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ANALYSIS OF PACKAGE LABELING:
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# ANALYSIS OF PACKAGE LABELING:
# AN EVALUATIVE TOOL TO COMPARE COST STRUCTURES AND IMPLEMENTATION OF POSTPONEMENT STRATEGIES

By

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**ABSTRACT**

**ANALYSIS OF PACKAGE LABELING:**

**AN EVALUATIVE TOOL TO COMPARE COST STRUCTURES AND IMPLEMENTATION OF POSTPONEMENT STRATEGIES**

**By**

**Irem Aydinsoy Kiyak**

The package labeling function within the pharmaceutical industry is examined for the purpose of developing a total cost simulation model for evaluating postponement strategies. A combination simulation-regression analysis is conducted using data obtained via the case study interview method. Based on these findings, variables were developed and tested in the model to determine the economic viability of postponing labeling to the distribution center level.

Different types of economic structure drive two separate printing technologies, namely plate (conventional) and plateless (digital). Depending on the technology utilized, pharmaceutical companies may generate cost savings through postponing the labeling function to the distribution center level in the supply chain. Digital printing is identified as an enabler to postponement due to significantly reduced setup times.

In conclusion, the study identifies and defines the product factors that have an impact on the total cost of printing labels for the pharmaceutical industry. Results indicate that the number of annual production runs is the factor that has the largest impact on total cost savings realized through the use of digital printing. Consequently, total cost savings achieved through digital printing technologies become increasingly greater as the number of annual production runs increase. The second largest impact is the number of brands, with the number of global markets and the frequency of marketing changes tied for the next order of importance. Managerial implications are discussed where labeling postponement becomes economically viable for a given product line in the pharmaceutical industry, based on the defined product factors.

***This dissertation is dedicated to my mother Saadet Aydinsoy, my father Halil Ibrahim Aydinsoy, and my husband Tunga Kiyak, for not letting me give up in hardship and for their endless patience, deep love, unconditional support, and confidence.***

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# CHAPTER I

# INTRODUCTION

It is only in the past decade-and-a-half that packaging suppliers have been considered as a strategic component of doing business and the supply chain (Cole, 1986). Alternative supply chain strategies such as postponement applied in forms of packaging or labeling can enhance supply chain competitiveness. Postponement is the delaying of product differentiation based on form, location, and/or time during manufacturing and logistics operations. The pharmaceutical industry for example, depends heavily on the labeling function of packaging. The timeliness of pharmaceutical labels is especially important for products under patent protection. Labels also play a very important role because they convey critical information to the consumers. Package labeling is also a vital milestone in launching a new drug or vaccine line, which is going through the initial regulatory approval process.

With the frequent changes in label regulations for the pharmaceutical industry, the manufacture/printing of labels becomes even more critical for increasing supply chain efficiency. Label obsolescence, inventory issues, and coordination of labeling process challenge the industry to provide the *right* labels at the best time and place, every time.

## GENERAL OVERVIEW

This study examines the cost structure of the supply chain for packaging label printing. The research is focused on investigating the label printing activities for pharmaceutical companies to present a total cost model that can be used to implement postponement strategies. The goal is to increase supply chain efficiency, maximize patent period utilization, and minimize total cost of printing labels. The need for this study has been determined from literature review and interviews with labeling companies. The model constructed will be validated through case study interview method.

Labeling postponement and speculation strategies have been discussed since 1988 as a cost saving mechanism (Zinn and Bowersox, 1988). Minimizing inventory and maximizing the ability and effectiveness of responding to customer orders are tools to help realize the ultimate goal of cost savings. The theory of postponement is a proven business strategy and has been practiced in the industry and widely accepted in the academic community.

Zinn and Bowersox (1988) analyzed labeling postponement as a type of manufacturing postponement and identified the specific costs that would be impacted. These include: (1) inventory carrying costs; (2) warehousing; and (3) processing (labeling). Adding to the Zinn and Bowersox approach, this study identifies the implications of postponement on the distribution cost for the package labeling process.

For example, the pharmaceutical industry faces constantly decreasing operating margins and tapering periods of market exclusivity between product approval and patent expiration (Hills and Gugliotti, 2001). For a blockbuster drug (over $1 billion in sales per year), a one-day delay of the initial launch of a new product costs up to $3 million (Trombley, 2003). The operating margins are tight and getting tighter due to short intervals of patent utilization. The frequent changes in the Federal Drug Administration (FDA) regulations also affect cost of package labeling operations, which may result in delayed product launch. The regulatory dynamics that are in place contribute as a critical factor to the timing of the pharmaceutical label production. Hence, pharmaceutical package labeling has severe cost implications for the supply chain.

In order to address the impact of package labeling postponement and costs on the supply chain, this study analyzes cost drivers for label printing and it identifies product factors influencing total cost for label printing and the decision to postpone label printing to the distribution center level. The analysis results in development of an economic model for implementing postponement strategies. The cost structure analysis of the pharmaceutical labeling function contributes significantly to the theory of postponement, promotes further research, and leads business people to further realize supply chain cost saving strategies.

## BUSINESS PROBLEM

Package labeling is recognized to have great potential for realizing cost savings in the supply chain. The challenges faced by the pharmaceutical industry constitute a pertinent starting point for the discussion of the business problem. The major impediments that the industry faces in package labeling are: limited patent period; regular content changes, and significant customization. Each are explained in detail below.

### LIMITED PATENT PERIOD

Patent period utilization is critical for pharmaceutical companies. To effectively utilize the patent period, rapid launch for products upon approval is key (McNeely, 2001). The final content requirements for the label are available only after the product is approved (McNeely, 2001). This leaves little time for companies to produce the labels and launch the product in order to make the most use out of the patent period (McNeely, 2001). In the case of postponement, the company chooses to wait until the approval on the final wording for the label is received. The other strategy is speculation where the company takes a risk and produces the labels without waiting for the final approval of wording of the label. The risk is substantial in this case since, if there are any changes, the whole label batch must be destroyed as specified by the FDA regulations and reprinted with the approved content (McNeely, 2001). Consequently, there are four probable business scenarios with their respective cost implications as summarized in Table 1.1 and explained below.

**TABLE 1.1**

Postponement vs. Speculation for Label Printing

| | Postpone | Speculate |
|---|---|---|
| Approval with change(s) | No Scrap or Rework<br>Decreased patent period | Scrap and Rework<br>Decreased patent period |
| Approval as is | No Scrap or Rework<br>Decreased patent period | No Scrap or Rework<br>Full patent period utilization |

The advantage of postponing label printing is to avoid the cost of scrapping and reprinting the entire label batch. On the other hand, the patent period is decreased compared to speculating when the label content is approved as is. Speculation is advantageous in the case of approval as is, but it is the most costly scenario of the four when approval comes with changes in label wording. The decision to postpone or speculate also depends on the type of printing technology that is employed by the company. The two types of printing processes utilized for printing on packaging materials are plate or press processes (conventional), and plateless processes (digital) (Twede and Selke, 2003). Digital printing technology is an enabler for postponement, since setup time is much shorter compared to conventional printing. With the goal to maximize patent period utilization, this research investigates the cost components for each decision and recommends strategies based on total cost savings.

## REGULAR CONTENT CHANGES

Label content change is an on-going activity because of the obsolescence of label requirements (McNeely, 2001). These changes are usually based on emerging safety issues. Therefore, the wording of the labels changes frequently and usually carries grave consequences for the consumers of the product (McNeely, 2001). This subsequently affects the demanded turnaround speed of the required package label supply chain, which could command the application of postponement–speculation strategies (McNeely, 2001). This could also become an impediment to patent period utilization through interruptions in product availability, hence inadequately satisfying the demand. As a summary, content changes add a factor (to patent period utilization) that influences the decision to postpone or speculate. The total cost model developed in this study, aids in the decision-making process (i.e. postpone or speculate).

## SIGNIFICANT CUSTOMIZATION

The substantial cost of market-specific labeling is a major cost factor (McNeely, 2001). Customization is especially critical for global markets with different label requirements, languages, and measurement units. McNeely (2001) states that digital printing theoretically presents a cost-effective approach to small-volume markets. Therefore, in order to serve these markets effectively, companies should analyze their supply chain for implementing postponement–speculation strategies. This also brings forth the issue of assessing the value of investing in innovative printing technologies, such as digital printing, or using providers of such services and reconfiguring the supply chain composition. Consequently, this study takes the customization factor into account in developing the tool for implementing postponement strategies.

## BUSINESS PROBLEM SUMMARIZED

These issues portray the importance of designing a model to analyze the cost structure of the package labeling and produce quantitative results for implementing postponement strategies. Postponement applications have been discussed as a global packaging strategy (Twede, Clarke, and Tait, 2000). Recent research has indicated that optimization of packaging logistics economies would justify postponement (Twede, Clarke, and Tait, 2000). Packaging and labeling postponement have been addressed as postponement strategies focused on costs associated with transportation, warehousing, and inventory carrying. (Zinn and Bowersox, 1988). The challenges affecting labeling (i.e., restrictions and regulations, labeling for global markets, and patent period utilization for pharmaceutical companies) have not been addressed using postponement strategies.

Preliminary interviews and brainstorming sessions with The John Henry Company (Lansing, Michigan) confirmed this challenge and revealed the existence of a viable business problem. Existing literature does not address these problems specifically for label printing. Therefore, a knowledge gap needs to be addressed and a model should be developed, which provides a solution to ease the predicament faced by the pharmaceutical industry.

## RESEARCH OBJECTIVES AND QUESTIONS

Package labeling is an important function that has great potential for realizing cost savings in the supply chain. In the literature and business practices, postponement strategies are being discussed and employed as a way to reduce manufacturing cost and increase efficiency. This study proposes to identify and analyze packaging postponement strategies and their implications for supply chain management. The objectives are to analyze the supply chain function for package labeling and to formulate a computer-based model that allows comparison studies by assessing postponement factors based on inventory costs and strategic benefits. Specifically, this research addresses the following questions:

- What are the significant cost drivers for package labeling and how does package labeling impact supply chain costs?

- What is the set of product factors that determine the total cost for label printing and affect the implementation of postponement strategies in package labeling?
- To what degree does each factor affect the total cost for package labeling and influence the decision to postpone package labeling to the distribution center level?
- What is the relative effect of these factors on postponement in package labeling?
- What types of management strategies can be derived from the model?

The study aims to use these questions to (1) develop a total cost model for the package labeling function (2) by defining the parameters that contribute to the supply chain, and finally (3) to use this model to suggest supply chain management strategies as they apply to package labeling operations.

## RESEARCH METHOD OVERVIEW

This study proposes to formulate a cost effective supply chain management tool that addresses the aforementioned issues by identifying the cost drivers for package labeling. First, product factors that affect the decision to implement postponement strategies are isolated. The typical value ranges for these product factors are identified through case study interviews. Next, the effect of each factor on the total cost of label printing and the decision to postpone is analyzed, first individually then relative to each other. Finally, the product factors that have the most significant impact on the total cost for label printing and the decision to postpone label printing to the distribution center level is identified.

