Chapter 4
The Role of Execution in Managing Product Availability

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1 Introduction

Several surveys show that a significant number of customers leave retail stores because they cannot find the products for which they are looking (e.g. Emmelhainz et al. 1991; Andersen Consulting 1996; Gruen et al. 2002; Kurt Salmon Associates 2002). Most research in operations management focuses on two factors to explain suboptimal product availability—poor assortment and poor inventory planning. Our research with several retailers during the last few years highlights a third factor, poor execution, or the failure to carry-out an operational plan. We find that even with the application of algorithms to select the appropriate stocking quantity and appropriate store assortment, the right product may be still unavailable to retail customers. For example, after auditing 50 products at ten different stores, management at a specialty retailer found that only 16 % of the stockouts could be attributed to statistical stockouts (cited in Ton 2002). Instead, 24 % of the stockouts were due to inventory record inaccuracy, discrepancies between the recorded and actual on-hand inventory quantity, and 60 % were due to misplaced products, products that were physically present at the store but in locations where customers could not find them.

Inventory record inaccuracy and misplaced products are two examples of poor store execution. These problems affect product availability in two ways. First, they lead to stockouts and hence compromise retailers' service levels. When the actual level of inventory for a particular product is lower than the planned level due to either inventory record inaccuracy or product misplacement, the actual service level will be

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lower than the planned service level. At Borders Group Inc., a formerly large retailer of entertainment products such as books, CDs, and DVDs, lost sales due to misplaced products reduced profits by 25 % (Raman et al. 2001). Andersen Consulting (1996) estimates that sales lost due to products that are present in storage areas but not on the selling floor amount to $560–$960 million per year in the US supermarket industry.

Second, for retailers that rely on automated replenishment systems to manage store inventory, execution problems affect future product availability through the distortion of historical sales and inventory data stored in these systems. Distortion of inventory data may prevent the triggering of a replenishment order when the system inventory is greater than the actual inventory or may unnecessarily trigger an order when the system inventory is less than actual inventory. Moreover, when a product that is actually out of stock is reported as in stock, the automated replenishment system may wrongly conclude there is no demand. The system observes no sales for that item because it is not available to the customer. Thus, even when multiple customers are willing to purchase that item, the system may automatically reduce the forecast of future demand which in turn causes the retailer to stock less of it or even to drop the item from the assortment entirely.

Despite their prevalence and impact, research on execution problems is limited. Much of the work in the retailing context focuses on the drivers of these problems and only recently have researchers attempted to incorporate these problems into existing planning models. In this chapter we summarize the existing research on store execution and identify future research opportunities in this area. The chapter is organized as follows. In Sect. 2, we describe the magnitude and root causes of the two execution problems, based on specific well-researched case studies. In Sect. 3, we describe the findings of the empirical studies that have identified factors that exacerbate the occurrence of execution problems. In Sect. 4, we describe the effect of execution problems on inventory planning and summarize how researchers have incorporated these problems into existing inventory models. Finally, in Sect. 5, we conclude with a discussion of future research opportunities.

2 Retail Execution Problems

Evidence of execution problems exists in a number of different contexts. Distribution centers,[1] manufacturing firms,[2] financial services,[3] utility companies,[4] hospitals,[5] and government agencies[6] have all faced problems with misplaced products

[1] See, for example, Bayers (2002), Millet (1994) and Rout (1976).

[2] See, for example, Hart (1998), Sheppard and Brown (1993), Tallman (1976), Brooks and Wilson (1993), Bergman (1988), Krajewski et al., (1987) Flores and Whybark (1986; 1987), and Woolsey (1977).

[3] See, for example, Cassady and Mierzwinski (2004) and Capital Market Report (2000).

[4] See, for example, Woellert (2004) and Redman (1995).

[5] See, for example, McClain et al. (1992) and Young and Nie (1992).

[6] By the Numbers (2005), McCutcheon (1999), Galway and Hanks (1996), Laudon (1986), Schrady (1970) and Rinehart (1960).

and/or record inaccuracy. The costs pertaining to the inability to execute an operational plan in these contexts, as in retailing, have been shown to be substantial. We describe below the extent of such problems in retailing and identify how they arise.

2.1 Inventory Record Inaccuracy

At Gamma Corporation,[7] a leading retailer with hundreds of stores and over $10 billion in sales, physical audits revealed that inventory record inaccuracy was pervasive throughout the chain (DeHoratius and Raman 2008). Discrepancies were found in 65 % of the nearly 370,000 audited inventory records with the absolute difference between system and actual inventory quantity per item per store ranging from 0 to 6,988 units (Fig. 4.1). The average absolute discrepancy between system and actual inventory was nearly five units, or 36 % of the average target quantity. Of those records that were inaccurate, approximately 58 % of them had positive discrepancies where the recorded quantity exceeded the actual and nearly 42 % of them had negative discrepancies where the on-hand quantity

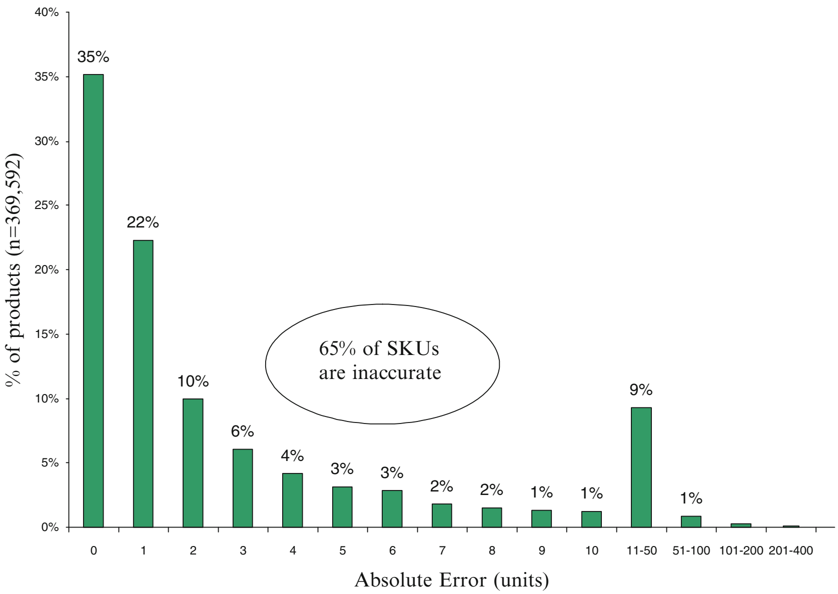

Fig. 4.1 Histogram of the absolute value difference between system and actual inventory measured in units (*Source*: Raman et al. 2001)

[7] Name disguised to preserve confidentiality.

exceeded the recorded quantity. Interestingly, nearly each product that was stocked out in the store at the time of the audit showed a positive on-hand amount recorded in the inventory management system. In other words, these stockouts were invisible to corporate merchandise and inventory planners.

