

# Virtually every major supply chain initiative within ECR assumes companies are working with accurate inventory data. This could be a big mistake

## Building on foundations of sand?

RESEARCH

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Computerised tracking of inventory at the SKU level is commonly assumed to be accurate. Yet physical inventory audits in one leading US retail chain revealed discrepancies in 65 per cent of the records collected. What's more, the average absolute error (the actual difference between recorded and on-hand inventory) was substantial – at 4.98 units per inventory record for SKUs that averaged only 14.09 units of inventory in a given store. Such error rates are unlikely to be unusual in retailing.

The retail chain concerned (hereafter called Gamma or Gamma Corporation) is a large, public retailer with highly modern operations including electronic point-of-sale scanning and automated replenishment systems in each of its nearly 1,000 stores and all of its warehouses.

Inventory record inaccuracy has many negative effects. On the basis of its last audit Gamma, which replenishes store inventory based on computerised inventory data, estimates that lost gross margins and additional inventory-carrying costs due to inaccurate inventory records reduced profits by roughly \$32 million per year, or the annual profit of roughly 100 stores.

Inventory record inaccuracy affects

labour productivity adversely. For example, many supermarkets, recognising their inventory records to be inaccurate, require stores to re-order merchandise manually, thus increasing labour costs and reducing profitability.

Inventory record inaccuracy also diminishes the benefits that can accrue from the use of information technology in retail supply chains. US retailers spend one per cent of annual sales, or roughly \$30 billion per year, on information technology to track sales, forecast demand, plan product assortment and control inventory. But inaccuracy substantially compromises the value of the data that is generated for planning replenishment, store level assortment, and promotions and markdowns.

Inaccurate inventory records also have a negative impact on the use of information technology upstream in the supply chain. Inaccurate retail sales and inventory data can confound manufacturers' efforts to manage retail inventory levels under vendor-managed inventory (VMI) programmes and render ineffective many collaborative planning, forecasting and replenishment (CPFR) programmes.

## Audits are conducted with a fair amount of technology and a substantial amount of management involvement

Our analysis employs two methodological approaches. One, termed “record level” analysis, takes each inventory record (that is, each store-SKU combination) as the primary unit of analysis to show the probability of an inventory record being accurate by item cost, annual units sold, and shipping source (whether a store received the SKU directly from supplier or from the retailer’s own distribution centre), controlling for product type and store differences.

Our second approach, termed “store level” analysis, examines the average absolute error per inventory record in a particular store. We show the magnitude of this error to be associated with store inventory density (total inventory holdings in a given square footage of selling space), total number of SKUs, frequency of inventory audits, and the distribution centre (DC) that ships its merchandise.

### The research

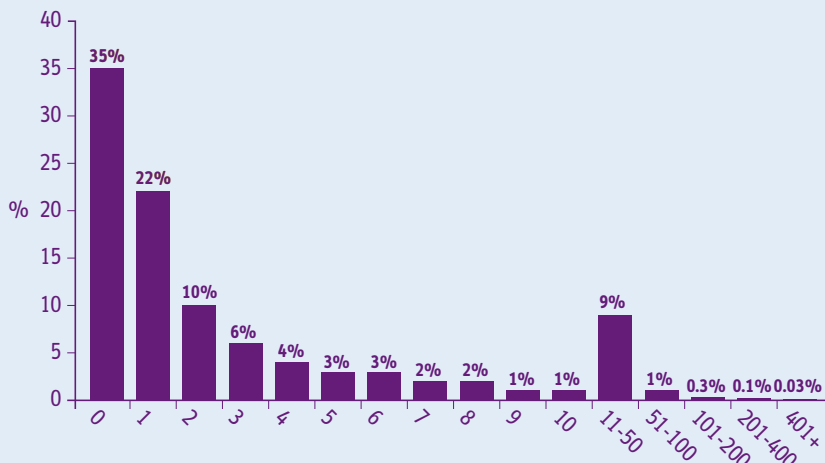
Gamma Corporation is a speciality retail chain with more than 1,000 stores worldwide offering a broad range of products in a self-service shopping environment. The product assortment does not vary substantially, despite the wide geographic dispersion of stores. Annual company sales, roughly \$10 billion in 1999, have been growing consistently.

