# COMPARATIVE ANALYSIS OF ERRORS IN PRE-PICK AND BULK ORDER VOLUMES AT FRITO-LAY


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## ABSTRACT

Order picking errors have an adverse effect on performance because they contribute to lost time, resources and customer loyalty. Therefore, it is imperative that organizations reduce errors as much as possible. However, organizations cannot effectively reduce errors until they understand the factors that determine and influence them and can isolate the sources of those errors. Product distribution at Frito Lay is very critical in the supply chain activities of the company and understanding and managing the level of errors that occur at the distribution phase of operations is critical for the firm's long term sustained competitiveness.

This study examines Frito Lay's order filling processes and how order volumes affect the level of errors. The company uses two types of order picking technologies: pre-pick and bulk order, conventionally also known as pick-to-light and voice-pick technology respectively. The main objectives of the study are: (a) to examine the impact of size of volume processed at the distribution center on errors recorded for each order pick technology and (b) the impact of regional and seasonal differences across Frito Lay's distribution network.

The data pertaining to pre-pick volume, pre-pick error, bulk volume and bulk error were collected for ten consecutive quarters time period ranging from first quarter of 2009 to the second quarter of 2011 and across 16 divisional distribution centers in four regions of the U.S. The data were organized into a panel for analyses using Stata® 12.1. With no a priori foundation for choosing any particular structural equation form, a number of structural equations were estimated and compared to consistency with economic theory and internal consistency. Two different sets of models were estimated: one for each

technology. The regression results from the analysis from the pre-pick order picking technology models showed the quadratic model was the “best” model, whereas the linear model turned out to be the “best” structural form for bulk order picking system.

This research provides valuable information to management in attempt to address errors in the order fulfillment system. Because errors may be human, and these human errors may emanate from lack of knowledge or poor skills, they can be addressed with training and education. The human errors may also be a result of processes in the plant. These could be addressed by the reconfiguration of processes and educating people about those processes. Finally, the errors may be motivational, leading to poor focus in executing responsibilities. To address these types of errors, management may choose to implement both positive and negative incentives. Positive incentives will provide rewards to employees who meet error reduction targets that are established at the beginning of certain periods. Negative incentives may include penalties for exceeding pre-specified error thresholds.

The Frito Lay system would benefit more from this research if the data had included human resource demographic data as well as economic information. It would have allowed the research to estimate the effect of errors on the economic performance of the different distribution centers and help determine the economically optimal level of errors at the different centers.

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# CHAPTER I: INTRODUCTION

Frito Lay's supply chain strategy is centered on retaining it's snack food market shares and be the industry leader in innovation of delivery of products from the farm to the store shelf. This is Frito Lay's competitive strategy for creating customer value and maintaining operational effectiveness, efficiency and product differentiation. At the heart of the company' distribution center are two order picking technologies: the Pre-pick (pick to light) and Bulk (voice directed) picking technologies used to fill order volumes. Pre-pick system consists of light displays that are installed on each fixed pick location in shelving units called packing modules, case flow racks and storage racks. Order picking tasks are uploaded to a modular system that lights up the display units one at a time as operators pick each order line. The light display identifies the pick location where the task is to be performed and the header display unit indicates the pick quantity and carton/tote to put the product into. The operator typically pushes a button on the light display unit to confirm the pick task has been completed. The fundamental advantage to pick to light system is that it is a visual technology that supports high speed order picking rates at manageable accuracy levels and best used to customize for assortment orders to meet changing consumer demands.

With voice directed or bulk picking systems, has an operator wear headset with microphones and communicate orally with a software system in real time to receive and confirm picking tasks in the warehouse. The computer voice instructs the operator to go to a pick location and pick the designated quantity along with any other instructions that are required to complete the work task. The fundamental advantage of voice directed picking is that it enables "hands-free" (and to extent "eyes-free") picking technology that means the operator’s only focus is finding the right location and picking the right quantity, and therefore is often associated with high accuracy and manageable efficiency (speed)

The pick to light system is used to deliver customized assortment orders that allows Frito Lay sales associates, also known as routes sales representative (RSR), to place assortment orders at a distribution center based on sales forecast models from store shelve condition, purchase history and previous years forecast models. Using a handheld computer, these orders are transmitted to a Frito Lay warehouse where the orders are picked at packing modular system consisting of several bays and are loaded on door to store delivery (DSD) trucks by a warehouse operations employee. The pre pick volume orders are placed by mid to low volume sales stores such as gas stations and independent stores. The voice pick orders are transmitted to the distribution center by the RSR using a similar method as Pre-pick, but in the case of Bulk order it is processed and picked using voice technology by the warehousing employee. At a Frito Lay distribution center, the size and the nature of volume order dictates the processing method used to fulfill the order, such as full case volume orders or assortment individual bags (eaches). Typically bulk or full case orders are placed by major multinational retailers such as Wal-Mart, Kroger, Target, etc. These formats of orders are processed using bulk voice pick system.

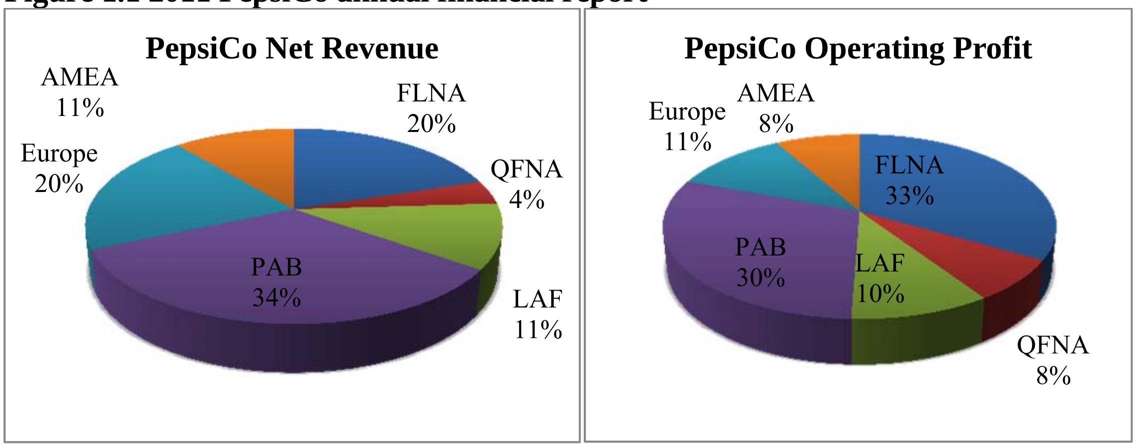
Logistics is a term used to refer to the planning framework used in the management of material, capital, service, and information and in an organization. It comprises increasingly intricate information, control, and communication systems required in today's economic environment. A distribution center utilizes logistics systems to fulfill the orders of its customers from its warehouses. Logistics systems assist in obtaining materials from various suppliers as well as assembling (or sorting) orders to fulfill customer orders. Often, distribution centers deal with order picking as a key function in distribution. Logistic systems are also used in retrieving items from storage locations to the transport units that are in turn used to deliver goods and commodities to customers' picking stations. Several decisions have to be made when designing a firm's order picking system (OPS). Among these are the establishment of picking-area layout, determination of storage policies, and configuration of a good storage and transport system. Other considerations include the picking method, material-handling equipment, picking strategy, and pick-assist technology (Ragatz et al. 2002). To maximize output and minimize cost and errors, one has to set a number of operating parameters. These can enhance business operations and assist in reaching the company's goals.