2.2 Misplaced Products

Misplaced products, whether they are mis-shelved or left in storage areas, lead to stockouts if customers are unable to locate the inventory they seek. At Borders, two surveys showed that approximately 18 % of customers who approached a salesperson for help experienced a phantom stockout (Ton and Raman 2003). That is, the product was physically present at the store but could not be found even with the help of a salesperson. Physical audits at 242 Borders stores showed that, on average, 3.3 % of a store's assortment (over 6,000 products per store) was placed in storage areas and had no presence on the selling floor (Fig. 4.2). At some stores, nearly 10 % of the assortment was missing from the selling floor. Note that these estimates of misplaced products are conservative because they do not include those products that have been mis-shelved either by customers or employees.

2.3 Root Causes of Execution Problems

We identify three sources of poor execution: (1) poor process design, (2) an operating environment that makes it challenging for employees to conform to

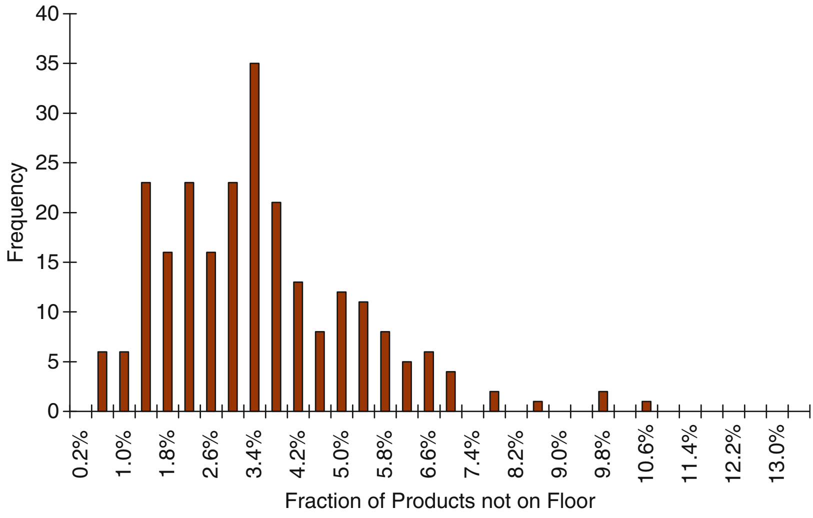

Fig. 4.2 Histogram for the fraction of products that are not available on the sales floor (*Source*: Raman et al. 2001)

prescribed processes, and (3) employee errors. Poor process design may result from, among others, poorly specified work content, poorly specified sequence of activities, inadequate time given to perform work, and an absence of feedback on process quality. At most retail chains for example, extra units of inventory that do not fit into display shelves are kept in storage locations. When the level of inventory of a particular product on the shelf approaches zero, employees are supposed to replenish units of that product from the storage locations. Since existing systems do not track the location of stored products, store employees have to rely on their memory to determine where products are stored in order to replenish the shelves. Not surprisingly, this poor process design often leads to product misplacement. Furthermore, at many retail chains, employees have to manually enter the price lookup (PLU) into the registers. This process requires employees to remember the PLU codes of hundreds of different products, making errors inevitable. Executives at one supermarket chain, for example, told us that, on average, they sold 25 % more "medium tomatoes" than the total amount shipped to their stores because store employees often entered the PLU code for "medium tomatoes" even when customers were buying other types of tomatoes, such as "organic tomatoes" or "vine ripe tomatoes". It is reasonable to expect inventory record inaccuracy to be more accurate at retail stores where electronic point-of-sale scanning is used.

Even when processes are well-designed, employees may deliberately choose not to follow them. In an operating environment where nonconformance to designed processes is not monitored or punished, employees may choose not to carry-out activities requiring substantial effort. In some cases, the operating environment may make it challenging for employees to follow designed processes. In numerous retail chains we have observed that instead of placing merchandise that does not fit into the display shelves into storage locations where extra merchandise is supposed to be stored, store employees hide it in places within the selling floor so that they do not have to travel all the way to specified storage areas. This nonconformance causes misplaced products. Similarly, during the checkout process in a supermarket store employees sometimes choose not to scan two products that are identical in price but different in flavor (e.g., two liter bottle of Diet Coke and two liter bottle of Coke) separately, scanning one product twice instead. While the employees do not create a discrepancy between the value of the inventory sold and the amount due the store from the customer since the products are identically priced, this action does create a discrepancy in two inventory records. The recorded on-hand quantity for one product will be unnecessarily depleted by two units while the other product's record will remain at its current level despite the product leaving the store. Similar discrepancies arise when store employees do not properly record a product returned or exchanged by a customer.

Even when processes are well designed and employees have the intention of carrying out store processes, they may commit errors which lead to execution problems. Many retail activities are prone to employee error. For example, at some stores, standard operating procedures could dictate that all products have presence on the selling floor. In shelving new merchandise, employees may fail to place some products on the selling floor and instead mistakenly take them to storage areas, leading to misplaced products. At another store, distribution center employees may pick and ship the wrong product to the store leading to discrepancies between recorded and actual inventory quantities in that store. Numerous other examples of employee errors could be observed when examining retail store processes. Cognitive psychologists have studied human error for a long time and have identified the mechanisms by which errors are generated and how they can be reduced (for more information on human error, see Reason 2002).

Finally, execution problems within the context of retail stores can also be caused by customers. Customer shopping habits, for example, contribute to misplaced products. At many stores, when customers remove products from the shelves and subsequently decide not to purchase them, they may not return the products to their appropriate location but rather place them in the wrong location in the store. These products remain misplaced until store employees find them and place them in their proper locations. Customer or employee theft is another contributor to inventory record inaccuracy. Hollinger and Langton (2003) estimate that inventory theft costs US retailers close to 1.3 % of annual sales or more than 26 billion dollars. Products that are removed from the store illegally are not removed from the inventory record until an audit is performed, the missing products identified, and the record corrected.