This study uses the Packaging-Logistics System Integration concept (Twede and Parsons, 1997) as a starting point in exploring the package labeling function. Twede and Parsons (1997) indicate that logistical packaging facilitates all product flow during manufacturing and distribution. Package labeling is a critical operation supporting the communication function as part of this integrated system. The functions of packaging (i.e., protection, utility, and communication) form the basis of packaging value analysis, which is the foundation for cost structure analysis (Twede and Parsons, 1997). This concept is utilized in analyzing the impact of postponement on the total cost of package labeling.

Packaging postponement has been described as the most interesting example of the value of integration of packaging-logistics (Twede and Parsons, 1997). Postponement-speculation strategies probe when and where to add value in the supply chain for overall cost reduction. Since packaging can be a critical cost saving point within the supply chain, postponement strategies should be studied and cost structure models should be developed to evaluate the justification of such strategies.

This study considers all types of postponement (i.e., form and logistics) (Van Hoek, Commandeur, and Vos, 1998). In package labeling, for example form postponement can occur in situations where a pharmaceutical manufacturer waits for FDA label specifications before product launch instead of taking a risk and producing labels by speculating on the label requirements. Similarly, logistics postponement occurs when transfer of goods are delayed in the supply chain in order to satisfy demand more effectively (Van Hoek, Commandeur, and Vos, 1998). Zinn (1986) concluded that packaging and logistics postponement–speculation offers the most potential for realizing cost savings. Generalizations for measuring the extent of savings should not be based on the predictors of product physical and demand characteristics (Zinn, 1986). Therefore, this study aims to identify the factors that formulate the cost model analysis of package labeling to indicate where postponement strategies are economically feasible.

The Zinn (1986) model of postponement for labeling addresses the question of postponing the labeling function to the warehouse level instead of applying labels at the plant. The main cost categories that Zinn (1986) considered were labeling, inventory, and warehousing. The model that this study proposes to develop accounts for the package-label value within the supply chain by focusing on postponement factors and their effects on inventory costs, coordination expenses, and strategic benefits. Market characteristics, such as short product life cycles, benefit tremendously from postponement.

In order to address these issues and construct the model, cost drivers in package labeling are identified. The next step consists of quantifying the effects of postponement on these cost drivers. For this, a set of product factors that influence total cost of label printing and the decision to postpone label printing to the distribution center level must be identified and tested.

To answer these research questions, data is gathered using case study interviews from alumni and contacts of the School of Packaging at Michigan State University and the customers of the John Henry Company, a label printer and manufacturer in Lansing, Michigan. The case study is a research strategy that comprises an all-encompassing method incorporating specific approaches to data collection and analysis (Yin, 1994). For the purposes of this study, this method aids in comprehensively explaining postponement factors for label printing, and why and how these factors influence the decision to postpone labeling to the distribution center level. The result is the surfacing of various manufacturing practices and the reasons behind them. This helps the results to be placed into context where they may be better understood.

## RESEARCH CONTRIBUTIONS

The underrepresented area of packaging in supply chain management requires researchers' attention. The simplest business oriented reasoning for this stems from the fact that packaging and logistics postponement–speculation has the most potential for realization of supply chain savings (Zinn, 1986). In addition, Twede and Parsons (1997) suggest that the value analysis of a logistical system's packaging requirements has the potential to dramatically improve a firm's profitability. Through postponement-speculation strategies, firms can realize more profitability. Contemporary printing technologies can be enablers to postponing label printing to the distribution center level. However, digital printing technologies present complications in complying with label content security measures, as mentioned previously. Therefore, with the emergence of digital printing technologies the package label regulations can only be expected to intensify and the issue of label obsolescence can be significant. In addition, immediate apprehension of significant cost savings can be anticipated by optimizing the cost structure of label printing. Consequently, this study develops an evaluative tool to produce a cost structure analysis of the package label supply chain.

Package labeling is also a critical function within the supply chain in its role of providing accurate information. This is especially important in the pharmaceutical industry. The cost model of the package labeling function is quite complicated. It includes a setup cost, which generally justifies high quantity production. On the other hand, frequent changes in label requirements push manufacturers toward manufacturing small quantities. This needs to be investigated in order to bring solutions to these problems and to come up with optimal management strategies.

This study analyzes potential cost savings and recommends postponement strategies for package labeling operations. The model developed also forms a basis for similar cost analysis tools in other areas of supply chain management. Overall, this research paves the way for significant cost savings and points to further research on the critical function of supply chain management (i.e., package labeling).

# CHAPTER II

# LITERATURE REVIEW

This chapter is divided into four sections each corresponding to the research streams on which this study is based. The first section provides an overview of the current printing technologies for labels. The second section reviews the postponement-speculation research field. The third section focuses on the activity-based costing model to establish a reasonably accurate way to track the cost items of label printing. In the fourth section, the total cost concept is introduced and its applications are discussed. The last section identifies the gap in literature, discusses the ways in which this study is based on these four areas of research, and presents the justifications as to how this research addresses these issues.

## PRINTING TECHNOLOGIES

There are two types of printing processes utilized for printing on packaging materials: plate or press processes, and plateless processes (Twede and Selke, 2003). Plateless process is more recent and produced using digital imaging technology and is referred to as digital printing technology in this study. The plate printing processes used most for packaging include flexography, rotogravure, and offset lithography (Twede and Selke, 2003). For the purposes of this study, these are referred to as conventional printing methods. The two methods (i.e., digital/plateless printing and conventional/plate printing) present different cost structures and bring different solutions to the printing and converting industry.

One important characteristic of plateless/digital printing includes fast label turnaround, which is due to replacement of plates and films used in plate printing process with electronic data (Clarke, 2001). This also endows digital printing with minimal setup times, thus decreasing the associated fixed costs (Emden, 2001-2003). Images and text are prepared and proofed electronically in digital printing (Clarke, 2001). This presents some challenges in terms of securing the integrity of the label content that has been proofed and approved for printing (Emden, 2001-2003). Since data can be modified in real time, the physical forces that are used in plate printing to ensure integrity do not apply to digital circumstances most of the time.

Labeling regulations can be expected to tighten through emergence of digital printing technologies and the efficiencies that this technology brings. With traditional printing methods, such as lithographic printing, plates are approved for each label job. Digital printing, on the other hand, has the capability of modifying label content and design in real time and on-demand, which endangers the viability of security measures. Such security measures involve absolute containment of the label content, preventing it from being modified once it has been approved. In the case of digital printing, approved label content is in the form of an electronic file, hence it is easier and faster to modify.

The opportunity for better information sharing is increased with digital printing through electronic data storage (Clarke, 2001). In addition, the quick turnaround and minimal setup costs associated with digital printing makes delaying the label printing activity possible, hence allowing postponement strategies (Clarke, 2001). With digital printing, costs are justifiable for small quantity orders (i.e., customized wine bottle labels for a specific party) (Emden, 2001-2003). From a cost perspective, digital printing has lower fixed costs but higher variable costs above a certain quantity of labels when compared to plate printing (Emden, 2001-2003 and Bence, 2001).

Falkman (2001) presented five primary reasons for the packaging industry to switch to digital printing. Table 2.1 below summarizes these reasons. First, there could be substantial cost savings for short-run printing jobs due to elimination of making the print plates. Second, customization of graphics or sequential numbering is possible. Third, digital printing also provides fast turnaround times, at least for short-run jobs. Fourth, product samples and prototype packages could be made through digital printing, since they are one-of-a-kind. Lastly, digital press is used for proofing, even if the job is transferred to a conventional flexo/litho press for the full run after approvals are received.

**TABLE 2.1**

Reasons for Digital Printing in the Industry

| |
|---|
| 1. Cost savings for short-run jobs due to minimal investment of time or money (print plates are not needed). |
| 2. Customization for graphics or for sequential numbering. |
| 3. Fast turnaround times, especially for short-run jobs. |
| 4. Supporting product samples and prototype packages well, due to one-of-a-kind nature. |
| 5. Providing proof process for flexo/litho jobs. |

Digital printing tends to be more cost effective in short production runs and plate printing is more likely to be cost effective in long production runs. Multiple solutions presents challenges for managers in making decisions with cost effective results. The total cost model constructed in this research accounts for both types of printing technologies and suggests printing solutions pertaining to different cost structures.

## POSTPONEMENT–SPECULATION STRATEGIES

Postponement is the delaying of product differentiation based on form, location, and time during manufacturing and logistics operations. For example, Hewlett-Packard (HP) delays the individual packaging of its DeskJet printers until the products arrive at the distribution centers (Howard, 1991). The types of postponement discussed in literature are time (logistics) and form (manufacturing) postponement (Pagh and Cooper, 1998). Bowersox and Zinn (1988) introduced four manufacturing postponement strategies including labeling, packaging, manufacturing, and assembly, in addition to time postponement (through centralized location) under the time (logistics) type. These are summarized in Table 2.2. Both labeling and packaging are analyzed as forms of manufacturing postponement in the Bowersox and Zinn study. The present study however, looks at implementing postponement strategies, regardless of the type (i.e., time and manufacturing) in addressing the business problem identified.

**TABLE 2.2**

Types of Postponement

| **Manufacturing (Form) Postponement** | **Logistics (Time) Postponement** |
|---|---|
| Labeling, Packaging, Manufacturing, Assembly | Centralized Location |

Producing goods based on forecasting the demand is referred to as speculation. The aim is to gain economy of scale in manufacturing and logistics and reduce stock-outs (Pagh and Cooper, 1998). The postponement–speculation matrix by Pagh and Cooper (1998) presents the four possibilities as summarized in Table 2.3. These include: speculation in logistics and manufacturing, postponement in logistics and manufacturing, postponement in logistics and speculation in manufacturing, and speculation in logistics and postponement in manufacturing.

**TABLE 2.3**

Postponement-Speculation Matrix

| | | **L O G I S T I C S** | |
|---|---|---|---|
| **MANUFACTURING** | | **Speculation** | **Postponement** |
| | **Speculation** (make to inventory) | The full speculation strategy | The logistics postponement strategy |
| | **Postponement** (make to order) | The manufacturing postponement strategy | The full postponement strategy |

*Source: Pagh and Cooper, 1998*

Examples of postponement strategies in business logistics practice have been recently revealed (Bowersox and Closs, 1996). This indicates an enduring need in research and business practice to investigate possible venues for implementation of these strategies.

HP's success in employing postponement–speculation strategies in the early 1990s exhibits the potential savings that still exist for the supply chain.

Identifying responsible parties in the implementation of postponement strategies remains crucial. For example, HP's case of employing product differentiation and packaging postponement significantly shifted responsibilities from the manufacturing plants to the distribution centers (Howard, 1991). This helped HP realize tremendous cost savings over a short period of time (Howard, 1991), which once again indicates the potential that exist for cost savings and improved manufacturing practices.

In addition, with a direct link to e-Commerce, the adoption of digital printing technologies is increasing, which allows easier implementation of postponement strategies (Clarke, 2001). Similarly, industry interest for increased computer, Internet, mobile phone linked data generation (Schoenmakers, 2001) and supply chain visibility drives more and more companies to consider postponement strategies. Furthermore, the TINA (There Is No Alternative) trends identified by DLF/Delfi in 1998 for Nordic trade apply to global trade as well. These trends include information technology, efficiency, consumer awareness, intelligent marketing, and consumer adapted retailing concepts (Olsmats, 2000); and also aids in forming the infrastructure to implement postponement strategies. Therefore, the current study of analysis and implementation of postponement strategies in package labeling is quite timely.