### 1.1 Company Overview

In 1932, C.E. Doolin entered a small San Antonio cafe and purchased a bag of corn chips. Mr. Doolin learned that the manufacturer of the chips was eager to sell his small business, so he purchased the recipe, and began to sell FRITOS® Corn Chips from his Model T Ford. Meanwhile, that same year, Herman W. Lay began his potato chip business in Nashville by delivering snack foods. Not long after, Mr. Lay purchased the manufacturer, and the H.W. Lay & Company was formed. H.W. Lay & Company became one of the largest snack food companies in the Southeast. Years later, in 1961, the Frito Company and the H.W. Lay Company merged to become Frito-Lay, Inc. Headquartered in Plano, Texas. In 1965 Frito-Lay and Pepsi-Cola merged to form PepsiCo. Today, Frito-Lay, the leading convenient foods company in North America brands, accounts for 60% of the U.S. savory snack market. Frito-Lay generates more than $13 billion in annual sales. Frito-Lay is PepsiCo's largest North American division, representing 20% of PepsiCo's net revenues and 33% of PepsiCo's operating profits with more than 30 plants, more than

16,000 sales routes and 200 distribution centers across the U.S. and Canada. PepsiCo report results under six segments: PepsiCo Americas Beverages (PAB), Frito-Lay North America (FLNA), Quaker Foods North America (QFNA), Latin America Foods (LAF), Europe and Asia, Middle East & Africa (Figure 1.1)

**Figure 1.1 2011 PepsiCo annual financial report**




Source: PepsiCo, Inc. 2011 Annual Report

Today Frito-Lay is a globally recognized company with the distribution of over 400,000 accounts selling services and food snacks around the US. (PepsiCo Annual Report). The firm offers over 100 lines of various branded products including Ruffles, Tostitos, Lays, Doritos and Rold Gold. Frito-Lay has an extensive coverage of the market through placing their products in retail outlets, wholesalers, grocery stores, vending machines and supermarkets. The distribution of snacks between the firm's distribution centers and supermarkets around the U.S. rose by about 56% according to data analysis by PepsiCo. Frito-Lay's biggest competitor in magnitude is Nabisco snacks. Other competitors in the same market are regional brands such as Philadelphia's Utz, Synders, Old Dutch, Bravo and Herrs. They each have to differentiate their products from Frito-Lay to compete with Frito-Lay. Frito Lay works hard to retain its market share as well as positions among the big firms in order to avoid losing their supply chain efficiency from seed to shelf.

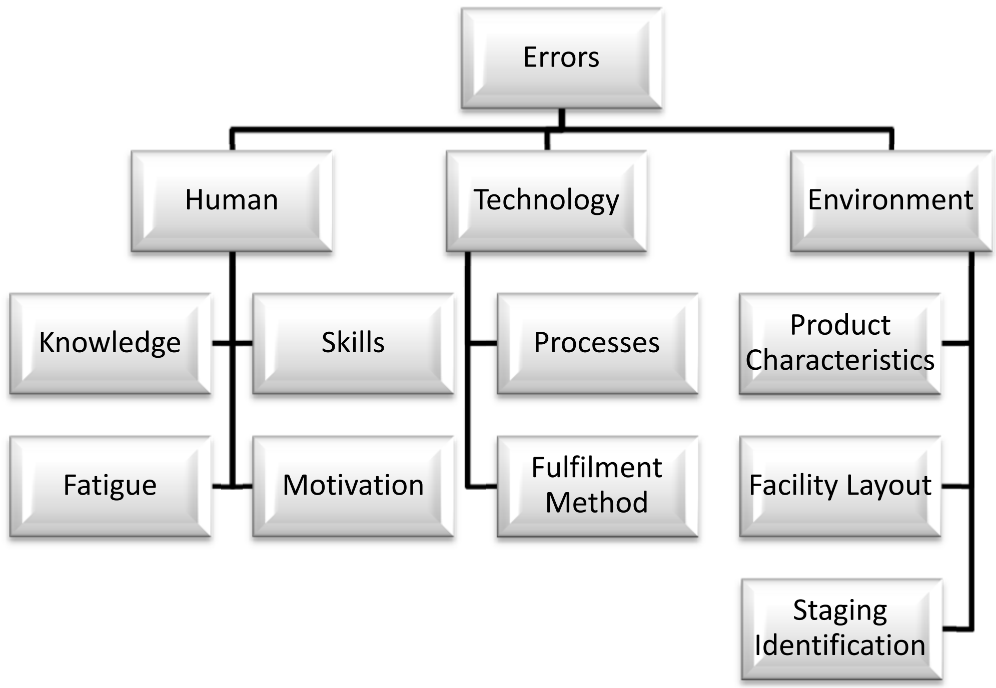
Frito Lay’s supply chain strategy is centered on retaining snack food market shares and to be the industry leader from innovations in research and development to the delivery of products from farm to the store shelf. Frito-Lay’s supply chain emphasizes a close relationship between the functional strategies within the whole chain, which is crucial to satisfying customer needs and enhancing profitably. These functional strategies cannot be formulated in isolation. They are closely intertwined and must fit and support each other if the company is to succeed in its mission. Supply chain optimization is a strategic competency for Frito Lay and a source of competitive advantage for creating customer value and enhancing the firm’s ability to gain and retain profitable business relationships by focusing on customer service and identifying any quality gaps and implementing continuous improvements to close those gaps. After all, the primary purpose of any supply chain is to satisfy customer needs by creating value and, in the process, maximize the overall value (supply chain surplus). Implementing service delivery improvement processes by addressing errors at distribution center is a competitive advantage for a firm in reduced cost; enhanced service and increased customer satisfaction. The three ways an organization such as Frito Lay can create customer value are through: Effectiveness (Meeting customer requirements in key ways, these include order accuracy); Efficiency (Providing service/product at an acceptable price for customer); and Differentiation (ability to create value-uniqueness and distinctiveness of service that customer’s value through innovation and continuous improvement.