Our data set comprises detailed information about each SKU in 37 Gamma

stores. Each store contains, on average, 9,989 SKUs, for a total of 369,592 inventory records. We obtained a representative sample by randomly selecting 12 stores served by each of three DCs operated by Gamma and gathered the results of the two most recent physical inventory audits conducted at each of 37 stores during fiscal years 1998 and 1999. The physical inventory audits consisted of lists of all SKUs in a particular store followed by two corresponding unit quantities, one representing the “system count” (the number of inventory units for each SKU recorded to be on hand at a particular store), the other the “actual count” (the number of inventory units for each SKU actually present in the store at audit time).

Audits are conducted with a fair amount of technology and a substantial amount of management involvement. Audit teams, using hand-held scanning devices to register the quantity of each item in the store, count the inventory when a store is closed to customers. Store managers, and at times management from the corporate office, are present to ensure timely and accurate counts. On completion of the audit, Gamma updates its inventory records to match the audit count. Although some inaccuracy in the audit itself is to be expected, because Gamma uses these audits for financial accountability we anticipate such inaccuracy to be limited.

**Exhibit 1: Histogram of the absolute difference between system and actual inventory levels for the 369,592 inventory records**



We also obtained for each SKU data such as the purchase cost at the time of the physical audit, sales during the year preceding the audit, and an indicator variable denoting whether the SKU was shipped from one of Gamma's DCs or direct from the vendor. Included in the physical audit results is a product classification that enables us to group SKUs into one of five different product categories. We also collected variables pertinent to understanding store differences – most important, for this study, the size of each store's selling area measured in square feet.

Our empirical data set was complemented by nearly 500 hours of fieldwork during which we met with personnel throughout Gamma Corporation. Visits to 15 stores and two distribution centres were invaluable in helping to shape our hypotheses about the drivers of inventory record inaccuracy. Exhibit 1 shows some top line results. It shows the absolute difference between system and actual inventory levels in the physical Gamma audit. It reveals that only 35 per cent of the inventory records in the sample were accurate; 22 per cent were wrong by just one unit, and so on. On average, the error rate was six or higher – which is surprisingly high considering that the average number of inventory units kept by this retailer was 14.

#### Causes of inventory inaccuracy

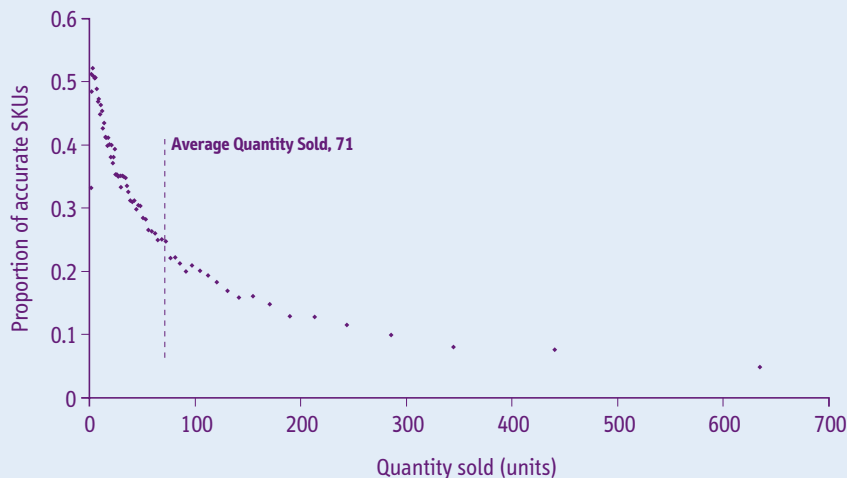
In designing the research, we aimed to test a number of hypotheses about possible causes of inventory inaccuracy. We list the main causes below:

- *Number of units sold in a year.* Errors in a store's inventory records can be traced to errors in tracking sales out of or shipments into the store. Despite extensive use of information technology, both processes are prone to error. Consider the simple process of buying two identically priced containers of store-brand ice cream, one coffee and one vanilla. It would not be unusual for the salesperson to scan one of these units twice. This rather innocuous step, often performed to save the customer time, induces two errors in the records; at the end of the transaction recorded inventory levels for both the coffee and the vanilla ice cream are inaccurate.