The literature highlights postponement strategy and its effect on supply chain efficiencies and cost savings in various industries. One good example is the HP DeskJet printer case. HP was able to cultivate the best features of the postponement-speculation strategies and transform the long-established lines of responsibility between manufacturing and warehousing toward a very successful global implementation of product differentiation and packaging postponement (Howard, 1991).

The key to achieving high levels of product customization is postponement of product differentiation until later in the supply chain network (Feitzinger and Lee, 1997). Increasing flexibility and lowering costs are two motivating goals for a company to standardize components for different products or to postpone the assembly of differentiated components until later in the manufacturing process (Feitzinger and Lee, 1997). Lee examined HP's process redesign for their printers that were being manufactured in the U.S. and shipped globally (Lee, Billington, and Carter, 1993). By postponing the differentiated components, namely the power supply and the user's manual, until the product arrives at the distribution center, HP realized tremendous cost savings resulting from reduced inventory and improved fill rates (Johnson and Anderson, 2000).

Building on this, Johnson and Anderson (2000) developed a model that analyzes the value of postponement. Johnson and Anderson (2000) explored factors such as inventory policy, forecast uncertainty, product variety, product mix, and postponement premium and then introduced a model which evaluated the impact of postponement on introducing product platforms. Similarly, this study identifies and examines the effects of product factors on the total cost for package labeling and the decision to postpone.

Zinn and Bowersox (1988) identified a methodology for postponement justification by introducing five types of postponement and developing cost models for each type. Among the types of postponement, the researchers included labeling and packaging, and identified cost categories associated with each. The cost categories for these two types of postponement were identified as: (1) inventory carrying costs; (2) warehousing; (3) processing (labeling or packaging respectively); and (4) transportation (packaging only) (Zinn and Bowersox, 1988). Suggestions for postponement justification produced by this research seem to have re-ignited the discussion on postponement among other researchers.

Lee and Tang (1997) discussed the concept of reorganizing the production process so that the product differentiation point would be delayed as long as possible, hence delayed product differentiation. The researchers came up with a model for analyzing costs and benefits of postponement through product/process redesign. This model accounted for factors such as processing cost, inventory cost at work-in-progress stages, lead times, design cost, etc. (Lee and Tang, 1997). The model enables businesses to redesign their production processes so that the complexity of manufacturing process is reduced and the flexibility is increased (Lee and Tang, 1997).

The inventory holding cost analysis as presented by Waller, et al. stated that it is more expensive to hold finished products than it is to hold materials. This is primarily due to the higher labor and material costs associated with finished product inventory as compared to material inventory (Waller, Dabholkar, and Gentry, 2000). The researchers concluded that the marginal benefit of postponing a process at the beginning of the supply chain would be less than that toward the end of the supply chain (Waller, Dabholkar, and Gentry, 2000). Labeling is positioned relatively towards the end of the manufacturing process. Therefore, this reinforces the focus in this study on postponement of package labeling due to its positioning in the supply chain.

Battezzati and Magnani (2000) confirm the classification of postponement into two types: logistics and manufacturing. In their research, they stated that logistics postponement is applicable in all situations with the most realized benefits when the distribution component incorporates product customization (Battezzati and Magnani, 2000). Package labeling can be considered part of the distribution process. For example, frequently changing Food and Drug Administration (FDA) label requirements has a major impact on pharmaceutical products, especially recently launched drugs waiting for regulatory approval. Manufacturing postponement on the other hand, results in efficiency when the process is redesigned to be modular and product differentiation is delayed to the last steps in the production process. Consequently, this study satisfies an existing knowledge gap in the literature by developing a total cost model to address these issues for pharmaceutical companies.

The benefits of postponement become even more visible in multiple markets. For example, European markets have been investigated for postponement justification and it has been concluded that assembly postponement strategies yield considerable benefits (Foster, 2000). Due to the multiple markets existing within Europe, postponement strategies bring in considerable savings even when they are applied at the package labeling and documentation stage (Foster, 2000). The savings mainly result from not having to stock up on the same product labeled/packaged and documented for countries in different languages (Foster, 2000). This documents the need to study global markets in developing the total cost model for implementing postponement strategies. Consequently, in this study the complexities of global markets are accounted for. The model develops solutions for pharmaceutical companies to address the business problem noted previously.

Twede, Clarke, and Tait (2000) discuss postponement applications as a global packaging strategy. Factors that justify packaging postponement are briefly discussed, such as characteristics of the product, market/demand structure, and manufacturing/logistics setup (Twede, Clarke, and Tait, 2000). The authors conclude that optimization of packaging and logistics economies of scale would justify postponement (Twede, Clarke, and Tait, 2000). Therefore, it is important at this time to create a model, which analyzes cost structures for implementation of postponement strategies in the packaging logistics function.

Postponement of packaging can reduce inventory and transportation costs, especially when the supply chain has a complicated structure (Richardson, 2001). More specifically, since package labels are being differentiated more and suppliers are applying more labels on packages (Richardson, 2001), postponement deserves further attention at this stage of the supply chain. One way of measuring this could include looking at the number of brands a company has. Thus, the present study considers the number of brands as a product factor that affects the total cost model for postponement decisions.

The literature review by Pagh and Cooper (1998) produced the postponement–speculation matrix for supply chain (see Table 2.3). The research emphasizes the importance of the integration of logistics and manufacturing activities and the role of postponement–speculation as an emerging strategy in effective supply chain management (Pagh and Cooper, 1998). The researchers also indicate that limited considerable effort has been made to bring postponement–speculation theory into practice for managerial decision-making. Focusing on the manufacturing plant level to end consumer, their research develops a diagnostic and normative framework for deciding on postponement–speculation strategies. The decision factors are categorized into three groups, as tabulated in Table 2.4, and are classified as follows (Pagh and Cooper 1998):

1. Product — Emphasis is on the life cycle and value of the product similar to Zinn's (1986) analysis.

2. Market and Demand — Focus is primarily on the relative delivery frequency and demand uncertainty.
3. Manufacturing and Logistics System — Highlighted area is the economies of scale or special knowledge needed in the processes.

**TABLE 2.4**

Postponement-Speculation Decision Factors

| **Product** | **Market and Demand** | **Manufacturing and Logistics System** |
|---|---|---|
| Life Cycle | Relative Delivery Frequency | Economies of Scale |
| Product Value | Demand Uncertainty | Special Process Knowledge |

Bowersox and Closs (1996) formulate postponement as time or logistics and form or manufacturing, consistent with previous literature. Some examples of manufacturing postponement include mixing of different colors of paint at the retail level based on direct demand from the consumers, blending octane grades at the retail pumps (Sunoco), and postponing the installation of market differentiated parts of HP DeskJet printers (e.g. parts dependent on voltage) to the distribution center level. All these cases are indicative of the business potential underlying postponement.

In a literature review by Van Hoek (2001), the pharmaceutical industry is referred as a process industry. Therefore, the processing cycle times might last longer than the customer order lead time, and the process cannot be decoupled at an intermediate stage (Van Hoek, 2001). The operating characteristics of the industry determine the feasibility of postponement types (Van Hoek, 2001). Package labeling constitutes a complicated manufacturing step and consequently needs researchers' attention in analyzing the problems associated with it. In support of this statement, Van Hoek (2001) refers to a conversation with Bucklin; who is the author of the founding article on postponement theory (Bucklin, 1965); from which he quotes "Postponement was introduced in the 1960s but look at the entire speculative inventory that is still stored in the channel" (Bucklin, 1965). Therefore, need for further research in this area is ample.

Following what has been practiced and researched so far, the objective of this study is to bring together a comprehensive evaluative tool that performs cost structure analysis for justification of postponement strategies in package labeling. As explained with numerous business cases and proven studies, the need for developing this economic model for package labeling postponement is evident.

## ACTIVITY–BASED COSTING

In order to accurately devise an economic model, first the cost structure of the labeling industry needs to be understood. Consequently, both indirect and direct costs should be taken into consideration. For the purposes of modeling or decision-making, it is necessary to develop cost relationships of direct and indirect costs, rather than estimates (Shapiro, 1999). Activity–Based Costing (ABC) is widely used in practice and seeks to allocate indirect costs (i.e. activities, to cost objects such as service, product, and customer costs) (Shapiro, 1999). In addition, ABC is referred to in the literature as "being approximately right" versus "being precisely wrong" (Ernst & Young LLP, 1994).

While the allocation of direct costs engages obvious drivers, such as machine hours for machine cost, indirect costs are not that straightforward (Shapiro, 1999). Shapiro indicates that indirect cost drivers may be volumetric, such as a cost driver for a receiving department that can be measured by the number of parts handled by the department during the planning period (1999). Or they may be non-volumetric; such as a cost driver for machine setup costs that equals the number of times a machine is setup during the planning period (Shapiro, 1999). Wiersema (1995) refers to the fact that traditional accounting tends to average out all costs, direct and indirect, and displays unit-driven results. However, batch-driven activities, such as label printing, include a setup component, which varies regardless of the number/volume of units produced. Therefore, it is crucial to incorporate such factors as they may drastically change the total cost of performing a particular job. As explained in the next chapter, allocation of the indirect cost drivers are very important and used to arrive at some of the differentiating factors for postponement.

It is also noted that the connection between ABC and supply chain optimization models is important but also complicated (Shapiro, 1999). In general, ABC starts out by mapping indirect costs in the company general ledger into cost categories (in this case, supply chain) with associated cost relationships, drivers, and resources (Ernst & Young LLP, 1994). With supply chain cost structure in focus, Shapiro (1999) indicates that the cost driver corresponds to a resource if its availability is limited. Shapiro also refers to the difficulty in interpreting accounting systems (i.e. calibrating costs across facilities due to use of multiple accounting systems) in modeling the supply chain (1999). The different cost structures used for digital and conventional printing need to be unveiled using activity-based costing; in order to identify the real cost drivers accurately.

One major contributor to the difference in cost structures between conventional and digital printing is setup costs (Emden, 2001-2003). Since setup costs tend to be calculated as indirect costs (Shapiro, 1999), ABC will be the most useful method in modeling the cost structures associated with digital and conventional printing. In addition, as explained in the next chapter, this research utilizes the case study research approach, which alleviates the aforementioned problem. The case study method provides comprehensive insight into the cost variables and factors involved in managerial decision-making.

Since ABC and optimization modeling are recognized to play complementary roles in identifying costs and cost relationships for supply chain decision-making, this study utilizes ABC principles and methodologies in identifying costs and cost relationships for package labeling. This assists in devising a cost model that properly accounts for the indirect costs for label printing, such as setup costs.

## TOTAL COST APPROACH

This research takes two supply chain management concepts into consideration: The total cost approach and postponement-speculation. Packaging is an integral part of the supply chain and therefore needs to be studied under theories applicable to supply chain management. The total cost concept is introduced, reviewed, and evaluated for its effects on postponement.

