
26–30	$100,019	$119,824	$115,203
31–35	$120,459	$125,718	$123,857
36+	$96,833	$119,074	$115,149

*Average weighted by number of respondents in each category

FIGURE 5



Note: Average salary includes base salary and bonus compensation

EDUCATION PAYS

According the data, employees who have completed a bachelor's degree can expect approximately eighteen percent more in total compensation over a comparable employee with a high school degree. Dedication to an advanced specialized master's degree will command approximately 18 percent more than a bachelor's degree and thirty-nine percent more than a high school diploma. Individuals completing a master's of business administration (MBA) degree can expect approximately thirteen percent higher compensation than those with a specialized master's degree and approximately 57 percent more than those with only a high school diploma. When adding in the variable of gender with education, the gap becomes widest at the bachelor's and specialized master's levels. For those employees with a bachelor's degree, males are earning approximately forty-one percent more than females, and with a specialized master's degree a thirty-five percent increase.

The compensation gap between male and female employees begins to narrow slightly with an MBA degree. From table 3 we saw that overall, males were earning approximately 31 percent more than females for all job classifications. Table 6 and figure 6 show that this gap narrows to approximately 9.5% with an MBA degree. It is extremely encouraging to note that as we have seen in previous surveys, the number of survey respondents who have obtained APICS industry certification continues to increase. Approximately 50% of survey respondents hold a CPIM (Certified in Production and Inventory Management) designation and approximately 25% currently hold a CSCP (Certified Supply Chain

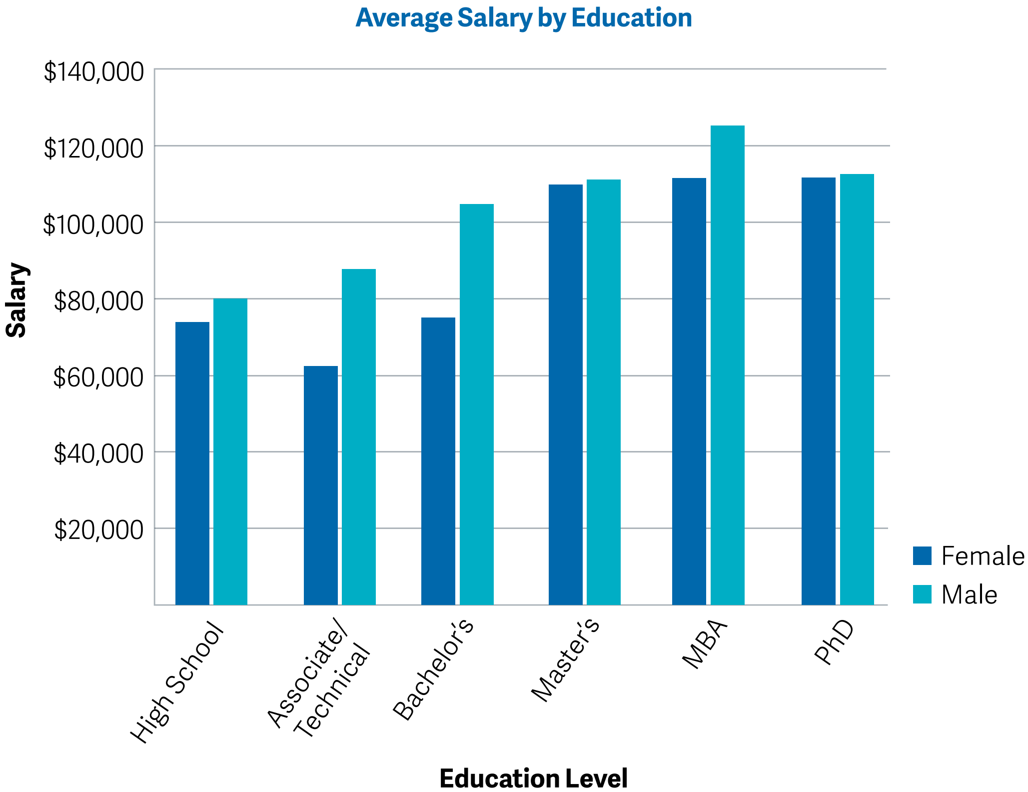
TABLE 6: Average Total Compensation by Education and Gender