### 1.2 Background and context

Frito-Lay a division of PepsiCo is responsible for manufacturing, marketing and selling potato chips, corn chips, and other snacks and sauces. Frito-Lay owns over 1,830 warehouse, and distribution centers, and offices worldwide and maintains over 30 production plants. This makes Frito Lay the biggest snack food distribution company in the world. In total, its sales comprised of about 60% of the savory snacks sold across the United States in 2009. Frito Lay categorizes its products into two groups based on the production location: foods manufactured or produced in the United States and those manufactured or produced outside the United States. Frito Lay’s core snacks include brands such as Cheetos and Fritos Corn Chips, Doritos, and Tostitos Tortilla chips. Others include Ruffles, Walker’s, and Lay's potato chips. Each of these brands generates annual worldwide turnover of over $1 billion in 2011. The firm also comprises numerous brands other than the chip category. These include Rold Gold pretzels, True North nut clusters, Cracker Jack Popcorn Snacks and nut crisps.

The numerous divisions of Frito Lay all act as distribution centers. The process of delivering goods relies on communication and efficient transport systems. Frito-Lay utilizes the latest technological equipment to enhance better, smoother transitions between purchasing, ordering and delivering goods. The mechanism to process volume orders at distribution centers and to deliver to the market at Frito-Lay comprises of two different order-processing systems. One is where goods are pre-picked in assortments of small formats using picking modules, and the second method is where the goods are delivered in bulk orders, which is usually full case orders destined for high volume retail outlets. It is expected that goods delivered in would bulk present minimal fill errors while those processed through pre-pick present significant errors that can be introduced at any of the stages from fulfilling orders by the distribution operation group to delivery at the store by the route sales representative. However, the extent of the differences between the errors in these two ordering methods is unknown. To what extent are pre-picked ordering errors higher than those of bulk ordering method, and is this significantly higher to warrant a strategic shift or management action? While any error in a system is unacceptable, there is a cost to error reduction and returns from those reductions. Thus, analysis of the relationships between the marginal benefits emanating from activities to reduce errors beyond a certain point have to be compared with the gains from such reductions. This study will look into at the distribution mechanisms of Frito-Lay in an attempt to determine the above mentioned error prevalence in filling out order volumes using data collected in the ten quarters ranging from time period of the first quarter of 2009 and until the first two quarters of 2011 were analyzed. Errors in order picking systems at Frito Lay distribution center operations is measured in terms of adjustments to an invoice at the point of sale. Errors fall broadly in three categories under picking over picking or mispicking an order, for example an order calls for 10 units of item A and operator picks 7 units of item A; therefore 3 units under pick error, Order calls for 5 units of item A and operator picks 10 units of item A; therefore 5 units over pick resulting in 5 errors and order calls for 10 units of item A and operator picks 10 units of item B; therefore 10 units resulting in 20 units of errors for wrong item pick. Source of picking errors in a distribution center fall into three broad categories (Figure 1.2): human, environmental and technological factors (Piasecki, 2003). Human errors can be knowledge, skills and/or focus/attention driven, while environment errors can be inventory characteristics, storage and staging identification housekeeping, and technology factors include order picking methods and the technology used to pick order.

**Figure 1.2 Sources of Errors**




Source: Adapted from Piasecki, 2003

The overall objective of this research is to evaluate the impact of volume orders processed on the amount of errors recorded in each of the bulk and pre-picked ordering systems and to determine the effect time (quarterly) and regional variability has on order fill errors. Management at Frito Lay distribution centers work under strict supply chain metric performance that requires a continuous improvement of accuracy, efficiency and minimization of errors in the order picking and delivery systems.

# CHAPTER II: LITERATURE REVIEW

A higher percentage of the quantitative research conducted addresses integrated logistical scheduling for the simultaneous development of various managerial decisions in Frito-Lay, including production systems, facility location, inventory management, procurement decisions, distribution, and the capacity to serve the consumer market. Frito Lay's problem focuses on integrated logistical preparation with a focus on coordinating product and transportation decisions. Specific interests have been shown in this field, but few analysts and researchers have analyzed this specific problem.

Logistical and academic studies have documented the various problems underlying distribution systems within Frito-Lay's numerous distribution centers and retail outlets (Thomas and Griffin. 1996). That study was restricted to previous research that examined picking and delivery of a volume order using pre pick or bulk order filling systems. Use of technological equipment, human labor and mechanical equipment to facilitate movement and order delivery is integrated into the study (Ragatz et al. 2002).

## 2.1 Background Information

Rudimentary stock handling models largely overlook this interaction because early theories assume that as soon as demand is created, it should be satisfied an immediately, leaving the transportation expenses to be covered by the customer (Cetinkaya, 2004; Sarmiento and Nagi, 1999). According to (Archetti et al. 2007), with this system, distribution costs are minimized. The past systems have been replaced, and recent studies have proven otherwise; for private-fleet suppliers who focus on distribution towards other destinations, this has not been the case. For instance, Vendor Managed Inventory (VMI/D) has been the focus of academic research during the past decade. Frito Lay participates in a vendor-managed inventory and delivery (VMI/D) program. Under a typical VMI/D program, a vendor is empowered to control its resupply timing and quantity at downstream locations (Cetinkaya and Lee 2004). Because effectively using transportation resources is imperative, a vendor is more likely to dispatch full-vehicle outbound loads to achieve economies of scale. However transport and distribution costs have increased, thus compromising distribution (Cetinkaya and Lee 2004, Toptal and Cetinkaya 2006). So far, two types of research emphasize on the interaction between stocks and transportation decisions (Bertazzi et al. 2005).