It is widely accepted that the concept of total cost logistics was first introduced by Lewis, Culliton, and Steele in 1956 when they justified an increase in the cost of air transport through the reduced total cost of the logistics chain (Bowersox and Closs, 1996; Lewis, Culliton, and Steele, 1956). The principle of total cost logistics states that instead of trying to reduce individual cost components in the logistics network, it is more effective to devise strategies that reduce the total cost of the logistics system. Decreasing the cost of one component such as plant to warehouse transportation does not necessarily imply that reduction in the total logistics cost will be realized. Through total cost approach, expenditures can be justified where needed, such as delivering goods fresh to consumers, while cutting back on activities that do not add value to the supply chain in an attempt to reduce the total cost of logistics (Bowersox and Closs, 1996).

In order to devise a model to be used in the implementation of postponement strategies, it is necessary to carefully examine the cost structure of the subject matter (i.e., package labeling) and maintain a total cost approach. Consequently in this study, an objective is to minimize the cost of doing business, the technique used is postponement, and the tool is an evaluative model designed with a total cost perspective.

Package labeling requires extensive coordination between the other supply chain activities, and it is also this coordination that savings can be realized. The supply chain is an integrated system, and therefore the efficiency and performance level of one activity will be affected by the other components. Bowersox and Closs (1996) support this in examining total cost analysis within the framework of an integrated logistics system. An appropriate example is the Hewlett-Packard Company's DeskJet printers case study , which shows lower total costs even though some of the cost items escalate (Howard, 1991).

Zinn (1986) investigated postponement strategies in business logistics by focusing on cost trade-offs within the objective of minimizing total cost of the business logistics. The study used the six cost categories identified by Lambert and Stock (1982): 1) transportation costs, 2) warehousing costs, 3) inventory carrying costs, 4) order processing and information costs, 5) production lot quantity costs, and 6) cost of lost sales (Zinn, 1986). The cost categories for labeling postponement have been identified as labeling, inventory, and warehousing (Zinn, 1986). Adding to the Zinn model of postponement, this study includes obsolescence cost of labels including time/expiration, regulatory/safety changes, marketing based changes (e.g. graphic changes on package) package engineering changes, and product line changes. In addition to obsolescence costs, the cost of elapsed time between approval and launching of patented products and setup costs for small volume or short run products also need to be considered in the model. All these cost factors make up the total cost structure of package labeling, and therefore need to be considered in developing the total cost model for implementing postponement strategies.

## ANALYSIS OF PACKAGE LABELING

In this study digital printing is reviewed as an enabling technology to postponement of label printing. Compared to conventional (plate printing), electrographic (digital or plateless) printing has minimal setup time and costs (Emden, 2001-2003). Delaying the printing activity is likely to be considered more by management since plate printing requires additional setup time. Second, the cost per unit produced by digital printing does not vary significantly with increased output to justify long production lines so work can be interrupted or performed at different times (i.e. conventional printing is more economical when compared with digital in long production run) (Emden, 2001-2003). Additionally, since setup activity is minimal compared to conventional printing, customization of labels is easier especially in multiple language production or even when presenting different information (Larson, 2000). Therefore, micro-segmentation or order-driven printing is made possible (Larson, 2000). Finally, the fact that digital printing techniques enable quick product launching to market (Larson, 2000) assists in delayed product differentiation (i.e. postponement).

So far, researchers have not addressed this aspect of enabling technologies in the area of package labeling. This study investigates an economic model for label printing and its effects on supply chain management. The research seeks economic justification for implementing postponement strategies by accounting for the effects of enabling technologies on label printing operations.

Even though the concept of postponement is not new to the supply chain management literature, the impact of labeling postponement on the supply chain has not been specifically addressed. Only one cost-benefit analysis of labeling postponement has been performed (Zinn, 1986). However this model did not encompass regulatory (government) or strategy-based factors. Even though value-based factors were included in the model, value of product-package system and package engineering design costs were omitted from the equation. In addition, regulatory factors play an increasingly important role in the pharmaceutical industry, which is highlighted in this research. Hence, there is a gap in literature and a need to comprehensively analyze cost function of package labeling and its effects on the supply chain.

The cost structure of label printing should be investigated from an Activity-Based Costing (ABC) point of view with a total cost perspective to understand business decisions that are driven by dynamics based on three categories, namely government and market, strategy, and value. These categories control the factors that have a significant impact on the total cost for printing labels. In addition, it is evident from the examples provided above that in the literature and business practice, postponement strategies are still being explored as a way to reduce manufacturing costs and gain supply chain efficiencies. There is still a tremendous potential for cost savings in postponement strategies and therefore, this research proposes to uncover when it is cost effective to implement postponement strategies in label printing, specifically for pharmaceutical companies. Another area where current literature falls short is in the approach to postponement strategies through ABC. This research utilizes the ABC model to deliver a total cost model for package labeling. Many cost items that may be hidden or inaccurately calculated can be accounted for in an "approximately right" manner.

In order to address these needs, this study aims to identify factors that are driven by government and market, strategy, and value based causes. Next, the research proposes to formulate an economic model for package label printing to implement postponement strategies. This model paves the way to a better understanding of the label printing operation and its position in the supply chain. The study effectively assesses supply chain management strategies in reducing total cost and accurately pinpoints areas that have the greatest impact on total cost for label printing and the decision to postpone.

# CHAPTER III

## MODEL DEVELOPMENT AND RESEARCH DESIGN

The model derived from the research questions reiterated below, eventually assists in quantifying the effects of package labeling postponement on the whole supply chain and provides management suggestions regarding use of postponement. Therefore, the following questions are addressed in this section:

- What are the significant cost drivers for package labeling and how does package labeling impact supply chain costs?
- What is the set of product factors that involve cost components that make up the total cost for label printing and affect the implementation of postponement strategies in package labeling?
- To what degree does each factor affect the total cost for package labeling and influence the decision to postpone package labeling to the distribution center level?
- What is the relative effect of these product factors and the individual cost components on postponement in package labeling?
- What types of management strategies can be derived from the model?

In order to craft answers to these questions, the following steps are taken:

i. Conceptualize the product and cost factors that generate the model for printing labels;

ii. Establish the relationship between these product factors and the total cost of printing package labels;

iii. Define relevant business environment by analyzing different business scenarios that is established by using typical values for the product factors;

iv. Determine the correlation between cost factors and the decision to postpone package labeling to the distribution center level, which in turn generates the cost model for printing labels.

The total cost simulation model is developed using Microsoft® Excel® and multiple variable regression analysis is conducted to assess the statistical significance of the independent variables.

This chapter is divided into four sections. The section titled Model and Theory Development introduces the research model and develops the theory for this study including cost and product factors that are included in the model of package label printing. The second section describes the model structure, which explains the relationships between the product and cost factors for package labeling. Research hypotheses are presented in the following section. The last section describes the method to be used and the overall design of the research.

## MODEL AND THEORY DEVELOPMENT

In developing the model, the cost structure of package label printing is examined. A series of preliminary and exploratory interviews were conducted with alumni and contacts of the School of Packaging at Michigan State University and the customers of the John Henry Company to uncover factors that have a significant impact on the total cost of printing labels. As explained in Chapters I and II the purpose of the study is best served by restricting the research to the pharmaceutical industry. This provides a focused approach for addressing the business problems specified in chapter I (i.e., limited patent period; regular content changes, and significant customization).

A total of seven features are identified for this business segment that stem from three categories; namely government and market, strategy, and value. These features are summarized in Table 3.1 with corresponding categories. The government enforces regulatory changes based on new medications and their implications on the public. The seasonality of product also affects inventory levels, which in turn affect total cost for printing labels. These features therefore represent outside forces that the company has little or no control over. In order to maximize business, companies employ strategic approaches on package labels such as monitoring market demand and changing label graphics accordingly, producing the same product under different brands, and expanding their business into global markets. Lastly, firms utilize value-based features such as package engineering design to lengthen the shelf life of a product. Value of any product-package system ultimately determines the price of the product that leads to the profitability of the product line.

**TABLE 3.1**

Features Impacting Cost of Printing Labels

| **Government & Market Based** | **Strategy Based** | **Value Based** |
|---|---|---|
| • Regulatory Changes (government based)<br>• Seasonality of Product (market based) | • Marketing based changes<br>• Number of Brands<br>• Number of Global Markets | • Package Engineering Design Changes<br>• Value of Product-Package System |

As explained in Chapters I and II, the case study interview method is used to setup the total cost model, identify the representative minimum, mode, and maximum ranges of values for each variable included in the model, and the business environment. The method is discussed in Chapter II and in the methodology and research design section in this chapter. A total of seven product factors affecting package-label printing are derived from the features that are introduced above, tabulated in Table 3.2, and explained in detail in the following section.

**TABLE 3.2**

Product Factors Affecting Cost of Printing Labels

| | |
|---|---|
| Regulatory Changes | → **Frequency of Regulatory Changes ($F_{rc}$)** |
| Marketing based changes | → **Frequency of Marketing Changes ($F_{mc}$)** |
| Package Engineering Changes | → **Frequency of Packaging Changes ($F_{pc}$)** |
| Value of Product-Package System | → **Value of Product-Package System ($V_p$)** |
| Number of Brands | → **Number of Brands ($N_b$)** |
| Number of Global Markets | → **Number of Global Markets ($N_m$)** |
| Seasonality of Product | → **Number of Annual Production Runs ($N_{pr}$)** |

A total of seven product factors affecting the total cost of printing labels are identified. Frequency of regulatory changes ($F_{rc}$) is a government driven effect. Frequency of marketing based changes ($F_{mc}$) is the consequence of strategy-based decisions. Frequency of package engineering design changes ($F_{pc}$) is the result of value-based decisions.

Similarly, value of product-package system ($V_p$) is the consequence of value based business features. Number of brands ($N_b$) and global markets ($N_m$) result from strategy based decisions. Finally, the number of annual production runs ($N_{pr}$) is the outcome of the seasonality of a product and additional market based features. The seven product factors are explained in detail under the Product Factors subheading in this Chapter. The cost factors that make up the total cost of printing labels are explained next.

## COST FACTORS

From a business perspective, the motivation to postpone is to maximize profits primarily through inventory reduction. In a general sense, profits equal revenues minus total cost. For the purposes of this study, revenues are assumed constant. However, it is also important to recognize the fact that postponement also has effects on revenue. For example, by utilizing postponement strategies, companies are able to customize certain products according to customers' needs, and therefore, have the customer pay more for the product than a more generic counterpart.

From the pharmaceutical industry point of view, the revenue gain will be realized through faster launch of patented products once approvals are received. Postponement–speculation has diverse effects on the speed of launch of a particular product. For example, a company that postpones label printing until product approvals are received may actually shorten the product's time to market. On the other hand, a costly situation may occur when labels are printed prior to receiving the approvals with a speculative approach on the label requirements and then to have the labels and/or inserts re-printed with accurate information.

Another business scenario is to print the labels with speculative wording and actually end up gaining time in launching the product if the approval is received without any changes in label wording. There are situations where pharmaceutical companies make such decisions based on experience. When materials are printed before approval, it is described as "at risk," meaning that if there are any changes in the wording for the labeling, the printed materials have to be destroyed (McNeely, 2001). In addition, McNeely (2001) notes that it is sometimes advisable to print the inserts "at risk," since it becomes a rate-limiting step in the launch process. However, there are some cases where not taking such risks may also depend on the company having digital printing capabilities that boast minimal setup time, and this alone may justify the costs associated with labeling postponement.