Education Level	Gender		Average*
	Female	Male	
High School	$73,539	$80,572	$77,999
Associate/Technical	$65,146	$86,216	$78,617
Bachelor's or 4-year university degree	$76,513	$102,629	$94,693
Master's	$111,132	$111,292	$111,248
MBA	$113,392	$125,090	$122,360
PhD**	$114,131	$116,435	$115,612

*Average weighted by number of respondents in each category

** Fewer than 25 responses for this category

FIGURE 6



Note: Average salary includes base salary and bonus compensation

Professional designation (Table 7). For employees holding these, not only do compensation levels move up significantly, (Figure 7), but the positive impact on hiring is extremely strong (Figure 8). Among the respondents in our most recent survey, individuals with the CPIM designation received approximately 8% higher compensation than those without the designation, and gained a 79% favorable impact on the hiring decision over those job candidates without the certification. Similarly, individuals with the CSCP designation received approximately 18% higher compensation than those without the CSCP certification, and a 77% favorable impact on the hiring decision over those without the certification.

TABLE 7

Certification	% of Respondents with Certification	Average % Increase in Compensation*
CSCP	25.2%	18%
CPIM	49.9%	8%

*Compared to respondents without the certification.

FIGURE 7

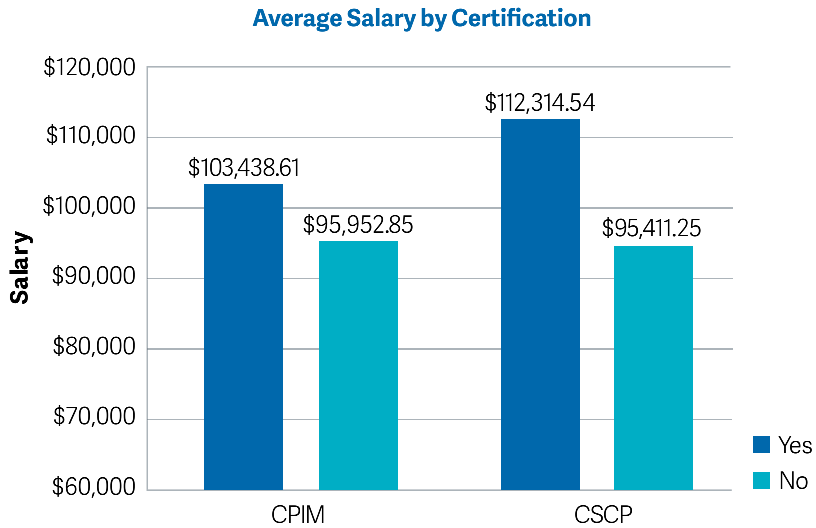
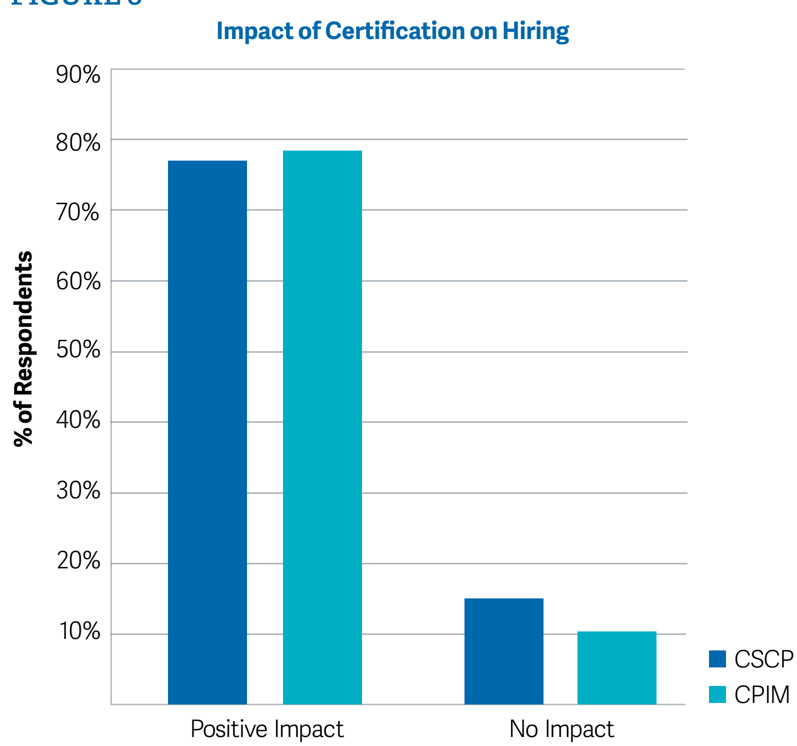