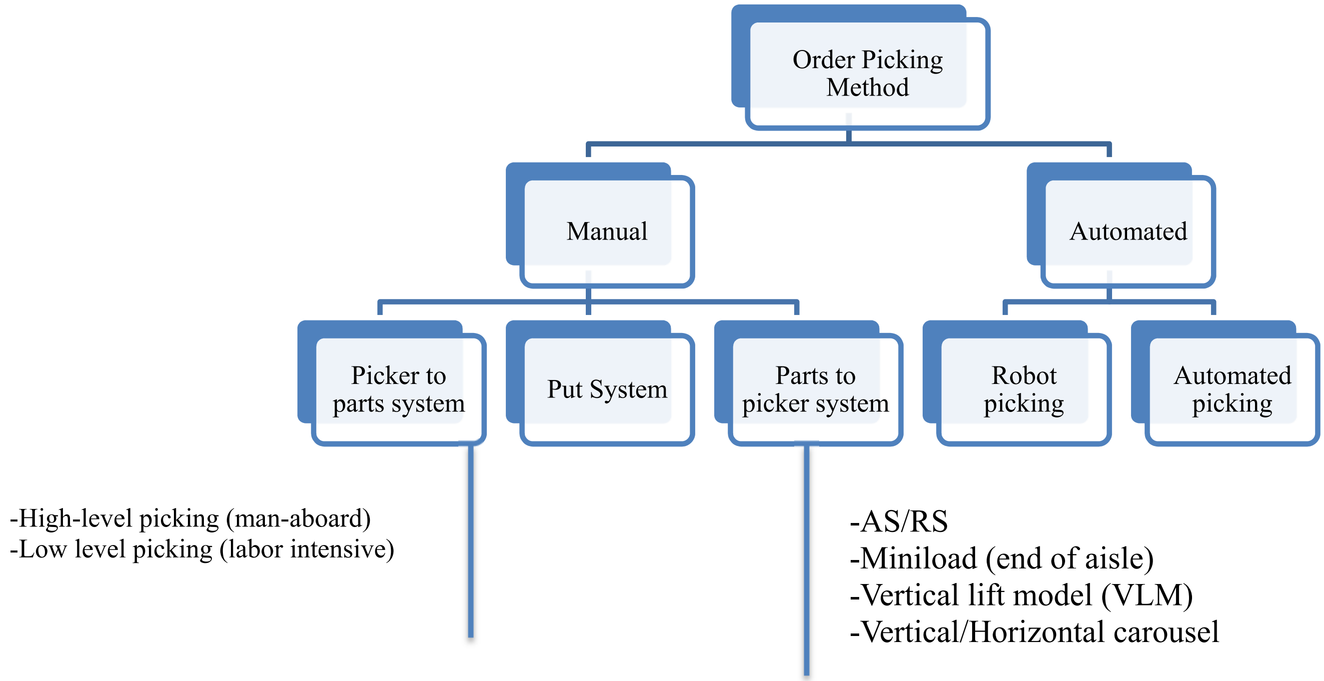
One approach models transportation costs as well as capacities in the inventory problem without measuring transportation-related policies such as joint replenishment, dynamic lot sizing, one-warehouse multi-retailer, problems in buyer-vendor coordination, classical economic order quantity and stochastic dynamic demand (Kleywegt et al. 2002). Most research (Cetinkaya 2004) in this field has neglected vehicle-routing considerations and placed more emphasis on stylistic supply chain parameters (Toptal and Cetinkaya 2006). In these systems, the vendor deals with a single buyer, or alternatively, multiple buyers, but the discussion on transport and delivery channels are left unaddressed. Transport systems and channels affect the delivery of a product when there are distribution center. This this has to be examined into to avoid losses that result from poor handling of transit goods. It is worth noting that errors may arise from any juncture within the supply chain; from the factory, to the distribution centers, and in transit to the picking point of the customer.

The second approach focuses on the integration of stocks and transportation policies by explicitly integrating both stock-related and transportation-related evaluation variables. The problems mentioned in transport routing problems by these authors and analysts range between vehicle-routing problems and delivery-routing problems (Viswanathan and Mathur 1997). It is also worth noting that the main problem in transport and supply chain mechanisms is characterized by forms of the inventory-routing problem as well at its various extensions (Kleywegt et al. 2002; Archetti et al. 2007; Bertazzi et al. 2005; Lee et al. 2006). Campbell and Savelsbergh (2004) studied the inventory-routing problem as part of the supply chain (Bertazzi 2008, Fumero and Vercellis 1999). In their research, they found that there were vehicle-routing problems whereby the vendor allowed for no shortages in the sizing, timing and routing parameters to influence the efficient delivery of inventory at the customer's picking point.

## 2.2 Order picking

Order picking systems have been used to manage the distribution center. Examples of order picking systems include clustering and scheduling of orders for customers, as well as the process of releasing the goods to the floor, and then picking them from the warehouse or storage. The final step is moving the goods to the customers. Many different order-picking systems are used in distribution centers and warehouses, where at times, several models are applied in the same warehouse. The following figures illustrate different stacking and order picking systems that are used in distribution centers.

**Figure 1.3 OP systems, where both humans and automated machines are utilized**




Source: Classification of order-picking systems (De Koster 2004)

Most warehouses use humans for the picking and distribution of their products, which include monitoring movement of inventory, walking or recording units along the warehouse's aisles, and/or picking up things. There are two types of switch-to-parts mechanisms, namely low-level and collection of high quality. In low-level OP systems, it is trusted to the order picker to take the requested inventory from shelves or storage spaces (bin-shelving). It is like a customer moving up and down the aisles in a grocery store filling his or her shopping basket with the required products. Given the intensity of the labor involved, low-level systems are often referred to as OP manual sampling methods. Some other order picking systems have higher shelves, where pickers are required to travel to positions to use a forklift to pick the specific item. Cranes are also used where the crane moves to the storage space as indexed in the automated storage system and awaits instructions to pick the item from storage container. This type of storage system is referred to as high level or a man-aboard OP.

Parts to picker mechanisms include the storage as well as retrieval systems (AS / RS) where a crane is used for most driveways. Additionally, a timetable is used for the resumption of any cargo units. The same can be used to support the load at the removal position (i.e., point E / S). This type of mechanism is known as the unit or system OP. Automatic machinery like cranes are used in different modes. The order is picked from the aisles and then taken to a recovery position where the humans receive the load and move it out to the next storage location or transport unit.

**2.3 Ways of achieving a good order delivery**

A key performance metric used in the supply chain industry is to measure to achieve perfect orders. This means that the order was delivered on time and in full without faults or errors, as well as with the appropriate paperwork. This is achieved when all the workers use the right performance methods in the supply chain and the right metrics indicators are in place to achieve efficiency and accuracy. This is a leading measure of a competitive strategy that differentiates one company from others. At Frito Lay along with order picking efficiency, order accuracy is a key performance measure used to monitor the level of service performance to customers and tracked to improve distribution center performance goals.

When shorter order lead times are used, a company can attain advantage over other competitors in the market. For instance, the more efficient and shorter the order lead time, the faster the delivery, therefore, there are less stale or spoilt goods. The customer receives the goods at the required time and in the right condition at the time of delivery, or shortly after placing an order. This reduces the loss and error in the supply chain mechanism. The delivery of the products is considered good and the quality of the products is maintained at stated performance levels. The customer places orders and gets them at the right time, place, condition, and with appropriate paperwork. This puts pressure on the competition due to the advantage earned through efficient, fast, timely and precise measures (McGraw 1996). With the technological equipment used at Frito-Lay, this can be achieved, and thus reduce costs. The use of multiple channels can also assist in timely bulk delivery using the right parameters. It is important that customer orders pass through an administrative unit that takes on the responsibility of double-checking that the orders are filled and the orders leave the warehouse. Pre-pick orders can present the warehouse operations team with a number of challenges, which include erroneous management of the pre-picked orders. It is at this point that there evolves errors in the order volumes picked and delivered. Each order has its own pick requirement, and if the supply chain at Frito-Lay fails in any way during the delivery of the orders, then the customer finds the delivery to be inefficient.