3 Factors That Exacerbate Execution Problems

Two empirical studies exist which examine specific drivers of misplaced products and inventory record inaccuracy. Research by DeHoratius and Raman (2008) and Ton and Raman (2006) consider these issues by comparing performance across retail stores within a chain. Both studies show large variation in execution performance across stores that are owned and operated by the same parent company, have the same incentives for store employees, use the same information technology systems, and are instructed to use the same standard operating procedures for shelving and replenishing inventory within the stores. As a result, these factors cannot explain the variation in performance. DeHoratius and Raman (2008) and Ton and Raman (2006) identify several alternative drivers of poor execution, namely inventory levels, product variety, employee turnover, lack of training, employee workload, and employee effort.

Note that the factors identified by DeHoratius and Raman (2008) and Ton and Raman (2006) contribute to execution problems by creating an operating environment that makes process conformance challenging or by making it more likely for store employees to make errors. How each of these factors contributes to execution problems is the subject of this section. We refer readers to the appendix for a description of the research methodology used including a precise identification of the independent variables used, a list of the control variables, and a brief description of the model estimation.

3.1 Inventory Levels

Proponents of Just-in-Time (JIT) manufacturing have argued repeatedly that inventory hides process problems and thus inhibits process improvements (Schonberger 1982; Hall 1983; Krafcik 1988). Production systems with high inventory levels have fewer learning opportunities and hence achieve lower quality over long term. A similar effect is observed at retail stores. Stockouts at retail stores that result from poor inventory planning or from poor execution are similar to production problems. Although these stockouts are not desirable, as they often lead to lost sales, like production problems they present opportunities for improvement. Since the likelihood of a stockout is higher at lower inventory levels, stores with lower inventory levels are likely to have more learning opportunities.

In retail stores where each product is given a specific space on the selling floor, a visual inspection of the shelves would allow store employees to identify the products that stocked out. When a product on the selling floor is stocked out, store employees could check whether the recorded inventory level for the product matches the actual quantity observed in the store. If there is a discrepancy between the recorded inventory level and the actual inventory on the selling floor, employees could investigate whether the discrepancy is due to product misplacement or record inaccuracy. If the former, employees could attempt to locate the extra units and bring them back to the appropriate location. If the latter, the retailer can create a formal quality process that lets employees adjust system inventory manually while also investigating the reason for the mismatch.

Retailers can learn from observing companies in other industries that maintain high levels of record accuracy. Arrow Electronics, a distributor of electronic parts and equipment, has close to 100 % inventory record accuracy, takes advantage of periods when inventory levels are low. Specifically, Arrow has a mechanism that triggers counts when either system or physical inventory reaches zero. If a part is physically stocked out in a location, the picking operators are instructed to verify that the system inventory for that part is also zero. Similarly, if the system inventory is zero, the picking operators are instructed to verify that the physical inventory for the part is also zero. When there is a discrepancy between the system inventory levels and physical inventory levels, warehouse operators investigate the source of the problem and when necessary make inventory adjustments to the system (Raman and Ton 2003).

Maintaining high inventory levels at retail stores can cause execution problems not only by reducing opportunities to easily identify discrepancies but also by increasing the complexity in the operating environment. All else being constant (e.g., the size of the selling area), stores with higher levels of inventory often have more units stored in storage areas. Since the replenishment process from storage areas, like most operational processes, is prone to employee errors, there are more opportunities to make errors in replenishing merchandise to the shelf. Thus, we expect more product misplacements in operating environments with high inventory levels.

Both DeHoratius and Raman (2008) and Ton and Raman (2006) provide empirical evidence to support the relationship between inventory levels and store execution. DeHoratius and Raman (2008) show that stores with higher inventory levels in a given selling area also have greater inventory record inaccuracy. Similarly, Ton and Raman (2006) show that stores with higher inventory levels per product also have a greater percentage of phantom products, defined as the products in storage areas but not on the selling floor. Ton and Raman (2010) confirm this finding using 4 years of data from the same research site.[8]

3.2 Product Variety

As with earlier claims that higher product variety increases the complexity in manufacturing settings (e.g., Skinner 1974; Anderson 1995; Fisher et al. 1995; MacDuffie et al. 1996; Fisher and Ittner 1999), more variety at a retail store increases the confusion and complexity in the operating environment and hence causes more process nonconformance or employee errors that lead to execution problems. Increasing product variety, for example, increases the difficulty of differentiating products during the checkout process. Consequently, store employees may scan one product multiple times without recognizing or caring that the customer is purchasing multiple different products, causing inventory record inaccuracy. Increasing product variety at a store also increases the number of steps performed in inventory replenishment at the stores. Given that stores have limited shelf space, store employees are required to move more units of products to storage areas at stores that have higher product variety. Since each step in replenishment is prone to errors, higher product variety is associated with more products that are in storage areas and not on the selling floor.

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3.3 Employee Turnover and Training

The average employee turnover for US businesses in general is about 10–15 % (White 2005). Retail stores, however, experience much higher rates of employee

[8] See appendix for details of this study.

turnover. According to the National Retail Federation, the average part-time and full-time employee turnover in the retail industry is 124 % and 74 % respectively. Ton and Raman (2006) report an average employee turnover of 112 % for part-time employees and 65 % for full-time employees at Borders stores. Interestingly, the authors show that stores with higher employee turnover also have a greater percentage of phantom products, suggesting these problems may be linked.

High levels of employee turnover affect store execution in numerous ways. First, employee turnover disrupts existing operations (Dalton and Todor 1979; Bluedorn 1982). When a store employee quits the store, there is often a period of finding and training a replacement. During this period, workload for existing employees is generally higher. Higher workload may lead to more errors and consequently more execution problems. Moreover, the departure of employees often causes demoralization of existing employees (Staw 1980; Steers and Mowday 1981; Mobley 1982). Demoralization may cause existing employees to make more errors in performing their jobs.

Second, employee turnover leads to a loss of accumulated experience (Argote and Epple 1990; Nelson and Winter 1982). As employees spend more time at the stores, they become better at performing their jobs and consequently make fewer errors. Ton and Raman (2006), for example, state that as employees spend more time at Borders stores, they become more familiar with the products in their sections and as a result become better at noticing those that are missing from the selling floor.