FIGURE 8



A TUTORIAL ON MANAGERIAL COST ACCOUNTING: YEAR-END REPORTING

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ABSTRACT

Building on the companion article "A Tutorial on Managerial Cost Accounting: Living with Variances" by Fry and Fiedler (2011), this current paper picks up where the previous paper left off and illustrates how the management accounting system (MCA) is linked to financial accounting (FA) to generate the year-end financial reports required by shareholders, banks, and the IRS. The prior paper focused on the detailed use of information provided by the MCA throughout the year and walked through the development of the yearly budget, calculation of product costs, determination of budget variances, derivation of the periodic income and statement of cash flows reports, and provides possible examples of dysfunctional behavior at a fictitious company called Mandrake Manufacturing. This tutorial concentrates on the interaction of the MCA and FA systems and the production of year end FA statements. In addition to providing information such as cost of goods sold, inventory values, and operating standards to the FA, the year end information provided by the MCA is also used to develop next year's budgets. In this present paper, the conversion of the MCA reports into the FA reports will be presented. Also, the impact of the MCA reports on future budgets will be discussed. As pointed out in F&F, it is vital that operations managers understand how the accounting systems used by their company function. Without such understanding, many of the problems associated with the improper use of the accounting systems will never be corrected.

INTRODUCTION

In any company, there are two distinct groups of stakeholders served by the company's accounting systems. Those stakeholders inside the company (the managers) are focused on managing while those stakeholders outside the company (investors, banks, and various governmental agencies) are concerned with assessing company performance. The managers need actionable information concerning the present and future while external users rely on the availability of standardized, accurate historical information. The informational needs of the two groups require different systems that can at times be at odds with each other. The internal managers are served by managerial accounting systems, and the external world views the company through financial accounting systems.

For most companies the managerial cost accounting (MCA) system is an important component of internal reporting and can act as a bridge between the two systems. The MCA calculates product costs, sets budgets based on future projections, and provides current reports in the form of budget variances between actual and projected performance. Further, the MCA provides information on product costs and inventory values that are used by the financial accounting (FA) system. FA is required for external reporting purposes. The major reports of the FA system are the balance sheet, the income statement, statement of changes in equity, and the statement of cash flows, which are in turn required by stockholders, banks, government agencies, and suppliers. Whereas FA practices are strictly regulated by rules established by systems such as generally accepted accounting principles (GAAP) or the international financial reporting systems (IFRP), the management accounting system has more flexibility in determining the rules it follows. The practices used by managerial accounting must simply "be reasonable." However, in companies that use the traditional MCA, the format of the weekly or monthly income statement closely mirrors that of the FA income statement.

While several authors have criticized the use of a FA-based income statement for internal use because of the potential for distortion (Hauser and Katz, 1998; Huntzinger, 2007; Johnson and Kaplan, 1987; Kaplan and Atkinson, 1998), companies that use traditional MCA by and large rely on this income statement to assess periodic operating performance (Fry and Steele, 1995; Bonsack, 1989; Taninecz, 2002).

The ability of MCA to link to the required FA system is one reason why MCA is a component of most managerial accounting systems (Hilton, 2009; Johnson and Kaplan, 1987). The inescapable fact that MCA is both widely used and can lead to operational inefficiencies and managerial distortions makes it vital that operational managers have an understanding of this critical accounting system.

This paper presents a tutorial that illustrates how the MCA is linked to financial accounting to generate the year-end financial reports for external agents such as shareholders, banks, and the IRS.

This tutorial builds on the companion article "A Tutorial on Managerial Cost Accounting: Living with Variances" by Fry and Fiedler (2011). While this present paper concentrates on the interaction of the MCA and FA systems as well as the production of year-end statements and next year projections, the earlier paper focused on the detailed use of information provided by the MCA throughout the year.