In this research, revenue is assumed to be constant, and therefore maximizing profit will depend solely on minimized total cost. At the same time, the study recognizes the importance of analyzing the effects of postponement on revenues, both from a purely research contribution and from a business perspective. Therefore, the impact of postponement strategies on revenue is discussed in the last chapter.

In the traditional cost accounting method, the cost elements for the labeling function can be grouped into two cost categories. These are fixed and variable costs. Fixed costs include personnel, utilities, depreciation (equipment), service (equipment), and depreciation (facility). Variable costs include substrate, colorant, equipment maintenance, and inventory carrying/warehousing. Fixed costs are normalized based on calculated totals on a per hour basis (QPR, 2002). The total cost then is the sum of fixed and variable costs. The traditional cost model of label printing is summarized in Table 3.3.

The traditional cost accounting model, however, does not accurately represent the indirect cost items involved in label printing. To compute these unaccounted sources of variance, the Activity-Based Costing (ABC) methodology should be followed, as explained in Chapter II.

**TABLE 3.3**
Traditional Cost Model of Label Printing

| **Fixed Costs** |
|---|
| Personnel/Labor ($50,000/person annual, 30 people for litho, 15 for digital) |
| Utilities ($10,000/year) |
| Depreciation (Equipment) |
| Service (Equipment, $5,000/month digital, $10,000/month litho) |
| Depreciation (Facility) |
| **Variable Costs** |
| Substrate ($1 per million square inches (msi), 20,000 8 ½ x 11 sheets per hour) |
| Colorant ($300 digital, $40 litho) |
| Equipment Maintenance/Cost of parts |
| Inventory Carrying/Warehousing |

*Source: Emden, 2001-2003*

ABC advocates claim that activities consume resources, and re-doing or re-working unacceptable work is an activity (Dickeson, 2000).

Accounting for this is important, especially, when manufacturers print labels "at risk" and have to re-do the work due to regulatory changes imposed upon approval of a new drug. In such cases, ABC principles need to be followed to properly account for the cost. Traditional costing methods do not account for activities such as setup in batch processes (Wiersema, 1995). Printing labels is a batch process. There is a setup activity required to print a certain label for a particular product, which stays constant whether the quantity of labels to be produced is 10 or 10,000 linear feet. This further suggests that the problem at hand needs to be approached utilizing ABC principles.

Following the Wiersema (1995) ABC model the activities for label printing can be regrouped as seen in Table 3.4. The process of implementing Activity Based Management (ABM) is introduced by first grouping the activities into two categories, namely Support Activities and Operating Activities. The next step involves assembling individual activities under these two activity categories (Wiersema, 1995). Hence, the cost category of operating activities is divided into direct, discretionary, and special requirements activities (Wiersema, 1995). Note that compared to information in Table 3.3, this structure identifies additional costs relating to label printing, such as setup costs, and segregates the cost items as they relate to activities.

According to the foremost ABC principle, activities consume resources, which this study follows. Table 3.4 presents these activities.

Support activity costs do not vary with the seven identified product factors and therefore are assumed not to have any effect on postponement decisions. Consequently, the main focus of this study is operational costs (i.e., costs that are driven by operating activities). This way, hidden costs associated with printing setup, inventory carrying, handling obsolete inventory, and more are revealed. Eventually, the effects of the seven product factors on the total cost of label printing and the decision to postpone labeling to the warehouse level are analyzed.

**TABLE 3.4**
Activity-Based Cost Model of Label Printing

| **A. Support Activities** |
|---|
| 1. Personnel/Labor |
| 2. Depreciation (Equipment) |
| 3. Service (Equipment) |
| 4. Utilities |
| 5. Depreciation (Facility) |
| **B. Operating Activities** |
| 1. Direct Activities |
| A. Printing Setup |
| B. Printing Run |
| 1. Substrate Usage Rate |
| 2. Colorant Usage Rate |
| 3. Equipment Parts Replacement Rate |
| 4. Inventory Carrying/Warehousing |
| 2. Discretionary Activities |
| A. Abnormal Scrap/Rework |
| 3. Special Requirements Activities |
| A. Special Customer Requests (such as expedited turnaround, customized labels) |

Regarding government and market, strategy, and value drivers for the product factors, the total cost of label printing involves printing production run (PR), inventory (INV), stock-out (STO), and obsolescence (OBS) costs. The percentage difference between projected and budgeted costs is incorporated into the case study interviews to incorporate an error percentage term into the total cost calculation. The error term of up to 10% is then used to recalculate the dependent variable (total cost). The data gathered through the case study interviews are used to establish the representative ranges of values for the cost factors and the variables used to calculate them.

$$T_c = PR+INV+STO+OBS \tag{3.1}$$

Functions for each of the cost factors are written out in terms of the independent variables product factors and other factors such as average annual volume (V), service level objective (SL), stock-out cost per day ($STO_{pd}$), and average annual order quantity (OQ). The volume and service level objective determine the production cycle.

$STO_{pd}$ = Stock-out cost per day

OQ = Order quantity

V = Average annual volume

$$OQ = V / (N_{pr} /2) \tag{3.2}$$

### Calculation for Printing Run Cost

Printing costs (PR) include technology costs that are associated with a particular technology adoption (i.e., digital versus litho) in addition to the volume of labels printed. Therefore, the activities that drive this cost category are all the direct activities (i.e., printing setup, substrate usage, colorant usage, and equipment parts under the printing run activity item). Table 3.4 summarizes these cost activities. The two product factors that directly impact the printing setup costs are number of global markets ($N_m$) and number of brands ($N_b$). At this point, it is beneficial to reiterate that the support activities are not impacted by the seven product factors; hence they are not taken into account in the total cost model. The equation below demonstrates the calculation of printing run costs.

$$PR = PS + (CONST_{PR} \times V) \qquad (3.3)$$

PS = Printing setup cost

$CONST_{PR}$ = Printing Run Cost Constant

$CONST_{PR}$ represents the annual expenses on substrate usage, colorant usage, parts replacement, etc. divided by average annual volume to arrive at unit cost. $CONST_{PR}$ has two different values for the case of digital and conventional printing, $7 per day for conventional and \$30 per day for digital (Emden, 2001-2003). Therefore, the printing setup cost will equal the cost constant for printing setup multiplied by number of brands and number of global markets combined.

$$CONST_{PR}\ (\text{conventional}) = (\$7 \times 365) / V \quad (3.4a)$$

$$CONST_{PR}\ (\text{digital}) = (\$30 \times 365) / V \quad (3.4b)$$

$$PS = (N_b + N_m) \times CONST_{PS} \quad (3.5)$$

$CONST_{PS}$ = Printing Setup Cost Constant

$CONST_{PS}$ represents the annual expenses on labor and materials for setup for each production run (double sided tape production in the case of conventional printing amounting to a representative value of \$800 and color setup mostly in the form of labor in digital amounting to a representative value of \$250). Therefore, printing run cost equals printing setup costs added to volume multiplied by the printing run cost constant, which is summarized in equation 3.6.

$$PR = ((N_b + N_m) \times CONST_{PS}) + (CONST_{PR} \times V) \quad (3.6)$$

**Calculation for Inventory Cost**

The inventory cost (INV) is the value of inventory, which is driven by the inventory carrying/warehousing cost activity under the printing run activity category. The product factor value of product-package system ($V_p$) is a direct factor that determines the value of inventory. Cost of inventory can be calculated by multiplying average annual inventory volume by value of product-package system (unit price of product) by the inventory carrying percentage cost constant (equation 3.7). Average annual inventory volume is reached by adding safety stock to order quantity divided by two, which is the averaging factor (equation 3.8). Equations below illustrate these statements.

$$INV = INV_{avg} \times V_p \times CONST_{ICC} \quad (3.7)$$

$INV_{avg}$ = Average annual inventory volume

$$INV_{avg} = SS + (OQ/2) \quad (3.8)$$

SS = Safety Stock (see Calculation of Stock-out Costs section below)

$CONST_{ICC}$ = Inventory carrying cost percentage factor (constant)

$CONST_{ICC}$ = 8% (time value of money tied up in inventory annually)

$$INV = ((SS + (OQ/2)) \times CONST_{ICC} \times V_p \quad (3.9)$$

## Calculation for Stock-out Cost

Stock-outs happen when consumers cannot find the product on the shelf at the point of purchase. This could result in potential lost sales, if the consumer instead purchases a competitive product instead. In addition to the potential lost sales, the stock-out costs include intangible components such as loss of goodwill and potential delays in other parts of the system (Nahmias, 2001, pg 264).

Stock-out cost is usually very hard to determine, and therefore service level can be used as its replacement (Nahmias, 2001). Quantifying service levels can be done in numerous ways, suggest Graman (1999) based on Fogarty et al (1991). However, service level generally refers to either the proportion of demand satisfied directly from the shelf (i.e., fill rate) (Graman, 1999), or the probability of not stocking out (Graman, 1999). Again, since most managers interpret stock-out as the proportion of demand met directly from stock, it is proper to use fill rate as the measure of service level (Nahmias, 2001).

Sox et al. (1997) addresses the issue of filling orders to meet the targeted service levels in a fixed length of service window. Therefore, it is necessary to identify variables representing the stock-out period, and the service level objective (SL). Graman (1999) expresses the proportion of demand satisfied directly from the shelf in a given stock-out period as expected number of stock-outs divided by the stock-out period. Therefore, the fraction of demand that is satisfied from the shelf would be one minus that. When we isolate the expected number of stock-outs and multiply by the profit margin ($M_p$) for each unit we arrive at the cost of stock-out as expressed in equation 3.10. However, due to the sensitivity of the profit margin data, the case study subjects were asked to provide daily stock-out costs instead ($STO_{pd}$). Therefore, as illustrated in equation 3.11, annual stock-out cost equals stock-out cost per day multiplied by the average annual volume times one minus service level.

$$STO = CONST_{STO} \times (100 - SL) \times M_p \tag{3.10}$$

$$STO = STO_{pd} \times V \times (1-SL) \tag{3.11}$$

$f(k) = (1-SL) \times (OQ/Ddct_{std})$

$SS = k \times Ddct_{std}$

$Ddct_{std}$ = Standard deviation of demand during cycle time

$Ddct_{std} = \sqrt{DDavg^2 \times CTstd^2 + CTavg \times Dstd^2}$

$DD_{avg}$ = Average daily demand = V/365

$CT_{std}$ = Cycle time standard deviation = $CT_{avg} \times 0.005$

$CT_{avg}$ = Average cycle time = $365/N_{pr}$

$D_{std}$ = $DD_{avg}$ standard deviation = $DD_{avg} \times 0.005$

## Calculation for Obsolescence Cost

Obsolescence (OBS) plays a major role in increased incentives to postpone labeling to the distribution center level. The product factors that impact obsolescence are frequency of regulatory changes ($F_{rc}$), frequency of marketing based changes ($F_{mc}$), and frequency of package engineering design changes ($F_{pc}$). Obsolescence is a cost category driven by the discretionary activity of abnormal scrap. This involves disposing of the scrap and rework. Rework cost is the same as the printing cost explained previously (see equation 3.3). Therefore, the cost of obsolescence is the cost of printing run multiplied by the sum of the product factors that contribute to the obsolescence of labels divided by the number of annual production runs. These are regulatory changes, marketing based design changes, and package engineering design changes. These statements are illustrated in the following equations.

$$OBS = (CONST_{obs} + PR) \times ((F_{rc} + F_{mc} + F_{pc})/N_{pr})) \quad (3.12a)$$

$CONST_{obs}$ = Scrap Handling / Disposal Cost Constant

$$OBS = PR \times (F_{rc} + F_{mc} + F_{pc})/N_{pr}) \quad (3.12b)$$

The case study interviews revealed that $CONST_{obs}$ is insignificant compared to the cost of rework. It also tends to be hidden, usually in different departments within a company, which makes it harder to quantify. Table 3.5 summarizes the total cost formulas and variables. Next, the seven product factors are discussed including their effects on cost factors and their identified ranges of values.