Third, because store employees typically leave their job within a year, retailers often choose not to invest in their training. In fact, new employees receive, on average, only 7 h of training in the retail industry (Managing Customer Service 2001). As a result of limited training, new employees often start performing their jobs without a full understanding of the existing processes and their impact on store operations. Hence, they regularly commit process nonconformance (e.g., the checkout scanning example in Sect. 2.3). Ton and Raman (2006) provides empirical evidence for the positive effect of training on store execution. The authors find a negative association between percentage of phantom products and the amount of training offered at the stores.

3.4 Employee Workload

For most retailers, store labor represents the largest controllable expense at retail stores. For example, in 2003, selling, general, administrative expenses, which consist largely of store employee payroll expenses, represented approximately 20 % of retail sales.[9] Consequently, many store managers are evaluated based on how well they manage payroll expenses at their stores. When store managers reduce

[9] Source: Standard & Poor's Compustat, 427 public firms with SIC Codes between 5200 and 5999.

payroll expenses—either by reducing the number of employees at the stores or reducing the number of hours worked—the amount of workload per employee increases. With increased workload, store employees are more likely not to conform to designed processes. They are also likely to make more errors in performing their tasks. For example, a salesperson is more likely to scan two similar products that have the same price together instead of separately if he or she sees a long line of customers waiting to be checked out. It is often more difficult to observe the accuracy of scanning than to observe the speed of scanning both by customers and store managers. Ton and Raman (2006) show that stores that have higher employee workload, measured as payroll expenses as a percentage of sales, also have higher percentage of phantom products.

3.5 Employee Effort

DeHoratius and Raman (2008) argue that employee effort affects inventory record inaccuracy. When store employees exert more effort into monitoring select products, the inventory records for these products are expected to be more accurate. Employee effort, however, is unobservable. Thus, the authors use two proxies, item cost and shipping method, for employee effort. They posit that employees exert more effort into monitoring expensive than inexpensive products and thus expensive items should be more accurate than inexpensive ones. Similarly, they argue that store employees monitor items shipped directly to the retail store from the vendor more closely than those items shipped to the store from the retailer's own distribution center. We discuss each of these proxies and their findings in turn.

Inventory shrinkage is a common problem at retail stores and store employees often spend considerable effort in shrink prevention activities (DeHoratius and Raman 2007). Inventory shrinkage has a direct impact on store operating profits and shrinkage of expensive products affects store profitability more than shrinkage of less expensive products. Given that store managers are often evaluated on their financial performance, controlling inventory shrinkage of expensive products is often a key priority for store personnel. Consequently, it is not unusual for store employees to monitor expensive and inexpensive items differentially. DeHoratius and Raman (2008) show that this differential treatment leads to lower levels of record inaccuracy for expensive items relative to inexpensive ones.

DeHoratius and Raman (2008) also show that the magnitude and likelihood of inventory record inaccuracy is lower for those products shipped directly to the retail store from the vendor compared to those products shipped to the store from the retailer's own distribution center. They posit that store employees pay more attention to checking shipments that arrive from vendors than other shipment types. They do so because when the value ordered by the store exceeds the value shipped from the vendors, stores receive a credit from the vendor. Stores do not, however, receive a credit from the distribution centers unless the discrepancy between what was shipped and what was ordered exceeds a threshold more than 30 times the average cost of a single product. Consequently, store employees pay more attention to checking shipments that arrive from vendors to ensure invoice accuracy. Moreover, shipments from the vendors tend to contain fewer products and hence easier for store employees to inspect.

4 How Execution Problems Affect Inventory Planning

Inventory planning at retail stores requires two main decisions, how much inventory to stock and when to replenish. The policies retailers establish with respect to these decisions have been shown to be critical determinants of store performance (see Tayur et al. 1999 and Graves and de Kok 2003). We use two examples to demonstrate how inventory record inaccuracy and misplaced products affect each of these decisions. These examples are described in detail in DeHoratius (2002) and Ton (2002). We then summarize research that incorporates execution problems into existing inventory planning models.

4.1 Inventory Record Inaccuracy and Inventory Planning

Management at Gamma received a letter of complaint from a regular customer noting that a specific product he sought was persistently out of stock (DeHoratius 2002). He stated that the product failed to be replenished even after bringing the stockout to the attention of the store manager. After researching the problem, Gamma management discovered that, although the product was out of stock, inventory records showed 42 units on-hand in that store. Because the inventory record showed that there was a sufficient amount of on-hand inventory to meet demand, the automatic replenishment system failed to release additional inventory to the store even though, in reality, there were no products on the shelf.

Sales records also revealed that this store had not sold a single unit of this product, a product that typically sold one unit per week per store, during the past 7 weeks. The demand forecast was then automatically updated to reflect the recent low levels of sales, namely zero sold in 7 weeks. Therefore, not only were customers unable to find the product on the shelf during the time when the product was out of stock but, even after re-stocking the shelf, their demand was less likely to be met in the future since the adjusted demand forecast reduced the target stocking quantity that needed to be maintained at the store. Moreover, it is important to note that the product might have remained out of stock until the next physical audit or cycle count had this customer not written to Gamma. Without inventory to sell the recorded quantity would remain at 42 units, never falling below the reorder point for this product.

DeHoratius and Raman (2008) found the lost revenue due to stockouts caused by record inaccuracy problems at Gamma amounted to 1.09 % of Gamma's retail sales and 3.34 % of its gross profit. They derived this estimate from examining those items similar to the one above—items that were out of stock at the store but with a positive on-hand quantity sufficiently large so as to prevent the automated replenishment system from triggering an order.

4.2 Misplaced Products and Inventory Planning

Figure 4.3 shows the cumulative number of customers who entered a store and the cumulative sales for a particular product, a type of bread, between 8:00 am and 8:00 pm. As shown in the figure, the cumulative number of customers entering the store steadily increased from 8:00 am to 8:00 pm. The particular product, on the other hand, was selling well until about 12:30 pm, did not sell at all from 12:30 to 4:00 pm, started selling again after 4:00 pm, and stopped selling after 6:00 pm.

During both of these periods when there were no sales for this particular product, the system inventory level for this product was positive. As a result, a simple interpretation of these sales and inventory data would be that the in-stock for this product was 100 %, and that there was no demand for this product between 12:30 pm and 4 pm, and after 6 pm. The reality, however, was quite different. Between 12:30 and 4 pm, the inventory was located in the backroom, and was not available to the customers. At 6 pm the product stocked out.