Fry and Fiedler (2011) walk through the development of the yearly budget, calculation of product costs, determination of budget variances, derivation of the periodic income and statement of cash flows reports, and examples of dysfunctional behavior at a fictitious company called Mandrake Manufacturing. The reader is encouraged to review Fry and Fiedler (2011) (hereafter referred to as F&F) to gain further insight into the processes involved in the use of MCA that lead to this tutorial.

In addition to providing information such as cost of goods sold, inventory values, and operating standards to the FA, the year-end information provided by the MCA is also used to develop next year's budget. In this paper, the conversion of the MCA reports into the FA reports will be presented. Also, the impact of the MCA reports on future budgets will be discussed. As pointed out in F&F, it is vital that operations managers understand how the accounting systems used by their company function. Without such understanding, many of the problems associated with the improper use of the accounting systems will never be corrected.

The Mandrake Manufacturing Example

Mandrake is a manufacturer. Each of their products is classified into one of four product families: broaches, files, inserts, and end mills. Based on forecasted weekly demand of 100 units for each product family, the capacity of 5,200 units a year in each of the 5 departments at Mandrake is expected to be 100 percent utilized.[i] Given the similarity of products within each product family, the estimated or budgeted cost to manufacture a tool within any of the product families is the same. As such, the estimated costs to produce a broach, file, insert, or end mill are $69.79, $42.04, $33.00, and $40.17 respectively. The cost calculations are presented in table 1.[ii]

TABLE 1: Calculation of Product Cost at Mandrake Manufacturing

Products	Direct Labor		Direct Materials		Overhead		Product Cost
Broaches	$14.33	+	$9.90	+	$46.46	=	$69.79
Files	$9.67	+	$4.00	+	$28.38	=	$42.04
Inserts	$8.00	+	$7.00	+	$18.00	=	$33.00
End Mills	$8.00	+	$4.00	+	$28.17	=	$40.17

During the year for any given week, total demand may not have been met due to a lack of capacity in one or more departments. This resulted in idle labor in other departments during that week.[iii] Each worker is paid for forty hours of work, so if a worker is idle, the MCA would record a negative labor variance. If the labor was fully utilized by producing unneeded inventory, no labor variance would be recorded by the MCA even if the inventory had no resale value. Now that the year has ended, Mandrake must prepare required financial reports using the data supplied by the MCA. For purposes of this paper, we will focus primarily on the income statement and the statement of cash flows.

Year End Reporting

If Mandrake produced only those units it could sell (scenario 1), it would have realized an identical net income and cash flow of $66,765.[iv] If Mandrake had chosen to minimize variances, thereby increasing inventories (scenario 2), the year-end net income would have been $96,231 with a cash flow of $54,909.[v] We present the year-end income and cash flow statement as determined by the MCA for both scenarios in table 2 below.

TABLE 2: Year Income Statement and Statement of Cash Flows

	Scenario 1 No Inventory	Scenario 2 With Inventory
Revenue	$1,023,877	$1,023,877
Cost of Goods Sold (Based on Standard costing)	$927,646	$927,646
Gross Profit	$96,231	$96,231
(+/-) Operating Variance Controllable	$0	$0
Direct Labor	-$7,269	$0
Overhead	-$22,170	$0
Net Profit	$66,765	$96,231

Statement of Cash Flows

	No Inventory	With Inventory
Revenue	$1,023,877	$1,023,877
Fix Costs (less)	$629,200	$629,200
Control	$0	$0
Labor Costs (less)	$208,000	$208,000

The income statements and cash flows statements that are shown in table 2 are in a format determined by the MCA and include yearly totals for the various operating budgets. In the Mandrake example, the two variances of note are direct labor and overhead absorption. For external reporting purposes, these two statements must be converted to a format consistent with FA.

Whereas the cost of goods sold (CGS) as presented in the MCA is based on the budgeted or standard cost of each product, the CGS for FA must be re-calculated based on actual operating costs. This difference is a byproduct of the different objectives of the MCA and FA systems. The MCA's CGS at standard is based on budgeted standard costs and is used for managerial evaluation through the calculation of operating variances. The CGS for FA is determined from the actual cost after they occur and are used for company evaluation. In other words, all budget variances must be zeroed out and rolled into CGS (scenario 1). Also, costs associated with any changes in inventory must be added to or subtracted from the CGS. This adjustment for changes in inventory is due to the well-established matching principle whereby costs and revenue must be matched together.