**TABLE 3.5**

Summary of Total Cost Formulas and Variables

$T_c$ = PR+INV+STO+OBS
PR = PS + ($CONST_{PR}$ x V) = (($N_b$ + $N_m$) x $CONST_{PS}$) + ($CONST_{PR}$ x V)
INV = (SS + (OQ/2) x $V_p$ x $CONST_{ICC}$
STO = $STO_{pd}$ x V x (1-SL)
OBS = PR x ($F_{rc}$ + $F_{mc}$ + $F_{pc}$)/$N_{pr}$)

$T_c$ = Total cost of printing labels
PR = Printing run cost
PS = Printing setup cost
INV = Inventory cost
STO = Stock-out cost
OBS = Obsolescence cost

$F_{rc}$ = Frequency of regulatory changes
$F_{rc}$ = Frequency of marketing based design changes
$F_{rc}$ = Frequency of package engineering design changes
$V_p$ = Value of product-package system
$N_b$ = Number of brands
$N_m$ = Number of global markets
$N_{pr}$ = Number of annual production runs

OQ = Order quantity = V / ($N_{pr}$ /2)
V = Average annual volume
$CONST_{PR}$ = Printing run cost constant
        $CONST_{PR}$ (conventional) = (\$7 x 365) / V
        $CONST_{PR}$ (digital) = (\$30 x 365) / V
$CONST_{PS}$ = Printing setup cost constant
$CONST_{ICC}$ = Inventory carrying cost constant (percentage)
        = 8% (time value of money tied up in inventory annually)
SL = Service level
$STO_{pd}$ = Stock-out cost per day
f(k) = (1-SL) x (OQ/$Ddct_{std}$)
SS = k x $Ddct_{std}$
$Ddct_{std}$ = Standard deviation of demand during cycle time
$Ddct_{std}$ = $\sqrt{DDavg^2 \times CTstd^2 + CTavg \times Dstd^2}$
$DD_{avg}$ = Average daily demand = V/365
$CT_{std}$ = Cycle time standard deviation = $CT_{avg}$ x 0.005
$CT_{avg}$ = Average cycle time = 365/$N_{pr}$
$D_{std}$ = $DD_{avg}$ standard deviation = $DD_{avg}$ x 0.005

## PRODUCT FACTORS

In this section, each product factor is defined and the effects of each factor on the total cost of printing labels are discussed. The ranges of values for the cost and product factors are presented in the last section of this chapter titled Methodology and Research Design. The data gathered through the case study interviews are used to establish the representative minimum, mode, and maximum ranges of values for the product factors and some of the cost factors as indicated previously. Therefore, the data set is not intended to represent any one specific case.

Each of the seven product factors has a distinct effect on the total cost of printing labels, which is presented in the section titled Model Structure. Depending on a given business environment as characterized by the collective effect of these product factors, the total cost of printing labels may increase or decrease. Similarly, as the value of the cost factors that compose the total cost of printing labels are varied, the incentive to postpone package labeling to the distribution center level will be higher or lower. Distribution center level represents the last leg of the supply chain where large-scale quality printing can occur. Again, the effects of various business situations (caused by these product factors) on total cost and the decision to postpone package labeling to the distribution center level are captured by these seven product factors.

As previously discussed, this study approaches the problem from the total cost perspective, since the goal for any business should be to reduce total cost. As explained in chapter II, all these variables are determinant factors for implementing postponement strategies from the perspective of minimizing total cost. Postponement strategies also bring in flexibility to the production processes, as explained in previous chapters. However, in this study the focus is on minimizing total cost. Since postponement has an effect on total cost, the impact of each of the factors is investigated to identify their relative effects on cost components that make up the total cost of printing labels. Next, each product factor is defined and its effects on the cost of printing labels are discussed.

**Frequency of regulatory changes ($F_{rc}$)**

This factor refers directly to the regulations and hence regulatory changes imposed by the Food and Drug Administration (FDA). As a result of numerous exploratory interviews with The John Henry Company, this emerges as one of the major challenges faced by the pharmaceutical industry especially in launching of compounds/products. Due to the sensitivity of the timing of the launch, companies sometimes take the risk of printing labels by speculating on the FDA regulations. The resulting effect of this factor on total cost of label printing and the decision to postpone is important. This factor results in obsolescence and an increase in costs for the printing setup activity due to the need to rework the setup/programming to comply with the changes each time they occur. Hence, as the frequency of changes increases, the cost of setup should increase. In addition, costs for printing run activities should also increase since most upgrades involve more information to be provided on a label (Emden, 2001-2003). This results from the costs incurred for the existing inventory of outdated labels. In addition, there should be an increase in abnormal scrap/rework activity related costs, but no changes will be observed for the special requirements cost category.

As determined through case study interviews, the range of representative values for this factor is one to three, averaging at two.

**Frequency of marketing based design changes ($F_{mc}$)**

Sometimes, label design is modified in the middle of a product launch, or heavy sales, driven purely by marketing factors. This condition results in increased numbers of abnormal scrap driving the total cost up. The effect of such situations on total cost and the decision to postpone is captured by this factor. This will have a similar effect on the cost drivers as the above parameter, since labels will need to be redone. Therefore, an increase in obsolescence will be observed. In addition, the colorant usage rate should increase due to the trend of employing more colorful and bright designs and more expensive ink (such as metallic ink), which permeate into updated label designs (Emden, 2001-2003).

Case study interviews revealed the range of values for this variable to be one to five, averaging at three. The reason for values to be less when compared to frequency of regulatory changes is mostly due to the relative flexibility of the change. Usually, when marketing based change occurs for a label, the cost of obsolescence is provided to the marketing department for the cost benefit analysis of making the change. Based on this, the changes may be implemented between production runs, which does not impact the total cost of printing labels.

**Frequency of packaging engineering design changes ($F_{pc}$)**

This factor is similar to $F_{mc}$, in that label production may need to be modified in order to accommodate changes in the packaging of the product. An example for this is the introduction of flexible pouch packaging for tuna fish. The information on the label is the same, however, due to the change in the package, label production needs to be altered. Therefore, the resulting effect of this factor on the total cost of label printing and the decision to postpone is important to explore. When the industry experiences higher probability package engineering design changes, the impact on the cost drivers should be similar to higher rates of regulatory changes. Most package engineering design changes involve more complicated designs such as more sophisticated folding to better prevent shock and vibration damage (Emden, 2001-2003). This inherently increases the cost of printing. There is also the probability of folding machines to be jammed more often, increasing the abnormal scrap/rework costs. The argument for the colorant usage rate may not hold since package engineering design change does not necessarily translate into more colorful labels. Obsolescence remains to be a factor that increases with higher frequencies of package engineering changes.

As determined through case study interviews, the representative range of values for this variable is zero to two, averaging at one.

Similar to the frequency of marketing based changes, the decision to implement the change can sometimes be postponed so as not to affect the total cost. In addition, package engineering design change is a value-driven change. Therefore, most of the time the goal is to minimize cost, which provides incentive for the firm to synchronize such changes with the other changes (i.e., regulatory changes or marketing based changes).

Table 3.6a summarizes the statements above by illustrating the product factor frequencies of regulatory, marketing based, and package engineering changes, their associated value ranges minimum, mode, and maximum, and their relation to cost factors, namely printing run, inventory, stock-out, and obsolescence.

**TABLE 3.6a**

Product Factors, Associated Ranges, and Their Relation to Cost Factors

| | $F_{rc}$ | $F_{mc}$ | $F_{pc}$ | | | | |
|---|---|---|---|---|---|---|---|
| Cost Factors | | | | | | | |
| PR | ↑ | ↑ | ↑ | | | | |
| INV | | | | | | | |
| STO | | | | | | | |
| OBS | ↑ | ↑ | ↑ | | | | |
| Associated Ranges | | | | | | | |
| Minimum | 1 | 1 | 0 | | | | |
| Mode | 2 | 3 | 1 | | | | |
| Maximum | 3 | 5 | 2 | | | | |

### Value of product-package system ($V_p$)

The value of the product has been documented to be a factor in postponement (Zinn, 1986). This thesis expands the investigation further to include the product-package system. Consequently, the effect of the value of product-package system on total cost and the decision to postpone is captured by this factor.

Zinn (1986) discovered that postponement of the labeling function to the warehouse level is a proper solution for products with higher value. These findings indicate that the higher the value of a product the higher the incentive to postpone labeling to the warehouse level (Zinn, 1986). The assumption is that the cost of carrying inventory of products with high values is also high; therefore, postponement remains to be a valid strategy. In this study, the variable is expanded to encompass the value of product-package system. The Zinn model of thinking should still be valid. In addition, the case should further be explored and measured through case study interviews if high value product-package systems require more attractive labels with complicated designs and more color. Therefore, an increase in cost for colorant usage rate is also expected in addition to the cost of carrying inventory. Printing setup should not vary, since the value of the product-package does not necessarily imply multiple setups.

The case study interviews revealed representative ranges of values for $V_p$ to be \$0.5 on the low end and \$2 on the high end, averaging at \$1.

Table 3.6b illustrates the product factor, value of product-package system, its associated value ranges, and its relationship to the cost factors.

**TABLE 3.6b**

Product Factors and Associated Ranges

| | $F_{rc}$ | $F_{mc}$ | $F_{pc}$ | $V_p$ | | | |
|---|---|---|---|---|---|---|---|
| Cost Factors | | | | | | | |
| PR | ↑ | ↑ | ↑ | ↑ | | | |
| INV | | | | ↑ | | | |
| STO | | | | | | | |
| OBS | ↑ | ↑ | ↑ | | | | |
| Associated Ranges | | | | | | | |
| Minimum | 1 | 1 | 0 | $0.5 | | | |
| Mode | 2 | 3 | 1 | $1 | | | |
| Maximum | 3 | 5 | 2 | $2 | | | |

### Number of brands ($N_b$)

Number of brands is an important factor especially when the scale is large. Having a large number of brands translates into having to do multiple setups for label printing jobs, which in turn has an effect on total cost of label printing. Depending on the number of brands, a company may need to print different kinds of labels (i.e., different print-job setups) for the same compound, since they are marketed differently. Therefore, the resulting effect of this factor on the total cost of label printing and the decision to postpone is incorporated into the cost model.

Number of brands also includes different indications of a compound, since the labels will be different for each indication. Large numbers of brands translate directly into increased activity in printing setups due to different label requirements for different brands, even though the brands may use the same base formula (compound). In addition, the more brands the shorter the length of each labeling run which results in higher cost of postponement (Zinn, 1986). On the other hand, with more brands, the opportunity to consolidate safety stocks becomes lower, which increases the cost of speculation relative to the cost of postponement (Zinn, 1986). Zinn (1986) concluded that the latter criteria turned out to be stronger therefore there was a greater incentive to postpone labeling.