Although one could argue that even if the product was available for sale no customer would have chosen to purchase it during 12:30 and 4 pm, we believe this

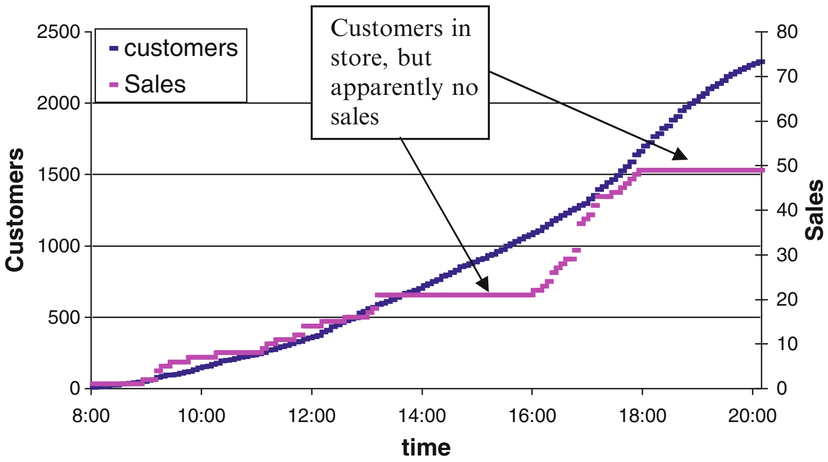

Fig. 4.3 Store sales versus customer entrances (*Source*: Ton 2002)

to be highly unlikely. Given that there was not change in the rate at which customers entered the store during this period, it is likely that the store lost sales as a result of this product misplacement.

4.3 Incorporating Execution Problems into Existing Research Streams

The two examples above demonstrate the challenge faced by retailers when deciding how much and when to replenish. Because retailers are unable to observe all customer actions, they rely on data to infer the actions of customers and plan accordingly. Yet, as the two examples reveal, these data can be misleading. In reality, execution errors lead to additional uncertainty and recently several researchers have begun to incorporate such uncertainty into both tactical and strategic planning models. This research shows the impact execution problems have on tactical decisions such as safety stock calculations, ordering policies, and the timing of inventory counts as well as strategic decisions such as channel coordination and technology choice.

Among the papers addressing tactical decisions in the presence of execution problems, Iglehart and Morey (1972) were the first to determine the optimal buffer stock that protects against shortages caused by record inaccuracy. Moreover, they determine the optimal frequency of inventory counts by taking into account the cost of holding buffer stock and the cost of conducting inventory counts to correct record inaccuracies. More recently, Kök and Shang (2007) derive the optimal joint inspection and replenishment policy by minimizing the total inventory and inspection cost. They create an inspection adjusted base stock policy which adjusts the replenishment order according to the level of inaccuracy and the chosen inspection policy. They argue that the order quantity needs to be increased to accommodate the additional uncertainty caused by record inaccuracy and that inaccuracy accumulates over time but that it can be corrected through inspection. Thus, if inspection cost is high, their model suggests auditing less frequently and carrying additional inventory to buffer against record inaccuracy.

Iglehart and Morey (1972) and Kök and Shang (2007) assume error in inventory records are random with a mean of zero. Thus, the discrepancy between the inventory record and actual inventory can take either sign. Moreover, both papers allow for a correlation between an item's demand and the magnitude of its inventory discrepancy. Emma (1966) and DeHoratius and Raman (2008) show empirically that the more frequently an item sells (i.e., the greater the demand) the greater the record inaccuracy. By taking into account these empirical findings, Iglehart and Morey (1972) and Kök and Shang (2007) offer practical solutions to record inaccuracy. However, one factor that limits the applicability of Kök and Shang's (2007) findings to the retail context is their backlogging assumption. In most retail settings, unfilled demand is lost rather than backlogged.

Offering an alternative solution to record inaccuracy, DeHoratius et al. (2008) propose the maintenance of a probabilistic inventory record to account for the presence of inventory record inaccuracy in retail systems. This probabilistic inventory record would take the place of the point estimate commonly used in retail to track inventory holdings. They model inventory inaccuracy through an "invisible" demand process that can either deplete or replenish physical but not recorded inventory. Using a periodic review process with unobserved lost sales, they demonstrate that the impact of inventory record inaccuracy can be mitigated through this probabilistic approach to inventory planning. Furthermore, they do so while taking into account the product characteristics that have been shown to impact record inaccuracy such as the cost of a product and its annual selling quantity (DeHoratius and Raman 2008).

Kang and Gershwin (2005) focus on one source of inventory record inaccuracy, namely theft, whereby the quantity of units recorded ends up being greater than that actually found on the retail shelf for a given item. Fleisch and Tellkamp (2005) also analyze inventory shortages caused by either record inaccuracy or misplaced products. Through simulation, these studies demonstrate that even small rates of inventory record inaccuracy and misplaced products can result in substantial lost sales and suboptimal retail performance.

Camdereli and Swaminathan (2005), Rekik et al. (2008), Atali et al. (2005), and Gaukler et al. (2007) focus primarily on strategic planning in the face of execution problems. Camdereli and Swaminathan (2005) not only derive the optimal inventory policy for a retailer that knows the proportion of its inventory that is misplaced but also show that decreasing the proportion of misplaced products impacts channel parties differently. They identify conditions for channel coordination in the face of reduced product availability due to misplaced products. Rekik et al. (2008) also examine the impact of reduced product availability due to misplaced products. Unlike Camdereli and Swaminathan (2005), the objective of Rekik et al. (2008) is to explore how the use of RFID technology can mitigate the cost of product misplacement. Gaukler et al. (2007) also examine the role of RFID by evaluating whether the use of this technology can improve in-store, shelf replenishment processes and hence product availability. They also discuss the impact of execution problems on channel coordination and the differential benefit RFID technology has among channel members. Similar to Rekik et al. (2008) and Gaukler et al. (2007), Atali et al. (2005) examine the value of RFID technology in reducing execution errors by comparing an inventory system with and without the visibility such technology provides. However, unlike the previously cited papers, Atali et al. (2005) evaluate not only product misplacement, one-sided errors that deplete inventory levels and reduce product availability, but also execution problems than can result in the actual inventory level exceeding the recorded level.