In the shipment of products to stores discrepancies can occur when DC employees incorrectly pick and pack an SKU not designated for a particular store. In an apparel DC, for example, it is quite easy for an employee to mistakenly pick a "medium" instead of a "large" garment. Because stores typically do not scan merchandise on receipt, such a shipment error might go unrecognised.

The opportunity for errors to occur varies with the flow of the SKU through various stages in the process of moving

Exhibit 2: Relationship between record accuracy and annual quantity sold per item



inventory from DC to consumer (for instance, errors in picking or scanning). We therefore expected SKUs with higher sales to be more likely to accumulate error and thus be inaccurate at the time of a physical audit. Exhibit 2 shows the research results confirming this expectation.

- *Item Cost.* We hypothesize that inventory records for expensive items are more likely to be accurate than those for inexpensive items. We observed that concern for inventory shrink led Gamma Corporation store managers and employees to pay greater attention to expensive items when checking shipments into their stores and monitoring shelf inventory levels. Exhibit 3 shows the actual audit results, confirming this hypothesis.
- *Mode of shipment.* Gamma stores receive most of their merchandise from company-owned DCs, but do receive some directly. Inventory records for items received directly from vendors are more likely to be accurate, for two reasons. First, vendor-direct shipments tend (a) to include fewer distinct items (fewer distinct SKUs in a shipment), providing less opportunity for confusion, and (b) to be smaller in quantity than those received from company owned DCs, making it easier to check shipment accuracy. Second, on receipt, store employees count each vendor-shipped item before stocking the items in the store. Should the actual and

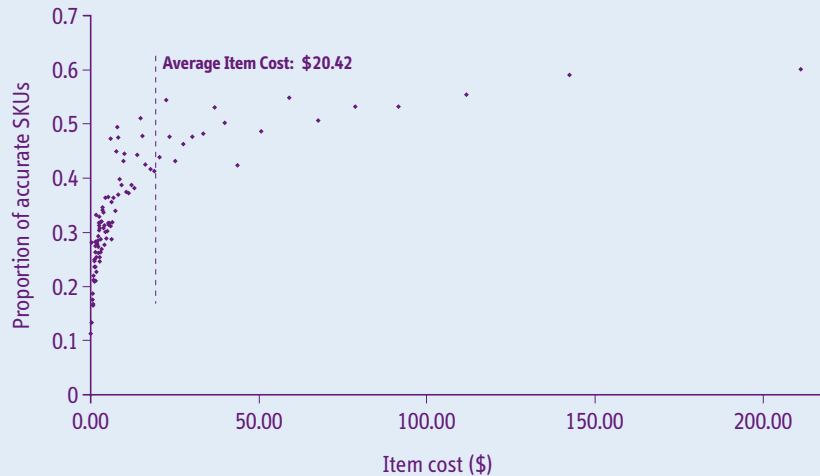
expected number of items not match, the store manager will contact the vendor directly. In most cases, the vendors will include missing items in the next shipment, or expedite an additional shipment.

Items shipped directly from DCs, on the other hand, are rarely counted. Store procedures for product shipped from DCs require only items that exceed a particular dollar amount to be counted before being placed on the sales floor. Moreover, DC managers decide whether stores should be credited for shipment errors and the likelihood of obtaining a credit depends on the relationship between the store and DC management.