# CHAPTER III: METHODS

Frito-Lay uses two metrics to measure the performance goals of its distribution centers: efficiency and accuracy. The main methods used in conducting this research include data collection and econometric analysis of data from the company's sales and distribution services from first quarter of 2009 to second quarters of 2011[1]. The collected data were analyzed using analytical techniques where ordinary least square regression methods were applied to test the hypothesis at the start of this research. Since the data collected for this study has time series component of ten quarters and cross-sectional components for 16 regional distribution centers, with volume order and corresponding errors, panel analysis can provide insight into the analytical questions in the study.

## 3.1 Panel Data

Time Series Cross Section (TSCS) data also known as panel data, is a cross-sectional dataset that varies over two or more different time periods. Panel data often arise in matched data that change over time and across units such as: business practices across firms, firms that borrow from several banks, a sample of employees that serve different organization. Panel data combines distribution activities of 16(n) regional distribution centers at Frito Lay over time period of ten quarters (T). Along with the cross-sectional units of fulfilling customer volume orders using either pre-pick or bulk volume filling methods and associated respective errors for each of the 16 regions, there are 10 periods, yielding an 160 observations (N) with explanatory variables of respective volume order for each order type, error as the endogenous variable and quarterly and seasonal variation recorded as dummy variables.

[1] The last sales data recorded for the study was two weeks before the end of third quarter, because of the author changing jobs.

### 3.2 Regression analysis

The variables used in the study include pre-pick order volume, pre-pick volume error, bulk order volume, bulk volume order error, regional and quarterly dummy variables. Descriptive statistics are used to analyze the mean differences with respect to the error changes recorded in respective samples for the last ten quarters. Regression analyses are used to evaluate the ability of the model based on the variables to detect volume impact on error errors recorded. To determine the best structural relationships between error (the dependent variable) and the independent variables, several functional forms were estimated and the "best" one chosen based on the results. The "best" model is then tested for specification error using Stata's Linktest command. This test regresses the actual dependent variable on the predicted dependent variable and the square of the predicted variable from the regression. If the model is specified accurately, then the predicted variable alone should be the only significant variable in the model. On the other hand, if it is misspecified, then other variables in the model will exhibit statistical significance.

For each regression model for Pre-pick or Bulk volume as the independent variable that will be used to determine whether the level of volume order processed have significant impact on the amount of errors recorded in the two ordering picking technologies. To quantify and understand if any seasonal or regional variation makes a difference, dummy variables are introduced into the analysis. For example, from the four regional distributions, we define a dummy variable North that is 1 for all North region observations and 0 for other regions; we can also define a south dummy variable that is 1 for southern distribution centers and 0 for others. In this case we will have to leave out one of the four regions in not have perfect multicollinearity among the dummy variables and the intercept. We will leave out the central region distribution centers as the reference category. The coefficients of the other variables measure the difference between each of the other regions and the central region. For seasonality, the fourth quarter is left out as the reference in the same analogy as the regions.

It's important to note that in the regression analysis, the relationship between one independent variables and a dependent variable shows the magnitude and direction of that relationship, however, regression does not show causation; causation is only demonstrated through substantive theory. For example, a regression with a pre-pick and bulk volume as an independent variable and error as a dependent variable would show a very high regression coefficient and highly significant parameter estimates for both pre-pick and bulk volumes, but we should not conclude that higher volume order processed at distribution center causes higher order errors. All the statistics indicate is whether or not they are correlated, and if so, by how much. It is important to recognize that causation is established through theory. To represent feasible relationships between error and volume in the study, the choice of a functional forms for an equation is important part of the specification of that equations several functional forms can explain the relationships from a simple linear regression model (in the Classical Assumptions, linear in the coefficients) to alternative functional forms such as polynomial, semi-log, double log, each was explored for both order picking methods. Linktest is used to detect any misspecification error in choosing the most feasible model, and "robustness regression check" was used as evidence of structural validity and plausibility

## CHAPTER IV: DATA ANALYSIS AND RESULTS

The data used in the study were obtained from Frito Lay's sales and operation measurement analysis recorded from the first quarter of 2009 to the first two quarters of 2011 for each of the order picking technology. This refers to the volume of orders processed at Frito Lay's distribution centers from January 2009 through June 2011. Pre-pick and bulk order error volumes are the dependent variables in this research. They are obtained by number of order adjustments or error recorded with regard to pre-pick or bulk orders. The four Frito Lay divisions provided the data on their volumes and error volumes for the period under consideration. The model developed to explain these errors is as follows:

$$y_i = f(V_i, D_i, t) \qquad (1)$$

where $V_i$ is the volume shipped from each distribution center *i* in period *t* and $D_i$ is the dummy for the distribution centers while *t* is the dummy for the quarters in which the errors were occurred.

### 4.1 Descriptive Statistics

The summary statistics of the data used in the analyses are presented in Table 4.1. The results show the mean error under the pre pick method was more than 12,000 units compared to about 4,472 under the bulk pick method. The standard deviation for the mean error under pre pick was also much higher than what was observed under bulk. The coefficient of variation that measures the percent change in standard deviation per unit mean for the two errors were respectively 75% and 67%. Thus, while the coefficient of variation for pre pick error was still higher, it was not as high as the independent components of the coefficient of variation statistic. The results also show the mean volume order processed using the pre-pick method in the last ten quarters was 146,417 units compared to about 51,471 units filled using bulk order pick technology. The standard deviation for the mean volume under pre pick was also much higher than what was observed under bulk by ratio. The coefficient of variation, which measures the percent change in standard deviation per unit mean for the two errors were respectively 45.7% and 36.7%. Thus, while the coefficient of variation for pre pick volume was still higher, it was not as high as the independent components of the coefficient of variation statistic.