5 Future Research Opportunities

There are several research opportunities for those interested in the impact of store execution on product availability, in particular, and on retail supply chains, in general. For example, the widely accepted theoretical relationship between inventory levels and product availability is that increasing inventory levels is associated with increased service levels and thus increased store sales. The empirical findings summarized in this chapter, however, suggest that increasing inventory levels also increases the occurrence of misplaced products and inventory record inaccuracy. Thus, through its effect on store execution, increasing inventory levels may also compromise service levels. There is an opportunity for management scholars to develop models where both the direct and indirect effects of increasing inventory levels of product availability are considered and to examine empirically the direct and indirect effects of inventory levels on stores sales. In Ton and Raman's (2010) longitudinal study, the direct positive effect of increasing inventory levels on sales is larger than the indirect negative effect through store execution. There may, however, be settings where the indirect negative effects outweigh the direct positive effects.

There is also opportunity to incorporate execution problems into models that estimate demand and assess forecast accuracy in the presence of stockouts (Wecker 1978; Agrawal and Smith 1996; Nahmias 1994; Raman and Zotteri 2000; Smith and Agrawal 2000). Raman and Zotteri, for example, argue that sales data could be used along with inventory data to incorporate lost sales estimates into the estimation of demand. More specifically, the authors generate an estimate of the lost sales by using inventory data to identify when a stockout occurred. Once it is known when the stockout occurred, the historical sales rate can be appropriately extrapolated to determine lost sales during the stocked out period. Thus, both observed demand when a product is in stock (e.g., sales history) and an estimate of unobserved demand when product is out of stock (e.g., lost sales estimation) can be used to estimate the demand more accurately. Consider a common situation, however, where there are no units of inventory for the product (either due to inventory record inaccuracy or misplacement) while the inventory records show a positive value for inventory. In this situation, sales for the product will be zero, while the inventory for the product will appear positive. Consequently, the above analysis will conclude that there was no demand for the product during the period when the inventory record was inaccurate or when the product was misplaced and the demand estimation will be inaccurate. The demand estimation could be improved by assigning a probability that the inventory record is not a true reflection of reality when the system inventory level for the product is positive and there are no observed sales.

Note that efforts to compensate for execution problems with robust decision support tools and efforts to prevent execution problems through, among others, improved process design, improved conformance to designed processes and error prevention are not mutually exclusive. There is much to gain from better understanding the ways to eliminate or reduce the prevalence of execution problems while simultaneously designing decision tools robust enough to account for the existence of execution problems. As we reviewed in this chapter, existing research has identified numerous factors that exacerbate the occurrence of execution problems. These factors are largely under the control of retail managers. For example, retail managers can choose to invest more in training or spend more on payroll expenses to reduce the occurrence of execution problems. These actions, however, result in increased costs. Given that higher profitability is the overarching goal, researchers and retail managers can develop models that optimize store profitability given the relevant costs and benefits of changes to training or payroll expenses. Moreover, retailers could institute a process improvement effort that identifies and corrects those employee actions leading to errors in product location or record inaccuracy.

Additional empirical research opportunities exist. For example, the findings of DeHoratius and Raman (2008) and Ton and Raman (2006) need to be tested using data from other retailers in order to determine their generalizability. The effect of human resource variables such as employee turnover, training, and workload on inventory record inaccuracy also needs to be examined. Moreover, opportunities exist for researchers to examine the impact of process design, technology, or employee incentives on execution. Given that most retailers do not alter process design, technology usage, or employee incentives across their own stores, researchers wishing to examine these factors would need to compare execution across several different retailers.

More research is needed to examine the relationship between storage area size and store execution. Proponents of lean production systems have argued that smaller repair areas would force employees to introduce procedures to reduce defects and hence production systems with smaller repair areas would be associated with higher quality. Most retail stores include areas for storing extra merchandise that do not fit into the display shelves. These storage areas are similar to the repair areas in manufacturing plants. Consistent with the lean production system argument, Ton and Raman (2006) hypothesize, but are unable to support with their data, a relationship between smaller storage areas and product misplacement. Nevertheless, the authors cite anecdotal evidence suggesting that smaller storage areas force store employees to better monitor products in the storage areas and to quickly replenish the selling floor with units from storage locations, lowering the level of product misplacements. Specifically, store execution suffered tremendously at one particular store when the store's storage capacity increased from one year to next.

One potential reason for the lack of statistical significance may be the imperfect measure the authors used for storage capacity. Although stores typically have multiple storage areas, Ton and Raman (2006) use size of the backroom as a surrogate for total storage in a store. In addition, it might be *how* the storage area is managed rather than its size that affects percentage of products that are in storage but not on the selling floor. Ton (2002) states that her store visits revealed a great deal of variation in the utilization of the storage areas. There were some backrooms that were very well organized, with products clearly categorized, and each shelf well displayed with labels that indicated what merchandise was stored on that shelf. In other backrooms there were no labels on the shelves and multiple products were stacked on top of each other. Some backrooms were so messy that there were boxes and carts in between the shelves that prevented employees from gaining access to large areas of the storage space.

There is also opportunity to conduct empirical research on the consequences of poor store execution. DeHoratius and Raman (2008) and Ton and Raman (2010) show the negative effect of poor store execution on store sales. Similar research can be conducted to examine the effect of store execution on other financial or non-financial measures of store performance. This includes the impact of store execution on the performance of retail supply chain initiatives such as vendor managed inventory or collaborative planning, forecasting and replenishment (CPFR) programs.

Note that in this chapter we focused solely on the effect of execution on managing product availability. The execution problems described in this chapter have implications beyond managing product availability. Accurate inventory data may allow a company to make same-day delivery promises or to integrate online and physical store operations (see Raman and Ton 2003 and Ton and Raman 2003 for teaching case examples). Thus, researchers can identify the impact of execution problems on business strategy as well as performance.

Appendix

DeHoratius and Raman (2008)

Research Site: The authors examine the drivers of inventory record inaccuracy using data from Gamma Corporation, a large specialty retailer with over 10 billion dollars in annual sales. Gamma uses electronic point-of-sale scanning for all its sales and an automated replenishment system for inventory replenishment.

Data: The authors collected data from physical audits of 37 Gamma stores in 1999. These data included detailed information about each stock-keeping-unit (SKU) contained in each store, amounting to a total of 369,567 observations, or SKU-Store combinations. Physical audits revealed the recorded quantity (the number of inventory units for each SKU recorded to be on-hand at a specific store) as well as the actual quantity (the number of inventory units actually present at the store for each SKU). In addition to SKU level data, the authors collected both store and product category data and complemented their quantitative analysis with extensive fieldwork.

Dependent Variable: The dependent variable is the inventory record inaccuracy of each SKU in each store. Inventory record inaccuracy (IRI) is measured as the absolute difference between the recorded and actual quantity for each SKU-store combination.