Exhibit 4 shows that the average magnitude of error per item differs from one store to another. This figure is reasonably consistent from one year to the next. These differences cannot be explained by differences in ownership, technology or processes because they come from within the same company using common technologies and processes.

Differences in store management can account, in part, for the variations found among the 37 stores. Managers familiar with practices at different stores observed that some store managers emphasise, through training programmes and job-allocation, inventory control procedures such as checking shipments into the store and scanning each item individually at

Exhibit 3: Relationship between record accuracy and annual quantity sold per item



the checkout counter. Future research might usefully develop quantitative measures for tracking store management practices and determine whether these measures are associated with variations in store level inventory inaccuracies.

So how can these differences be explained? We looked at a number of factors including store inventory density, number of SKUs sold, days elapsed since the last audit, and which of the three company DCs serves the store.

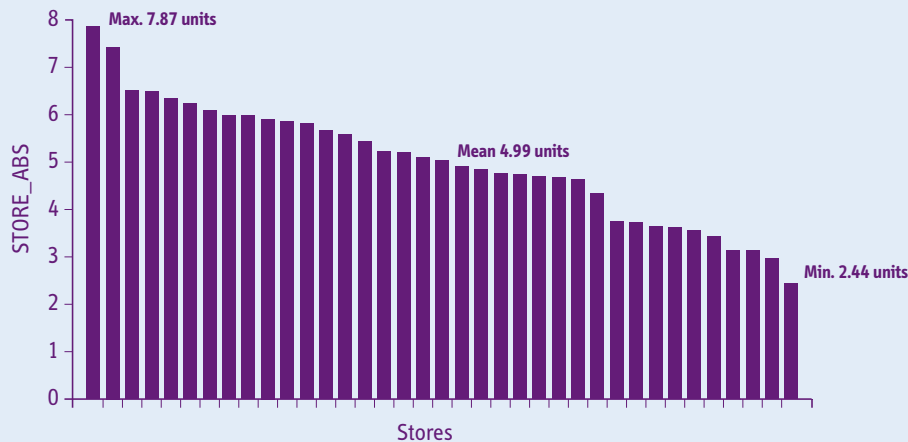
- *The DC that serves the store.* Gamma stores do not receive merchandise from more than one company-owned DC. Although merchandise might be received directly from vendors, vendor-direct merchandise is excluded from this part of our analysis.

DC processes play a significant role in ensuring inventory record accuracy at stores. A new store audit conducted by Gamma revealed that 29 per cent of inventory records were inaccurate before a single customer had entered the store. We hypothesize that the ability to accurately pick and ship inventory to stores varies among the three DCs we studied: each DC is run independently by its own management team. Moreover, the DCs interact differently with the stores to which they ship. For example, one DC provides credits to stores that complain about mis-shipments more readily than the other two. That DC uses the credits as a source of valuable and continuous

feedback on the accuracy of its shipments. These differences lead us to expect inaccuracies to be a function of the DC that serves a particular store.

- *Inventory density at the store.* We expect more crowded stores to have higher levels of inaccuracy. Gamma stores, like those of many other retail chains, are becoming increasingly crowded as merchandisers stock more inventory in a fixed amount of square footage. Such crowding, measured by the total units of inventory per square foot of selling space, makes it difficult not only to track the movement of inventory but also to readily identify stockouts that, in turn, can be used to detect discrepancies between system and physical inventories. Because stockouts are easily visible, store managers can readily check the recorded inventory levels for these items and spot mistakes.
- *Variety (number of SKUs) at the store.* We expect inaccuracies to be higher at stores with more SKUs than with fewer: it is difficult to monitor large numbers of different SKUs. Increased product variety leads to stores carrying multiple items that are very similar to each other. Sometimes, it is difficult to differentiate them during the checkout process. As a result, salespeople may scan one item many times without recognising that the customer is purchasing multiple products that differ from each other. Similarly, SKU proliferation, according to DC

Exhibit 4: Average inventory error per item at each of the 37 Gamma stores



managers, leads to confusion in the DC “picking process”. Greater variety in stores usually leads to greater variety in the DCs serving them. A large number of similar SKUs implies that pickers in the DC may easily pick one SKU instead of another by accident. This is especially true if the SKUs are located in close proximity to one another.