**Table 4.1 Summary of descriptive statistics at Frito Lay's distribution center**

| Overall<br>Variable | N | Mean | Std. Dev. | Min | Max | Coefficient of Variation |
|---|---|---|---|---|---|---|
| Pre-pick Vol. | 128 | 146,417 | 68,149 | 45,816 | 400,238 | 47% |
| Pre-pick error | 128 | 12,971 | 9,471 | 3,862 | 64,313 | 73% |
| Bulk Vol. | 128 | 51,471 | 19,354 | 25,879 | 106,883 | 38% |
| Bulk error | 128 | 4,472 | 2,818 | 1,016 | 13,364 | 63% |

In general, descriptive statistics inform much about the variables used in the study alongside offering a thorough discussion of the data including the mean, standard deviation recorded, and also the minimal and maximal values with respect to the variables. Descriptive statistics do not, however, allow conclusions to be made beyond the data we have analyzed or reach conclusions regarding any hypotheses we might have made. They are simply a way to describe our data. The mean is the average, the most common measure of central tendency. The mean for volume processed at Frito lay's distribution center in the U.S for the last ten quarters is 146,000 units for pre-pick and 51,000 units for bulk.

The standard deviation is the average difference between observed values and the mean. The standard deviation is used when expressing dispersion in the same units as the original measurements. It is used more commonly than the variance in expressing the degree to which data are spread out (Texas Auditor's Methodology Manual). In this study pre-pick volume and error are more dispersed when compared to bulk volume and errors. The coefficient of variation measures relative dispersion by dividing the standard deviation by the mean and then multiplying by 100 to render a percent. The average quarterly volume of pre-pick order was 146,000 units with average quarterly errors of more than 12,000 units, while the average volume of bulk order was 51,000 units with an average error of 4,472.

There is considerable variation of error rates (errors divided by volume) in pre-pick as compared to bulk. Figure 1.4 provides a comparative overview of the average error rates by region. Although at about 10%, Central Region has the highest pre-pick error rate, its bulk error rate was only second among the four regions at about 14%. The figure also shows significant disparity between bulk and pre-pick in each region. The pre-pick rate for the West was about 8% compared to a bulk error rate in excess of 16% on average. Figure 1.5 shows same average error rates by quarter. Unlike the regional comparison, there was very little difference between the bulk and pre-pick within quarters and also across quarters. For example, in no quarter was the average error rate was above 10.5% or below 7.0%. However, the first quarter presented the highest average error rates for both pre-pick and bulk systems.

**Figure 1.4 Mean Pre-Pick and Bulk Error Rates by Region**

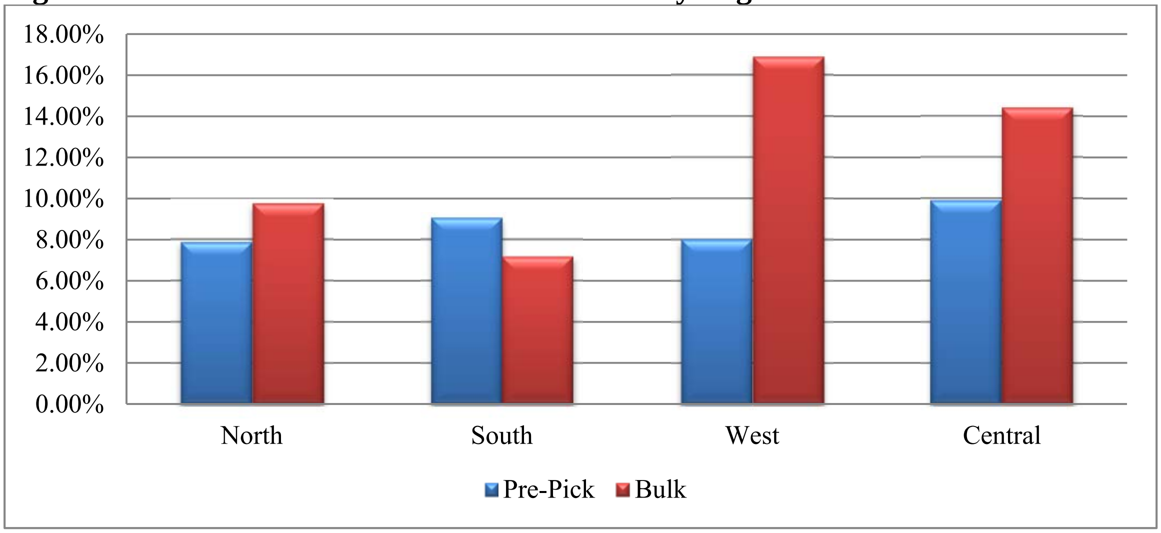
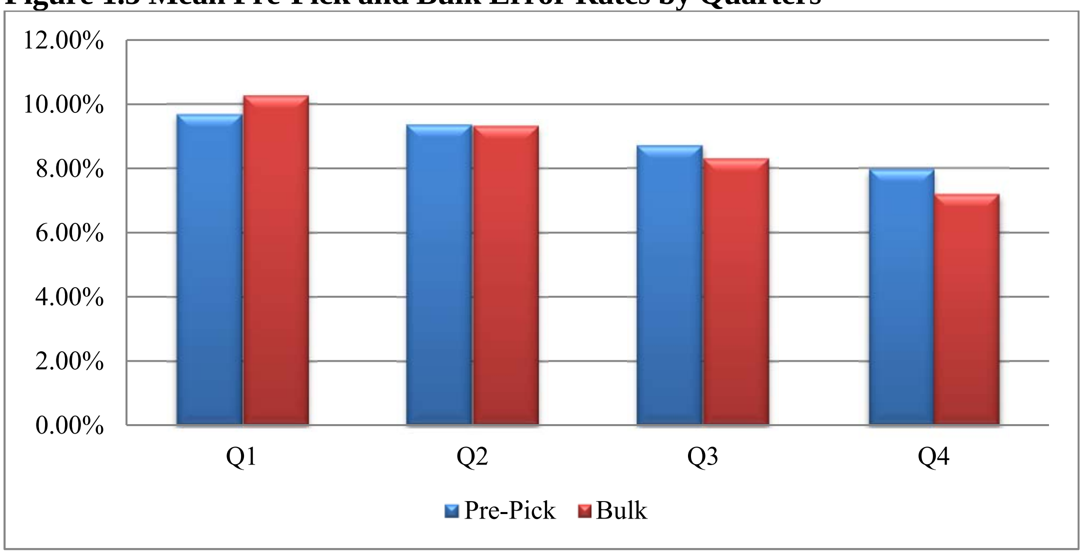



**Figure 1.5 Mean Pre-Pick and Bulk Error Rates by Quarters**




## 4.2 Regression Results

Tables 4.2 show the results of the regression results for different specification of the models for pre-pick technology. The four specified models are linear, quadratic, semi-log and double-log functional forms. The "best" model for each technology was selected based on the theoretical expectations about the signs on the coefficients, the coefficient of determination, $R^2$, and the internal consistencies of the model estimated using Stata's Linktest command to test for misspecification errors. The idea behind Linktest is that if the model is properly specified, one should not be able to find any additional predictors that are statistically significant except by chance. Linktest uses the linear predicted value ($\hat{y}$) and linear predicted value squared ($\hat{y}$) as the predictors in the model.