From the case study interviews, it is evident that the number of brands a pharmaceutical company carries on a particular compound can be as little as five or as many as 20, averaging at 12.

Table 3.6c summarizes the statements above by tabulating the product factor number of brands, its associated value ranges, and its relationship to the cost factors.

**TABLE 3.6c**

Product Factors, Associated Ranges, and Their Relation to Cost Factors

| | $F_{rc}$ | $F_{mc}$ | $F_{pc}$ | $V_p$ | $N_b$ | | |
|---|---|---|---|---|---|---|---|
| Cost Factors | | | | | | | |
| PR | ↑ | ↑ | ↑ | ↑ | ↑ | | |
| INV | | | | ↑ | | | |
| STO | | | | | | | |
| OBS | ↑ | ↑ | ↑ | | | | |
| Associated Ranges | | | | | | | |
| Minimum | 1 | 1 | 0 | $0.5 | 5 | | |
| Mode | 2 | 3 | 1 | $1 | 12 | | |
| Maximum | 3 | 5 | 2 | $2 | 20 | | |

**Number of global markets ($N_m$)**

An apparent effect of this factor is the need to deal with multiple languages. Having multiple languages translates into having to do multiple label printing setups for each language. Similar to the number of brands, this factor affects total cost of printing labels and the decision to postpone.

The same effect from greater number of brands should be expected from larger number of global markets primarily due to the increased number of languages the process has to accommodate. As a summary, printing costs are expected to increase with more global markets.

The case study interviews indicate that the number of global markets that a pharmaceutical company generally operates in can be one or four, averaging at three. Table 3.6d illustrates the product factor number of global markets, its associated value ranges, and its relationship to the cost factors.

**TABLE 3.6d**

Product Factors, Associated Ranges, and Their Relation to Cost Factors

| | $F_{rc}$ | $F_{mc}$ | $F_{pc}$ | $V_p$ | $N_b$ | $N_m$ | |
|---|---|---|---|---|---|---|---|
| Cost Factors | | | | | | | |
| PR | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | |
| INV | | | | ↑ | | | |
| STO | | | | | | | |
| OBS | ↑ | ↑ | ↑ | | | | |
| Associated Ranges | | | | | | | |
| Minimum | 1 | 1 | 0 | $0.5 | 5 | 1 | |
| Mode | 2 | 3 | 1 | $1 | 12 | 3 | |
| Maximum | 3 | 5 | 2 | $2 | 20 | 4 | |

**Number of annual production runs ($N_{pr}$)**

This factor is mostly driven by the seasonality of product ($S_p$). In the case of a stock-out of a product with seasonal demand (such as allergy medication), company may lose consumers for a longer period of time, depending on the length of the season. This, in turn affects the decision to postpone and the total cost of printing labels.

As the number of annual production runs increase, the cost of holding inventory decreases. This is primarily due to the ability of satisfying the demand by less inventory. Assuming a constant annual demand, a company may choose to produce the demand in one run versus weekly runs. In the first case, the annual average inventory will be demand divided by two, assuming linear expenditure of inventory. In the latter case, the company produces demand divided by 52 (weekly demand), and therefore the annual average inventory will be demand divided by 52 divided by two. Similarly, as the annual production runs increase, the abnormal scrap/rework costs will decrease due to less inventory being subject to obsolescence. However, the cost of stock-outs increase due to reduced inventory holdings.

The case study interviews indicate that production can happen as often as weekly or in very rare cases (seasonal) two times a year. This assigns the lowest value for this variable to be two and the highest 50, averaging at 12.

Table 3.6e tabulates the product factor number of annual production runs, its associated value ranges, and its relationship to the cost factors.

**TABLE 3.6e**

Product Factors, Associated Ranges, and Their Relation to Cost Factors

| | $F_{rc}$ | $F_{mc}$ | $F_{pc}$ | $V_p$ | $N_b$ | $N_m$ | $N_{pr}$ |
|---|---|---|---|---|---|---|---|
| Cost Factors | | | | | | | |
| PR | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | |
| INV | | | | ↑ | | | ↓ |
| STO | | | | | | | ↑ |
| OBS | ↑ | ↑ | ↑ | | | | |
| Associated Ranges | | | | | | | |
| Minimum | 1 | 1 | 0 | $0.5 | 5 | 1 | 2 |
| Mode | 2 | 3 | 1 | $1 | 12 | 3 | 12 |
| Maximum | 3 | 5 | 2 | $2 | 20 | 4 | 50 |

## MODEL STRUCTURE

The statements summarizing how the seven product factors relate to the total cost of printing labels are illustrated in Tables 3.7 and 3.8 below. The direction of the arrow indicates the relationship between product factors and cost categories (i.e., the up-arrow specifies a directly proportional relationship and the down-arrow indicates an inversely proportional relationship between the product factor and the corresponding cost category). In addition, the seven product factors relate to the ABC model of cost activities as illustrated in Table 3.8.

**TABLE 3.7**
Effect of Product Factors on Cost Factors of Printing Labels

| | PR | INV | STO | OBS |
|---|---|---|---|---|
| $F_{rc}$ | ↑ | | | ↑ |
| $F_{mc}$ | ↑ | | | ↑ |
| $F_{pc}$ | ↑ | | | ↑ |
| $V_p$ | ↑ | ↑ | | |
| $N_b$ | ↑ | | | |
| $N_m$ | ↑ | | | |
| $N_{pr}$ | | ↓ | ↑ | |

**TABLE 3.8**
Cost Activities versus Product Factors

| | $F_{rc}$ | $F_{mc}$ | $F_{pc}$ | $V_p$ | $N_b$ | $N_m$ | $N_{pr}$ |
|---|---|---|---|---|---|---|---|
| 1. Direct Activities | | | | | | | |
| A. Printing Setup | + | + | + | 0 | + | + | + |
| B. Printing Run | + | + | + | + | 0 | 0 | 0 |
| 1. Substrate Usage Rate | 0 | 0 | 0 | + | 0 | 0 | 0 |
| 2. Colorant Usage Rate | + | + | + | + | 0 | 0 | 0 |
| 3. Equipment Parts Replacement Rate | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4. Inventory Carrying/Warehousing | 0 | 0 | 0 | + | 0 | 0 | - |
| 2. Discretionary Activities | | | | | | | |
| A. Abnormal Scrap/Rework | + | + | + | 0 | 0 | 0 | 0 |
| 3. Special Requirements Activities | | | | | | | |
| A. Special Customer Requests | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

([0] denotes no change, [-] denotes a decrease in the cost activities as the product factors increase, and [+] denotes an increase in the cost activities as the product factors increase.)

These illustrations summarize the product factors and their effects on the total cost of printing labels. The next section discusses the research hypotheses.

## RESEARCH HYPOTHESES

New technologies, such as electrophotographic/digital printing, bring greater incentives to implement postponement strategies in package labeling. The purpose of this research is to develop an economic model for implementing postponement strategies. The study presents a model that includes seven product factors and uses a total cost approach in analyzing the effects of these factors on the total cost for printing labels and develops economic justification for postponement in various cases.

The question that the hypotheses address is: How does each of the seven product factors impact the total cost for printing labels and the decision to postpone? Below are the expected effects of each of the seven product factors has on the decision to postpone, namely propositions for this study.

A. The HIGHER the frequency of regulatory changes ($F_{rc}$), the GREATER the incentive to postpone labeling to the distribution center level, and the GREATER the cost of obsolescence and the cost of printing runs (most upgrades involve more information to be put on labels).

B. The HIGHER the frequency of marketing based changes ($F_{mc}$), the GREATER the incentive to postpone labeling to the distribution center level, the GREATER the cost of obsolescence and the cost of printing runs (most changes involve more color to be put on labels; or more expensive colorant, such as metallic ink).

C. The HIGHER the frequency of packaging engineering design changes ($P_{pc}$), the GREATER the incentive to postpone labeling to the distribution center level, the GREATER the cost of obsolescence and the cost of printing runs (most changes involve more complicated designs such as folding to better prevent shock and vibration damage).

D. The GREATER the value of product-package system ($V_p$), the GREATER the incentive to postpone labeling to the distribution center level (generally, as the value of product-package system increases the cost of printing labels increases).

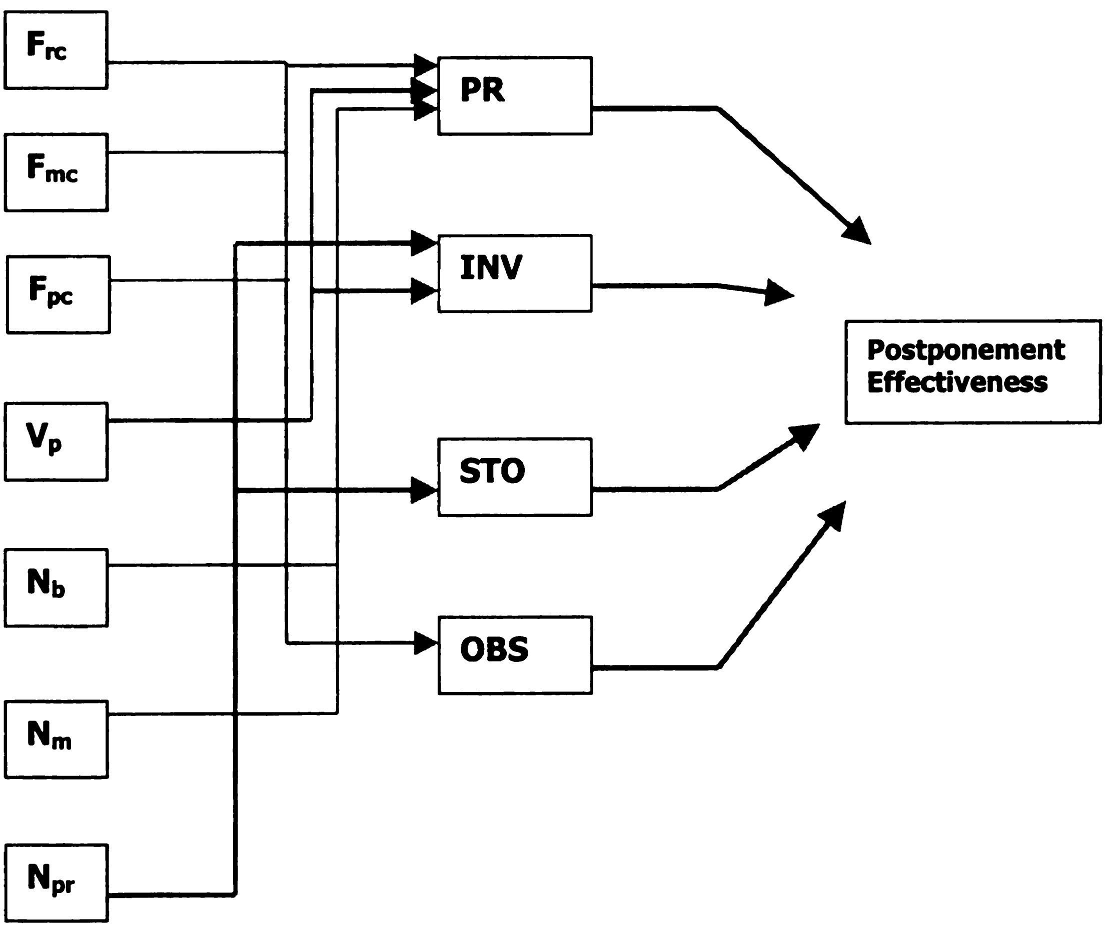
E. The GREATER the number of brands ($N_b$), the GREATER the incentive to postpone labeling to the distribution center level.