Independent variables: SKU level variables include the cost of the item, its annual selling quantity, and whether the item had been shipped to the store from one of Gamma's distribution centers or directly from the vendor. Store level variables are the number of units in a given selling area, product variety, and the number of days between the current and previous physical audit.

Empirical Model: Because these data have a multi-level structure (SKUs are contained within stores and product categories), the authors fit a series of hierarchical linear models to examine the drivers of IRI. In addition to all independent variables, the empirical model includes control dummy variables for each region ($REGION\_ONE_k$, $REGION\_TWO_k$). Equation (4.1) below summarizes their model.

$$\begin{aligned} IRI_{ijk} = {} & \Theta_0 + b_{00j} + c_{00k} + e_{ijk} + \pi_1{}^*\left(QUANTITY\_SOLD_{ijk}\right) + \pi_2{}^*\left(ITEM\_COST_{ijk}\right) \\ & + \pi_3{}^*\left(DOLLAR\_VOLUME_{ijk}\right) + \pi_4{}^*(VENDOR_i) + \pi_5{}^*\left(VENDOR\_COST_{ijk}\right) \\ & + \gamma_{001}{}^*(REGION\_ONE_k) + \gamma_{002}{}^*(REGION\_TWO_k) + \gamma_{003}{}^*(DENSITY_k) \\ & + \gamma_{004}{}^*(VARIETY_k) + \gamma_{005}{}^*(DAYS_k). \end{aligned} \tag{4.1}$$

where

IRI_{ijk} is the record inaccuracy of item i ($i = 1\ldots,n_{jk}$) in product category j ($j = 1\ldots,68$) and store k ($k = 1, \ldots,37$).
Θ_0 is a fixed intercept parameter.
The random main effect of product category j is $b_{00j} \sim N(0, \tau_{boo})$.
The random main effect of store k is $c_{00k} \sim N(0, \tau_{coo})$.
The random item effect is $e_{ijk} \sim N(0, \sigma^2)$.
τ_{boo}, τ_{coo}, and σ^2 define the variance in IRI between product categories, stores, and items, respectively.
π_1–π_5 are the fixed item level coefficients and γ_{001}-γ_{005} are the fixed store level coefficients.

Each of the variables is defined below:

$QUANTITY\_SOLD_{ijk}$ is the annual selling quantity of item i in product category j and store k.
$ITEM\_COST_{ijk}$ is the cost of item i in product category j and store k.
$DOLLAR\_VOLUME_{ijk}$ is the interaction between the cost of the item and its annual selling quantity.
$VENDOR_i$ is a dichotomous variable that takes the value of one if the item is shipped direct to the store from the vendor and takes the value of zero if the item is shipped to the store from the retail-owned distribution center.
$VENDOR\_COST_{ijk}$ is an interaction term between the way in which an item was shipped to the store and its cost.
$DENSITY_k$ is the total number of units in a store divided by that store's selling area (units per square foot).

$VARIETY_k$ is the number of different merchandise categories within a store
$DAYS_k$ measures the number of days between audits for a given store.

Findings: The authors find significant positive relationships between IRI and an item's annual selling quantity, store inventory density, store product variety, and the number of days since the last store audit. A significant negative relationship exists between IRI and an item's cost as well as its dollar volume. The way in which an item is shipped to the store is a significant predictor of IRI such that items shipped direct to the store from the vendor are more accurate than items shipped from the retail distribution center. This relationship, however, depends on the cost of an item. Specially, the difference between vendor-shipped and DC-shipped items is greater for inexpensive items than for expensive ones.

Ton and Raman (2010)

Research Site: The authors examine the drivers of misplaced products using data from Borders Group, a large retailer of entertainment products such as books, CDs, and DVDs. To ensure product availability, the retailer has invested heavily in information technology and merchandise planning to make sure that the right product is sent to the right store at the right time.

Data: The authors collected data from physical audits of 242 Borders stores in 1999. Physical audits provide data on the total units of inventory at the store, total number of products at the store, and the number and dollar value of the products that were present in storage areas but not on the selling floor. In addition to physical audit data, the authors collected data on store attributes and human resource characteristics. The authors complemented their empirical data with extensive fieldwork.

Dependent Variable: The dependent variable, % phantom products, is the percentage of products that are in storage areas but not on the selling floor. The authors call these products "phantom" because they are physically present in the store and often shown as available in retailers' merchandising systems, but in fact are unavailable to customers.

Independent variables: The authors use the following independent variables: inventory level per product, total number of products in a given area, size of the storage area, employee workload, employee turnover, store manager turnover, and the number of trainers at the store.

Empirical Model: The authors estimate the parameters of Eq. (4.2) using ordinary least square estimator to examine the drivers of % phantom products. In addition to all independent variables, the empirical model includes the following control variables: store sales, store age, seasonality, unemployment rate, and a dummy variable for each region. Note that, one variable, store sales, is an endogenous variable and hence the authors employ instrumental variable estimation to cope with endogeneity. The authors use corporate sales as an instrument for store sales.

$$\begin{aligned}\%Phantom\ Products_i = {} & \beta_0 + \beta_1 Seasonality_i + \beta_2 Unemployment\ Rate_i + \beta_3 LN(Age)_i \\ & + \beta_4 Sales_i + \beta_5 Wage_i + \beta_{6j} Region_i + \beta_7 Inventory\ Depth_i \\ & + \beta_8 Product\ Density_i + \beta_9 Storage\ Size_i + \beta_{10} Labor\ Intensity_i \\ & + \beta_{101} SM\ Turnover_i + \beta_{12} FT\ Turnover_i + \beta_{13} PT\ Turnover_i \\ & + \beta_{14} Training_i + \varepsilon_i\end{aligned} \tag{4.2}$$

$$i = 1, 2, \ldots, 242$$
$$j = 1, 2, \ldots, 17$$

Each of the variables is defined below:

% Phantom Prodcuts_i is the number of products in storage but not on floor in store *i* divided by the total number of products in store *i*.

Seasonalityij is the seasonality index for month *j* in which the audit is conducted at store *i*. The seasonality index for month *j* is calculated as: $\theta_j = \dfrac{\sum_{i=1}^{242} S_{ij}}{\left(\sum_{j=1}^{12}\sum_{i=1}^{242} S_{ij}/12\right)}$

Unemployment Rate$_i$ is the unemployment rate of the metropolitan statistical area in which the store is located in 1999.

ln(*Age*)$_i$ is the natural log of the age of store *i* (in months) during the time of the audit.