The results for the pre-pick regression models table show the quadratic model presented the highest $R^2$, with the independent variables explaining about 69% of the variability of pre-pick error. Table 4.3 show the results of the Linktest for each of the specification model, the predicted value ($\hat{y}$) for the quadratic model, with a t-statistic of 4.8, was the only significant variable in the model, suggesting that the quadratic model was not a misspecified model. The F-value (8, 119) for the model was 33.52 indicating that the overall model was significant at the 1% level. The results show that volume was not statistically significant in explaining error but the square of volume was significant at the 1% level. Quarter 4 was the only period that exhibited significant difference from Quarter 1, which was used as the reference period in the models, exhibiting a statistical significance at the 1% level. The results show that the errors in Quarter 4 were nearly 4,000 units lower on average than the errors in Quarter 1. The other quarters exhibited the same signs, implying that they were both lower than Quarter 1. This would suggest that Quarter 1 has the highest pre-picked errors across all the regions. The Central Region was used as the reference region in the models, and no other region was statistically different in its errors from the Central Region. However, the signs indicate that with the exception of the Southern Region, all the other regions had lower pre-picked errors than the Central Region. The joint F-test F (3,119) for the quarters was 2.95, indicating that the quarters are significantly different from each other. Regional joint F-test F (3,119) was 1.13, indicating that the regions are not significantly different from each other, we therefore fail to reject the null hypothesis that there is a difference in the regions.

Tables 4.4 show the results of the regression results for different specification of the models for bulk order picking technology The results for the bulk regression models table show the linear model had the highest $R^2$, with the independent variables explaining about 45.1% of the variability of bulk error. The F-value (7, 120) for the model was 14.09, indicating that the overall model was significant at the 1% level. Table 4.5 shows the results of the Linktest for each specification model, the predicted value ($\hat{y}$) for the linear model, with a t-statistic of 1.7, was the only significant variable in the model suggesting that the linear model was not a misspecified model. The results show that the volume was significant at the 1% level in explaining error. Quarter 4 and Quarter 3 were significantly different from Quarter 1 at the 1% level and the 10% level respectively. Like in the case of pre-picked errors, the signs on the period coefficients suggest that Quarter 1 has the highest average bulk errors. The only regions statistically different from the Central Region were the Northern and the Western Regions. They were statistically different at the 10% and 5% levels respectively. These two regions also showed higher average bulk errors – in excess of 1,000 units – than the Central Region. The Southern Region, while not being statistically significantly different from the Central Region, showed a lower average bulk error about 278 units lower than the Central Region.

**Table 4.2: Regression for Pre-Picked Errors**

| Independent Variables | Linear | | Quadratic | | Semi log | | Double log | |
|---|---|---|---|---|---|---|---|---|
| | Coefficient | t-value | Coefficient | t-value | Coefficient | t-value | Coefficient | t-value |
| Volume | 0.11*** | 13.56 | 0.01 | 0.49 | | | | |
| Volume Squared | | | 0.00283*** | 3.74 | | | | |
| Log (Volume) | | | | | 15,459.42*** | 10.08 | 1.06*** | 14.31 |
| Quarter 2 | -532.52 | -0.37 | -399.95 | -0.29 | -551.82 | -0.33 | -0.04 | -0.53 |
| Quarter 3 | -1,562.13 | -1.09 | -1,298.02 | -0.95 | -1,614.58 | -0.96 | -0.11 | -1.39 |
| Quarter 4 | -4,227.41*** | -2.80 | -3,927.71*** | -2.73 | -3,466.94** | -1.96 | -0.25*** | -2.88 |
| North | -1,986.67 | -1.33 | -1,988.90 | -1.41 | -2,281.32 | -1.30 | 0.00 | -0.06 |
| South | -361.07 | -0.24 | 264.28 | 0.19 | -2,067.01 | -1.20 | 0.07 | 0.87 |
| West | -1,656.16 | -1.10 | -1,041.61 | -0.73 | -3,316.84* | -1.92 | -0.07 | -0.80 |
| Intercept | -1,241.61 | -0.64 | 6,186.08** | 2.28 | -166,094.30*** | -9.07 | -3.11*** | -3.52 |
| R-squared | 0.657 | | 0.693 | | 0.529 | | 0.668 | |
| Adj. R-squared | 0.637 | | 0.672 | | 0.502 | | 0.648 | |

* (10% level); ** (5% level); *** (1% level).

**Table 4.3: Linktest Results for Pre-Picked Model**

| Predicted | Linear | | Quadratic | | Semi log | | Double log | |
|---|---|---|---|---|---|---|---|---|
| | **Coefficient** | **t** | **Coefficient** | **t** | **Coefficient** | **t** | **Coefficient** | **t** |
| Pred (Error) | 0.07 | 0.37 | 0.95 | 4.80 | -0.53 | -2.55 | -5.37 | 2.76 |
| Pred $(Error)^2$ | 0.00003 | 4.88 | 0.0000011 | 0.24 | 0.00006 | 7.84 | 0.34 | 3.27 |
| Constant | 5696.77 | 396.0 | 333.09 | 0.21 | 7294.91 | 5.53 | 29.38 | 3.26 |

**Table 4.4: Regression Results for Bulk Error Model**

| Independent Variables | Linear | | Quadratic | | Semi log | | Double log | |
|---|---|---|---|---|---|---|---|---|
| | Coefficient | t-value | Coefficient | t-value | Coefficient | t-value | Coefficient | t-value |
| Volume | 0.10** | 9.30 | 0.09 | 1.53 | | | | |
| Volume Squared | | | 4.93E-07 | 0.09 | | | | |
| Log (Volume) | | | | | 5,128.01*** | 8.87 | 1.04*** | 8.65 |
| Quarter 2 | -451.64 | -0.84 | -451.07 | -0.84 | -469.46 | -0.86 | -0.13 | -1.17 |
| Quarter 3 | -935.84* | -1.74 | -935.02* | -1.73 | -957.45* | -1.75 | -0.20* | -1.75 |
| Quarter 4 | -1,826.09*** | -3.27 | -1,826.50*** | -3.26 | -1,826.08*** | -3.20 | -0.39*** | -3.27 |
| North | 1,014.52* | 1.88 | 1,017.43* | 1.88 | 1,041.63* | 1.89 | 0.31** | 2.73 |
| South | -277.58 | -0.52 | -277.98 | -0.51 | -206.55 | -0.38 | -0.11 | -0.97 |
| West | 1,062.12** | 1.97 | 1,067.34* | 1.97 | 988.23* | 1.80 | 0.24** | 2.15 |
| Intercept | -174.65 | -0.24 | -31.35 | -0.02 | -50,469.39*** | -8.08 | -2.90** | -2.24 |
| R-squared | 0.4511 | | 0.451 | | 0.429 | | 0.445 | |
| Adj. R-squared | 0.419 | | 0.414 | | 0.396 | | 0.413 | |

* (10% level); ** (5% level); *** (1% level).