Since in scenario 2 Mandrake increased its inventory over the past year, all costs required to build that inventory must be subtracted from the calculation of CCS, since the inventory has not been sold and has generated no revenue. This is the basis of accrual based accounting, i.e. the matching principle, on which both the MCA and FA systems are based. The value of the inventory, $41,323, is simply the sum of the direct labor variances, overhead absorption variances, and any materials purchased but not sold ($7,296 + $22,170 + $11,857).

In table 3 below, we present the income statement and statement of cash flows in a format consistent with FA. To make the conversion from the MCA to FA, we must calculate a cost of goods manufactured (CGM), which represents the total manufacturing costs for a certain time period, in this case one year. CGM is used to calculate the cost of goods sold on the FA income statement.

In scenario 1, Mandrake produces no excess inventory. In scenario 2, Mandrake uses the "produce units" mentality to minimize variances, thereby producing excess inventory.

As shown in scenario 1, the year's accumulated variances are accounted for in the calculation of cost of goods manufactured by totaling up all manufacturing costs incurred for last year. Basically this increases the CGS at standard of $927,646 reported by the MCA by $29,466, which is the direct labor variance of $7,296, plus the overhead absorption variance of $22,170. This result is the cost of goods manufactured of $957,112, which is shown on the income statement reported by FA.

The beginning inventory of zero is added to the CGM while the ending inventory of zero is subtracted. The result is the CGS reported on the FA income statement. Simply stated, due to the "operating inefficiencies" as measured by the budget variances, Mandrake's cost to produce the products available for sale was greater than expected. And since no inventory was built, the increased costs must be captured in the CGS. In other words, the costs due to the budget variances must be treated as a period expense. The CGS is then subtracted from the revenue of $1,023,877 to result in a year ending net income of $66,765.

In scenario 2, Mandrake operated at "100 percent efficiency," defined as no unfavorable budget variances. This of course was due to Mandrake's decision to build inventory according to the "produce units" mentality. However, since the inventory was not sold, all the costs necessary to build those units will be reported when and if the inventory is sold, thereby matching costs and revenues. At year end, Mandrake has built $41,323 in inventory.

The value of the inventory, $41,323, is simply the sum of the budget variances ($7,296 + $22,170), plus the extra materials that had to be purchased to keep all departments busy ($11,857). To calculate the CGS, the beginning inventory of zero is added to the CGM while the ending inventory of 41,323 is subtracted. The result is $927,646, which is the CGS reported on the income statement reported by FA.

In effect, increasing inventory allowed Mandrake to increase "operating efficiencies" reported by the MCA while reducing the CGS reported by the FA at year end. The reduction in CGS resulted in a higher net income of $96,231. In reality, the budget variances and the extra cost for materials are stored in inventory and are deferred until which time as the inventory is sold. In other words, in scenario 1 there was no inventory to defer the variances, so they had to be treated as a period expense, effectively decreasing net income. In scenario 2, the variances are attached to the increased inventory, thus are deferred to a later period, effectively increasing net income.

TABLE 3: Year End Income Statement With Cost of Goods Calculation

	Scenario 1 No Inventory			Scenario 2 With Inventory		
Revenue			$1,023,877			$1,023,877
Total Labor Cost	$208,000			$208,000		
Total Overhead Cost	$629,200			$629,200		
Total Material Cost	$119,912			$131,769		
Cost of Goods Manufactured		$957,112			$968,969	
Add Beginning Inventory		0			0	
Subtract Ending Inventory		0			-$41,323	
Total Cost of Goods Sold			$957,112			$927,646
Net Income			$66,765			$96,231

Statement of Cash Flows

	Scenario 1 No Inventory	Scenario 2 With Inventory
Revenue	$1,023,877	$1,023,877
Fix Costs (less)	$629,200	$629,200
Control	$0	$0
Labor Costs (less)	$208,000	$208,000
Material Purchases (less)	$119,911	$131,768
Resulting Cash	$66,765	$54,909

Also presented in table 3 is the statement of cash flows. Since there was no change in inventory for scenario 1, the ending cash of $66,768 is equal to operating income. In scenario 2, the ending cash of $54,909 is less than the net income of $96,231. This is due of course to the extra materials that were purchased to build the inventory and the deferment of the budget variances until a later time period.