Sales$_i$ is the total sales at store *i* in 1999.

Wage$_i$ is the average hourly wage at store *i* in 1999.

Region$_j$ are 17 dummy variables indicating region in which store *i* is located.

Inventory Depth$_i$ is the total number of units in store *i* divided by the number of products in store *i*.

Product Density$_i$ is the number of products in store *i* divided by the total selling area of store *i*.

Storage Size$_i$ is the backroom area of store *i* divided by the total selling area of store *i*.

Labor Intensity$_i$is the payroll expenses at store *i* in 1999 divided by sales at store *i* in 1999.

SM Turnover$_i$ is a dummy variable indicating the departure of store manager at store *i* in 1999.

FT Turnover$_i$ is the total number of full-time employees in store *i* that departed in 1999 divided by the average number of full-time employees in store *i*.
PT Turnover$_i$ is the total number of part-time employees in store *i* that departed in 1999 divided by the average number of part-time employees in store *i*.[10]
Training$_i$ is the total number of "trainer months" at store *i* in 1999.

Findings: The authors find significant positive relationships between % phantom products and inventory level per product, total number of products in a given area, employee workload, and store manager turnover. The authors find partial support for the positive relationship between employee turnover and % phantom products. The authors also find a significant negative relationship between % phantom products and the amount of training at the store.

Ton and Raman (2007)

Research Site: The authors examine the effect of product variety and inventory levels on store sales using data from Borders Group.

Data: The authors collected data from physical audits of all Borders stores from 1999 to 2002. The dataset includes 356 stores, some of which opened between 1999 and 2002. As a result the authors do not have 4 years of data for all 356 stores.

Dependent Variables: The authors use two dependent variables. First is the percentage of phantom products, products that are in storage areas but not on the selling floor. The second dependent variable is store sales.

Independent variables: The authors use the following independent variables: inventory level per product, total number of products at a store.

Empirical Model: The authors estimate the parameters of Eq. (4.3) to examine the effect of product variety and inventory levels on % phantom products and estimate the parameters of Eq. (4.4) to examine the effect of % phantom products on store sales. In both equations, the authors control for *factors that vary over time for stores and are different across stores* (seasonality, unemployment rate in the store's metropolitan statistical area, amount of labor used in a month, employee turnover, full-time employees as a percentage of total employees, store manager turnover, and the number of competitors in the local market), *factors that vary over time but are invariant across stores* (year fixed effects), and *factors that are time-invariant for a store but vary across stores* (store fixed effects).

The authors use ordinary least squares (OLS) estimators in estimating both Eqs. (4.3) and (4.4) and report the heteroskedasticity robust standard errors for OLS. In addition to OLS estimators, the authors also treat Eqs. (4.3) and (4.4) as

[10] Full-time and part-time turnover include only employees that were responsible for inventory management.

seemingly unrelated regressions (SUR) allowing for correlation in the error terms across two equations. In addition, because of autocorrelation in the error terms of Eq. (4.4), the authors consider a flexible structure of the variance covariance matrix of the errors with first-order autocorrelation and estimate the parameters of Eq. (4.4) using maximum likelihood estimation.

$$\begin{aligned} \%Phantom\ Products_{it} = \alpha_i + \lambda_t + \beta_1\ Product\ Variety_{it} \\ + \beta_2 Inventory\ Level_{it} + X_{iy}\beta + \varepsilon_{it} \end{aligned} \tag{4.3}$$

$$\begin{aligned} Sales_{it} = \delta_i + \phi_t + \gamma_1 \%Phantom\ Products_{it} + \gamma_2\ Product\ Variety_{it} \\ + \gamma_3 Inventory\ Level_{it} + X_{iy}\gamma + \varepsilon_{it} \end{aligned} \tag{4.4}$$

$$\begin{aligned} \alpha_i, \delta_i &= Fixed\ effect\ for\ store\ i,\ i = 1,\ 2\ \ldots,\ 356, \\ &\quad in\ equations\ (1)\ \text{and}\ (2)\ respectively \\ \lambda_t, \phi_t &= Fixed\ effect\ for\ year\ t,\ t = 1999,\ 2000,\ 2001,\ 2002 \\ &\quad in\ equations\ (1)\ and\ (2)\ respectively \end{aligned}$$

Each of the variables is defined below:

%Phantom Products$_{it}$ is products that are in storage areas but not on floor at store i in year t at the time of the physical audit divided by the # of products at store i in year t at the time of the physical audit

Sales$_{it}$ is sales during the month preceding the audit at store i in year t

Product Variety$_{it}$ is the # of products at the store at the time of the physical audit at store i in year t

Inventory Level$_{it}$ is the # of units at the store at the time of the physical audit at store i in year t divided by the # of products at the store at the time of the physical audit at store i in year t

The vector X_{iy} represents the following control variables:

Seasonality$_j$ is the seasonality index for month j in which the audit is conducted at store. Let S_{ijt} =sales at store i in month j in year t. Then the seasonality index for month j is $\dfrac{\sum_{t=1}^{4}\sum_{i=1}^{267} S_{ijt}}{\left(\sum_{t=1}^{4}\sum_{j=1}^{12}\sum_{i=1}^{267} S_{ijt}/48\right)}$.

Unemployment$_{it}$ is the unemployment rate of the metropolitan statistical area in which the store is located during the month preceding the audit at store i in year t.

Labor$_{it}$ is the payroll expenses during the month preceding the audit at store i in year t.

Employee Turnover$_{it}$ is the fraction of employees that are charged with managing inventory that had left during the month preceding the audit at store i in year t.

Proportion Full$_{it}$ is the fraction of full-time employees during the month preceding the audit at store i in year t.

Store Manager Turnover$_{it}$ is a dummy variable that has a value of 1 if the store manager had left the company voluntarily since the last physical audit at store *i* in year *t*.

Competition$_{it}$ is the total number of Barnes & Noble and Borders stores in the area during the month preceding the audit at store *i* in year *t*.

Findings: The authors find that increasing both product variety and inventory level per product at a store is associated with an increase in % phantom products. The authors also find that an increase in % phantom products is associated with a decrease in store sales. As a result, their empirical analysis shows that through store execution, increasing product variety and inventory levels has an indirect negative effect on store sales. This indirect negative effect, however, is smaller than the direct positive effect of increasing inventory levels and product variety on store sales.

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