**Table 4.5: Linktest Results for Bulk Model**

| Predicted | Linear | | Quadratic | | Semi log | | Double log | |
|---|---|---|---|---|---|---|---|---|
| | **Coefficient** | **t** | **Coefficient** | **t** | **Coefficient** | **t** | **Coefficient** | **t** |
| Pred (Error) | 0.76 | 1.71 | 0.94 | 2.15 | 0.27 | 0.57 | 5.61 | 1.87 |
| Pred $(Error)^2$ | 0.00034 | 0.55 | 0.00005 | 0.15 | 0.00011 | 1.61 | -0.29 | -1.54 |
| Constant | 394.37 | 0.49 | 107.33 | 0.13 | 1130.87 | 1.42 | -18.41 | -1.54 |

Elasticity allows for the estimate of the response rate in the dependent variable to a percentage change in the regressor of interests. The bulk and pre-pick volume elasticities of error were estimated using Stata's "margin module" which estimates the elasticities for each observation in the dataset and reports the average. The result for the pre-pick volume elasticity of pre-pick error was 1.07, significant at the 1% level. This suggests that, on average, a one percent change in volume would result in a 1.07% change in errors in the same direction. For bulk, the elasticity was 1.19%, showing that the response for bulk is nearly three times as large as the response for pre-pick.

# CHAPTER V: SUMMARY AND CONCLUSIONS

The goal of this study was to determine the effects of volume, regions and time on the amount of error recorded for two distinct order picking technologies used at Frito Lay distribution centers. With no prior theoretical foundation for determining the right model to which to fit the data, the “best” structural equation was selected based on model statistics and the mis-specification test tool (Linktest) available in Stata, the econometric software used in the research. The selected models resulting from the experiment of structural equations fitted to the data were quadratic and linear for pre pick and bulk order picking technology respectively.

The direction and magnitude (size) of coefficients reveal the contribution of each of the variables to the overall impact of errors on volume recorded in the order picking technology. The results show that volume has a positive effect on errors regardless of the method used to fulfill orders. This would suggest that attempts to reduce error should be focused on managing the volume-error relationship. How does volume of product picked and/or fulfilled in the distribution center connect to errors?

## 5.1 Future Research

The direct relationship presented in this research is a simplification of a more complex problem that related to the sources of error in the distribution center (Figure 1.2). From this figure, it was pointed out that human sources of error can be influenced by fatigue, job knowledge and skills as well as motivation. It was also noted that errors could come from technological and environmental sources in the fulfillment process and the distribution center. The data available for this research only presents the errors without any information on the sources.

To address the challenges presented in this research, then, it is necessary to identify the sources of the errors that are measured. For example, if the errors are coming from human sources, then they can be isolated and dealt with. Errors caused by lack of job knowledge or skills, although often more complex, are actually easier to address than those caused by lack of focus. Employee training and skill development can be organized around areas considered to be specific points to increase employee awareness and overcome any challenges they face. For example, educating employees on the best practices on order picking can often resolve knowledge-related errors. Additionally, process changes can be made to eliminate barriers that contribute to errors. For example, the layout of storage in the warehouses can be organized to minimize fatigue and decrease error risks.

Focus related errors are much more difficult to improve due to underling factors such as motivation, stress, distractions and fatigue. The motivational literature provides some approaches to address the motivational factors influencing focus-related errors. For example, Markman and Brendl, (2000) discuss incentives such as approach and avoidance goals. Approach goals help people focus on desirable outcomes their activities produce, such as performance bonuses. Avoidance goals cover those that people work towards avoiding, such as penalties. Management can evaluate opportunities for creating motivations (positive and negative) to help employees develop acute perspectives to what they do and how they do them to minimize motivation-related focus errors. Frito Lay has recognized the importance of aligning incentive between groups in the supply chain to provide customer value, sales and operations now not only have to live by the mission of "one team, one goal", but together they impact each other's reward and recognition (incentives) for competition of award of operational excellence, which is nationally awarded to the region that created most customer value by metric of accuracy and sales profitability combined with significant payout. As explained in the science of success by Koch (2007), incentives do matter; especially when employee incentives are aligned with attaining business results of the organization outcome that is directly tied to their performance or contribution to the organization.

Stress, distractions and fatigue may be addressed by improving on-site physical activity facilities for employees. Research supports providing employees with recreational activities that help them improve their energy levels during the work period, enhance their attention, and in so doing contribute to reducing the risks for errors (Tsai et al. 2012).

Technology and environment sources of error can be addressed through the same process of isolating the source and its effect on the error and developing a credible and effective intervention protocol for it. The extent of the empirical benefit of this research is in identifying and quantifying the error-volume relationship for both fulfillment methods. The next stage of effectively addressing the problem is to go deeper and collect data on the sources of these errors in order to determine their relationships and magnitude of effect so that management can develop an effective strategic response to the problem.

Firms today face stiff competition, expanding global markets and increasing customer demands. These increase pressure on the firm to lower total costs and increase efficiency in the entire supply chain, shorten throughput times, reduce inventories, expand product choice, increase responsiveness to the market, improve quality and customer service, coordinate global demand supply, and manage changing production schedules. In order for firm to meet all these pressure points, it must adopt best practices, manage and use information strategically, control inventory from raw materials to finished goods and create long term customer value.

Regardless of error introduced at any of the five stages of the distribution process (receiving, put away, replenishment, order picking or consolidation), it is economically impossible to attain zero error in any system. As such, the strategy should be to reduce errors to the point where performance is maximized in each of the order fulfilling systems.

In light of the foregoing, it is strongly recommended that the company begin to collect data linking errors to sources and also to individuals so that the right actions may be taken. The link to sources allow a targeting of solutions to the appropriate source while knowing is causing the errors can allow for the determination of the appropriate intervention – skills, education, training, etc. Additionally, the link between errors and economic outcomes would be extremely helpful. Therefore, the costs of these errors – rework, lost sales, customer discounts, etc. – need to be identified too to facilitate estimation of the benefits-cost relationships for driving errors down. Recognizing the driving errors to zero is probably uneconomical, then knowing the constraints confronting the organization, it may be possible to determine the optimal levels of errors and volume, helping the company to structure its distribution centers to achieve the highest profitability per error rate.

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