Comparing the two scenarios, we see that if inventory is increased, net income is 44 percent greater than when no inventory is built ($96,231 compared to $66,768). Ending cash, on the other hand, is 22 percent less than when no inventory is built ($54,909 compared to $66,765). Of course, the operating strategy employed by Mandrake managers would be a function of the importance the company placed on minimizing variances for "operational efficiency" and the desire to report year-end profitability versus the desire for lower inventories and cash flow.

Last Year's Performance And Next Year's Budget

The impact of last year's performance on next year's budget will depend on whether or not Mandrake managers follow a no-inventory policy or follow the "produce units" mentality. As such, we will discuss each scenario and its impact on the following year.

Scenario 1: No Inventory Policy

By not building inventory, Mandrake incurred losses totaling $29,466 due to inefficient operation, identified by the MCA as budget variances in labor and overhead allocation. The implication for management is that due to the inefficient use of direct labor, the actual labor rates and hence overhead absorption rates were higher than budgeted. For next year, assuming the exact same demand is forecast, the cost to manufacture the four products will need to be recalculated. In table 4, we show how this calculation is done.
First, the utilization of each department is calculated by dividing the labor hours utilized (row 1) by the labor hours available (row 2). This results in the labor utilization for each department (row 3). Mandrake pays each worker $41,600 per year ($20/hour x 2,080 hours). Because of demand fluctuation, the worker in lathe is only productive 94.73 percent of the time he/she is at work. So for the 2,080 hours that worker is at work, he/she is busy only 1,970.37 hours. Thus the lathe worker is being paid $21.11 ($41,600/1,970.37 hours) per hour he/she is productive. We define this as the effective labor rate. We show this rate for each department in row 5.

TABLE 4: Analysis of Capacity Usage

		Lathe	Drilling	Milling	Polishing	Heat Treatment
1	Total Labor Hours Utilized	1,970.37	1,970.15	2,028.00	2,038.83	2,028.00
2	Total Available Labor Hours	2,080	2,080	2,080	2,080	2,080
3	Utilization Percentage	94.73%	94.72%	97.50%	98.02%	97.50%
4	Hourly Labor Rate	$20.00	$20.00	$20.00	$20.00	$20.00
5	Effective Labor Rate	$21.11	$21.12	$20.51	$20.40	$20.51
6	Dept Overhead	$130,000	$130,000	$67,600	$150,800	$150,800
7	Dept Overhead Rate/Hour	$62.50	$62.50	$32.50	$72.50	$72.50
8	Effective Overhead Absorption Rate/Hour	$65.98	$65.98	$33.33	$73.96	$74.36

The overhead absorption rate for each department must also be recalculated due to the difference in effective labor utilization. Again using table 4, we divide the yearly department burden rate (row 6) by the actual hours each department is expected to be utilized (row 1). For the lathe department, we divide the yearly overhead burden of $130,000 by the expected hours that department is to be utilized (1,970.37). This results in an effective overhead absorption rate of $65.98 per labor hour. In row 8, the effective overhead absorption rate for each of the 5 departments is shown.

Based on the new labor and overhead absorption rates, Mandrake must now re-calculate product costs. The new product cost calculations are shown in table 5 comparing the old product cost calculations with the newly calculated costs. The operating inefficiencies, as captured by the budget variances, have resulted in an increase for each of the four product costs.

It is likely that an increase in product costs would not be viewed favorably by senior managers at Mandrake. To maintain expected product margins, selling price would have to be increased. From a marketing perspective, this could easily result in a lower market share, further reducing profitability. At this point, it is likely that the operations manager could receive mixed signals regarding the priority of maintaining low inventories and/or overall profitability. If indeed senior managers stress profitability and low product costs, the operations manager would be encouraged to adopt the "produce units" approach during the upcoming year.