- *Days since last physical audit.* System inventory levels are updated to reflect actual inventory levels immediately after an audit. Because these data subsequently deteriorate through errors in tracking transactions (such as inventory misshipments, incorrect inventory scanning and so forth), inventory inaccuracy might be expected to increase with the number of days since the last inventory audit.

#### A quality challenge

Inventory record inaccuracy poses similar challenges to the quality movement of a few years ago. Managers can take steps to reduce the frequency and magnitude of inaccurate inventory records or design policies that buffer against inventory record inaccuracy. However, retail managers are often unaware of the presence, extent, and magnitude of inventory record inaccuracy.

Gamma managers, for example, were unaware that their inventory records were substantially inaccurate. By drawing attention to the problem of inventory

record inaccuracy, our research has led Gamma managers to reassess the benefit they expected to reap from recent information technology investments. Information technology projects intended to improve supply chain performance – such as vendor-managed inventory (VMI) and collaborative planning, forecasting and replenishment (CPFR) – rely on the availability of accurate inventory data to improve decision-making.

Inaccurate inventory records cause firms to incur higher levels of stockouts (or lower fill rates) and maintain higher than planned inventory levels. Stockouts are particularly expensive for items with high stockout costs. Gamma managers, prior to our research, had identified roughly 250 “never-out” items that had extremely high stockout costs. Despite their importance to Gamma customer service, our research predicts that these items, being often inexpensive and likely to sell large numbers of units, are most likely to have inaccurate inventory records. Gamma managers realised that managing inventory record accuracy was an essential aspect of managing stockouts for these items.

Gamma management subsequently introduced a number of short-term changes to focus managerial attention on inventory record accuracy for these items. First, they altered the “mystery shopper” programme to reward a store if a certain

## Without accurate inventory records, automatic replenishment and electronic data interchange systems simply won't deliver their hoped-for benefits

subset of “never-out” items were in stock and penalise the store otherwise. Corporate managers also verify system and actual inventory levels for a few “never-out” items during their store visits. Gamma also decided to count “never-out” items more frequently to ensure greater accuracy.

Our study makes three contributions. First, it provides much needed empirical evidence that inventory record inaccuracy is a significant problem. Second, it uses extensive empirical data from multiple stores of one firm to identify drivers of inventory record inaccuracy. These include not only previously recognised variables such as item sales and cost, but also product variety and inventory density, variables never before associated with inventory record accuracy (to our knowledge). Third, it demonstrates that the problem of inventory record inaccuracy exists in contexts other than manufacturing where it previously has been observed.

There are, however, still many detailed issues which cry out for deeper understanding. Existing literature on supply chain planning and co-ordination assumes inventory levels to be perfectly known. There is considerable opportunity and need to document the extent of inventory record inaccuracy and its impact on a firm's and supply chain's profits, for example. We also need to

identify the optimal frequency of inspection (physical audits) under different circumstances. Additionally, research on optimal assortment and inventory levels for a given store size needs to take into account the impact of both inventory levels and product variety on the accuracy of inventory records.

Tackling inventory inaccuracy is vital for a simple but fundamental reason. Retailers are investing vast sums of money, management time and effort in attempts to calculate optimal stocking quantities, determine optimal frequency of replenishment and share inventory status with other firms in the supply chain. All these laudable goals depend on the prior existence of accurate inventory records. So do automatic replenishment and electronic data interchange systems that are widely seen as answers to our supply chain problems including poor forecasting and “the bullwhip effect”. Without accurate data, retailers and their suppliers are building their supply chain castles on foundations of sand.

### Further information

For an expanded paper proving further details of results, a discussion of methodology and detailed literature references, contact: [araman@hbs.edu](mailto:araman@hbs.edu)