TABLE 5: Updated Calculation of Product Cost at Mandrake Manufacturing

Product	Original Direct Labor	Effective Direct Labor	Direct Materials	Original Overhead	Effective Overhead	Original Product Cost	Effective Product Cost
Broaches	$14.33	$15.03	$9.00	$46.46	$48.68	$69.79	$72.71
Files	$9.67	$9.91	$4.00	$28.38	$29.07	$42.04	$42.98
Inserts	$8.00	$8.31	$7.00	$18.00	$18.78	$33.00	$34.08
End Mills	$8.00	$8.22	$4.00	$28.17	$28.92	$40.17	$41.14

Scenario 2: Produce Units Mentality

If Mandrake used inventories to eliminate budget variances ¬ scenario 2 overall net income would have been greater than scenario 1 when no inventory was built $96,231 compared to $66,768. Both scenarios resulted in a positive cash flow with scenario 1 having a cash flow of $66,765 while scenario 2 had a cash flow of $54,909. However, in scenario 2 there were no operating inefficiencies as measured by the zero budget variances. Thus the cost to make each product for all intents and purposes met the expected budgeted amounts. There is then no need to re-calculate product costs and the budgeted amounts for the upcoming year would match those of the past year. In addition, the assets reflected on the balance sheet would be increased by the value of the inventory, $41,323. From an operations manager's perspective, operating efficiencies were equal to those budgeted, total costs met budget, the cost to produce each product met budget, and likely all financial objectives were met, perhaps resulting in a hefty year-end bonus.

INVENTORY WRITEOFF

If managers at Mandrake had put greater emphasis on profitability than on maintaining low inventories, the result would be the $41,323 increase in inventory that would have been accounted for, as discussed above. However, if it was determined, due to market changes, that the inventory was of little or no value, management would have to make the decision if and when to write off the inventory and recognize the loss.

Managers often prefer to accumulate such inventories and then take a portion, or even all, of the loss during either exceptionally good or bad financial times. In good times, relatively small write offs can go unnoticed and act to smooth out performance and projections. In financial downturns, there is a technique termed "big bath" where firms recognize the writeoff of accumulated bad assets. This can wash the financial statements when it can be blamed on external factors like the economy or the weather (Sherman, Young, and Collingwood, 2003). If Mandrake management recognizes that the inventory has no value, they may choose to write it off on the year-end FA income statement.

In table 6 below, we show the FA income statement assuming that management decided to write off the obsolete inventory at year end. Of course, should management decide not to write off the inventory, the net income will not be affected and the assets of the company as reflected on the balance sheet would not change.

As clearly seen, the inventory writeoff reduces net income by the amount of obsolete inventory, from $96,231 to $54,909. Cash flow would remain unaffected. In this simple example, production of valueless inventory wasted $11,856 in extra materials, thereby immediately decreasing cash flow. However, the impact on profitability of building inventory is delayed until such time as the inventory is written off. And since the inventory was accumulated over several previous months, it is likely that the evaluation of the manager who decided to build the inventory would never be impacted. Indeed, without a complete understanding of how the MCA and FA systems interact, it is likely that management would be unable to link the excess inventory to the desire of the operations manager to minimize budget variances. Given this, it is understandable that managers may be encouraged to follow a strategy not consistent with longterm company success.

TABLE 6: Income Statement with Inventory Write-off

Revenue		$1,023,877
Beginning Inventory	0	
Cost of Goods Manufactured	$957,112	
Ending Inventory	-$41,322	
Total Cost of Goods Sold		-$927,646
Net Income		$96,231
Adjustments		
Inventory Write-off	$41,322	
Total Adjustments		-$41,322
Adjusted Net Income		$54,909

The major implication for accumulating inventory and then deciding to write it off is that it hides the reason the inventory was accumulated in the first place. Remember, inventory was accumulated due to the "produce units" mentality by managers in an effort to minimize budget variances. Simply stated, variances are hidden in the accumulated inventory. If companies are willing to accumulate inventory until such time as it is less harmful to financial statements to take the writeoff, several years of inventory could easily accumulate. And even if a company is willing to write off inventory at the end of each year, it is probable that the reason for the inventory would never be discovered. In this case, managers would continue to operate using the "produce units" mentality, thus using inventory to absorb budget variances. Since there are no unfavorable budget variances, the budget, from the managers' perspective, was met. There is then no need to re-calculate product costs which could lead to a selling price increase.

TABLE 7: Calculation of Product Contribution Margin at Mandrake Manufacturing

Product	Original Product Cost	Effective Product Cost	Selling Price	Contribution Margin	Effective Contribution Margin
Broaches	$69.79	$72.71	$75.00	$5.21	$2.29
Files	$42.04	$42.98	$50.00	$7.96	$7.02
Inserts	$33.00	$34.08	$35.00	$2.00	$0.92
End Mills	$40.17	$41.14	$44.00	$3.83	$2.86

DISCUSSION

Mandrake could decide to operate following any of the two scenarios above. If managers chose to follow the no inventory policy, the resulting profit and cash flows would have been $66,765. During the budgeting process for the upcoming year, product costs would have increased due to the unfavorable budget variances realized. In order to maintain product profit margins, selling price for each product would have likely been increased as well. From a senior manager's perspective, the operations managers at Mandrake did not perform well against their performance objectives.

If Mandrake managers chose to follow the "produce units" mentality, the resulting income would have been $96,231 with a cash flow of $54,909. Since there were no unfavorable budget variances, product costs would have remained unchanged for the next year. And since the performance objectives set by the MCA budget were met, the performance appraisal of the operations manager would have been positive.

At year end, senior managers at Mandrake would have to decide when to take the loss due to the writeoff of obsolete inventory. If managers were responsible and decided to immediately recognize the loss due to the inventory, the net income would have been adjusted downward by $41,323 from $96,231 to $54,909. Cash flow would remain unchanged at $54,909. Of course, should management decide to delay the inventory write off, the losses would not show up until much later. And if we assume that the company adopts a strategy to write off any inventory that is older than say two years, a common practice, Mandrake would have two years of accumulated inventory valued at $82,646 on the balance sheet. Operation managers could continue to follow the "produce units" mentality in perpetuity, realizing a yearly income of $54,909 and a cash flow of $54,909, both of which are less than the no inventory policy.

In this case, it is unlikely that senior managers would be able to directly link the inventory accumulation to the "produce units" mentality used on the factory floor.

CONCLUSION

In this paper, we continue with a tutorial on how the MCA interfaces with the operations management function. We show how the year-end MCA reports are converted into the FA reports required by every company. If not carefully applied, MCA has the potential to encourage dysfunctional behavior, such as producing unneeded inventory. As noted, this gives the operational manager not only the opportunity to avoid unfavorable variances but also to show lower product costs and higher FA profits. Eventually, FA standards will force the write off of the worthless inventory, but this may never be fully traced back to the MCA and the decisions made by the operations manager to build the inventory in the first place. In effect, the manager could continue to build inventory to hide budget variances in perpetuity. This has serious implications for distorting managerial evaluations by rewarding managers that build inventory while penalizing responsible managers that follow the no-inventory policy due to unfavorable budget variances.

These practices also have the potential to distort product costs and thus profitability. When operations are pressured by demand that exceeds production capabilities, the manager would naturally produce those products that had the highest profit margin. As noted in table 7, broaches originally had a higher gross margin than end mills ($5.21 vs. $3.83).

After the re-calculation of product costs due to the unfavorable budget variances, end mills had a higher gross margin than did broaches ($2.86 vs. $2.29). By building inventory, thus hiding budget variances, Mandrake is able to keep budgeted product costs lower than if they decided to not build inventory. At this point, one might ask: what is the true product cost? Unfortunately, the answer depends on the production strategy used by the operations managers. The organization that produces excess inventory might never recognize the new cost allocations and would continue to operate with possibly erroneous product cost information.

It is conceivable from the above discussion that many companies could be operating at lower profits and cash flows than necessary without being aware that the inappropriate use of the MCA is the culprit. Evidence from the literature suggests that companies frequently report inventory writeoffs. Commonly, these writeoffs are blamed on poor forecasts. We suggest that many of these writeoffs may be due to a lack of management understanding of how the MCA interfaces with operations management and how the MCA is converted to the publically reported FA reports required by external stakeholders.

i. (Table 1 in F&F).

ii. We have re-created the cost calculations from F&F.

iii. The F&F tutorial showed that even though the actual total product demand at Mandrake was equal to the forecasted demand, a small variation in weekly demand introduced operational variances. While Mandrake had a perfect average budget for the year, i.e. demand for the year exactly matched forecasted demand, slight variations in weekly demand resulted in direct labor and overhead absorption budget variances (table 6 in F&F) and idle labor in other departments during that week (table 4 in F&F).

iv. Calculated by multiplying F&F table 6 by 13 to represent 52 weeks of operation.

v. Calculated by multiplying F&F table 7 by 13

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