F. The GREATER the number of global markets ($N_m$), the GREATER the incentive to postpone labeling to the distribution center level.

G. The GREATER the number of annual production runs ($N_{pr}$), the LOWER the incentive to postpone labeling to the distribution center level (the GREATER the cost of stock-outs but the LOWER the cost of inventory).

Distribution Center Level as referred here, represents the last leg of the supply chain where large-scale quality printing can occur. Figure 3.1 presents a diagram of the research hypothesis explained above. These hypotheses are tested using the methodology explained in the next section.

**FIGURE 3.1**
Research Hypotheses Diagram



# METHODOLOGY AND RESEARCH DESIGN

This section explains the case study interview method used to develop the model and verify ranges for the product and cost factors. Next, the cost simulation is discussed in detail.

## CASE STUDY INTERVIEW

Case study research method is utilized to explain each product factor and their relationship to the total cost of printing labels. This way, the context of label printing is more comprehensively investigated. For example, Yin (1994) indicates that survey, as an alternative research strategy, has extremely limited ability to investigate context.

The case study is conducted in the form of interviews. The case study subjects who are invited to participate in the study are mostly alumni or other contacts from Michigan State University's School of Packaging and contacts and customers of The John Henry Company. In order to effectively assess the relationship between the product factors and total cost of printing labels, a particular industry is chosen. Due to the seemingly amplified effects of the product factors, the primary business selected is the pharmaceutical industry.

A set of exploratory interviews is performed following formal interviews. First, the interviewees are asked verify the product factors and their effects on the total cost of printing labels. Then, as explained previously in this chapter (Model and Theory Development: Product Factors section), the case study participants provide three ranges of values for each product factor (i.e., minimum, mode, and maximum). The data gathered through the case study interviews are then used to establish the representative ranges of values for the product factors and average annual volume. Table 3.9 illustrates these values.

**TABLE 3.9**

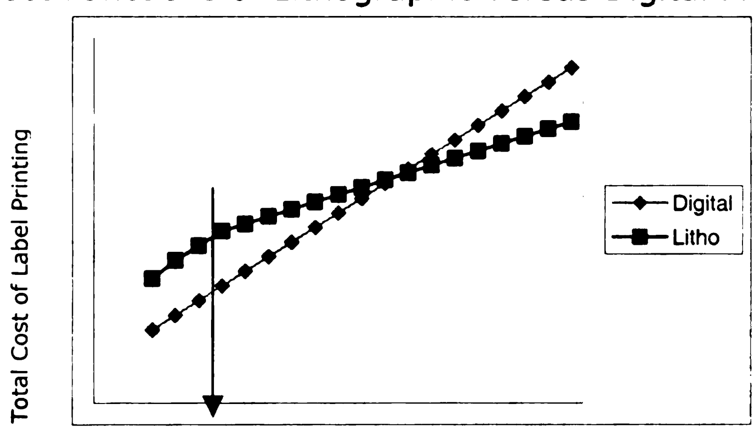
Product Factors and Associated Ranges

| | $F_{rc}$ | $F_{mc}$ | $F_{pc}$ | $V_p$ | $N_b$ | $N_m$ | $N_{pr}$ | V |
|---|---|---|---|---|---|---|---|---|
| Minimum | 1 | 1 | 0 | $0.5 | 5 | 1 | 2 | 500,000 |
| Mode | 2 | 3 | 1 | $1.0 | 12 | 3 | 12 | 20,000,000 |
| Maximum | 3 | 5 | 2 | $2.0 | 20 | 4 | 50 | 100,000,000 |

The cost model for printing labels is constructed starting from label quantities of 1,000 up to 10,000 linear feet in 1,000 increments. The reason for this stems from the fact that the economical run length for digital printing for labels seems to be within a range of 2,000 (Emden, 2001-2003) to 7,500 linear feet (Bence, 2001). Somewhere within this range, the cost function of litho intersects with the cost function of electrophotographic/digital and takes a downward trend while the cost function for digital moves upward with respect to total cost. This statement is illustrated in Figure 3.2 with hypothetical numbers. Even though Zinn (1986, p 178) indicates that demand levels do not have any effect on the decision to postpone, this research still takes the demand levels into account when analyzing total cost as articulated above. It should also be noted that the study takes into account the varying ways of measuring label production quantity. The preliminary interviews suggest that linear-feet is the favorable measure, however the interviewees are given the opportunity to comment on this.

**FIGURE 3.2**

Cost Functions of Lithographic versus Digital Printing




2,000 linear feet according to Emden and 7,500 linear feet according to Bence.

The case study subjects are then asked to build and explain a business case for each possible business scenario. During this process, the effect of the production volume is also considered to explain which of these factors has the most impact on total cost with each level of production volume.

The data collected through the case study interviews are used to establish the representative ranges of values for the cost factors, the variables that are used to calculate them, and the product factors. The representative ranges of values are then used to validate the research hypothesis, to develop a total cost model for printing labels, and to quantify the effects of postponement. This consists of validating the data using a spreadsheet software application using Microsoft® Excel®. The section titled Cost Simulation explains the method in detail.

When litho printing methods are used, setup costs are higher with respect to digital printing and variable costs decrease with the increased quantity of labels produced (Emden, 2001-2003). In the case of digital printing however, setup costs are observed to be less than litho printing setup costs, and variable costs stay constant regardless of the quantities of labels produced (Emden, 2001-2003). These statements are summarized with representative numbers in Figure 3.2 (Emden, 2001-2003) above.

## COST SIMULATION

In conducting the investigation, cost model developed earlier for package-labeling system is built into the simulation. The data collected through the case study interviews are used to establish the representative ranges of values for the cost factors, the variables that are used to calculate them, and the product factors. A combination simulation-regression analysis is conducted using the data obtained through the case study interviews. The simulation model is developed to observe the impact of all the independent variables on the cost drivers and the package labeling system cost for digital printing and for conventional printing. A multiple regression analysis is then executed in order to identify the independent variables among the cost drivers so as to isolate the ones with the greatest impact on postponement. A package labeling supply chain system profile is developed to reveal when savings can be achieved. The effects of postponement on each of the seven product factors are explored with a focus on minimizing total cost utilizing the spreadsheet model.

Next, the effects of production quantities on the ABC cost factors are investigated. As explained previously, the support activities are not taken into account since a facility must run whether it produces 10,000 or 1 million linear feet of labels at any given time frame. Therefore, the category of operating costs is the group under consideration.

Finally, the individual and relative impact of the seven independent variables listed as frequency of regulatory changes ($F_{rc}$); frequency of marketing based changes ($F_{mc}$); frequency of package engineering design changes ($F_{pc}$); value of product-package system

($V_p$); number of brands ($N_b$); number of global markets ($N_m$); and number of annual production runs ($N_{pr}$) on total cost should be analyzed. The fact remains that the operating activity cost items is the contributing cost activity in this analysis.

As explained in the section titled Model and Theory Development and summarized in Table 3.8, the items listed under printing run under direct activities as Substrate Usage Rate, Colorant Usage Rate, and Equipment Parts Replacement Rate, are not expected to be affected with increased/decreased levels of any one of the seven independent variables, namely product factors. This argument also holds for the Special Requirements Activities. Further, it is observed that an increase in either number of brands or number of global markets results only in significantly increased levels of the cost item listed under direct activities as printing setup. On the other hand, increased levels of Printing Setup, Inventory Carrying/Warehousing, and Abnormal Scrap/Rework should be recorded as the frequencies of regulatory ($F_{rc}$), marketing based ($F_{mc}$), and package engineering based design changes ($F_{pc}$) increases.

The goal is to identify the factor(s) with the most impact on postponement, as it relates to total cost. This way, the area where postponement has the most impact on total cost is isolated. To achieve this, regression analysis is run on the dependent variable and contains the independent cost factors. The dependent variable is the difference of total cost of printing labels between postponement (digital printing) and speculation (conventional printing) strategies. Therefore, a negative difference favors using digital printing method. Digital printing is acknowledged as an enabler to postponement in Chapter II under the section titled Analysis of Label Printing. Hence, a negative difference suggests implementing postponement as package label printing strategy.

The cost simulation is run for two different sets of models; one representing the cost model of printing labels using digital technology and the other representing the cost model of printing labels using conventional printing method. This is to capture the possible conditions under which postponement strategies are justified. The collection of settings under which postponement strategies are the least expensive can be expressed as a relevant range for using digital printing technology. As explained previously in this chapter under the section titled Product Factors, the minimum, mode, and maximum data values are collected using case study interviews, as illustrated in Table 3.10.

**TABLE 3.10**

Examples of Variables and Associated Ranges

| | Variable 1 | Variable 2 | Variable 3 |
|---|---|---|---|
| Minimum | 1 | 4 | 7 |
| Mode | 2 | 5 | 8 |
| Maximum | 3 | 6 | 9 |

A triangular generating function in Microsoft® Excel® is used to generate individual observations for each of the seven variables (i.e., product factors). With a normal distribution, the data alleges infinity, which is not the case in this study (Closs, 2003). In addition, the triangular function provides us with the opportunity to evaluate non-symmetric distributions, which allows the possibility to have the values range freely without forcing symmetry.

The triangular generating function assumes a cumulative distribution for a triangular probability density function and takes random values of each variable. In order to ensure statistical significance, one thousand observations are generated using this function. Each observation represents a unique combination of the seven product factors with each factor independently following a triangular probability distribution. Appendix B lists the first twenty-five observations in the simulation model. As pointed out previously, for each observation, the cost of printing digital and conventional are calculated and the difference of the costs indicates the favorable method. Table 3.11 illustrates this method with ten observations as sample. In this illustration, variable 1 has minimum 1, mode 2, and maximum value of 3.

**TABLE 3.11**
Example of Cost Simulation

| | Variable 1 min | Variable 1 mode | Variable 1 max | Variable 1 | Tc (digital) | Tc (conv.) | Tc (digital-conv.) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 3 | 2 | - | - | - |
| 2 | 1 | 2 | 3 | 2 | - | - | - |
| 3 | 1 | 2 | 3 | 2 | - | - | - |
| 4 | 1 | 2 | 3 | 2 | - | - | - |
| 5 | 1 | 2 | 3 | 1 | - | - | - |
| 6 | 1 | 2 | 3 | 2 | - | - | - |
| 7 | 1 | 2 | 3 | 3 | - | - | - |
| 8 | 1 | 2 | 3 | 1 | - | - | - |
| 9 | 1 | 2 | 3 | 2 | - | - | - |
| 10 | 1 | 2 | 3 | 2 | - | - | - |

Even though the seven product factors are treated as independent variables, it must also be noted that many other factors are likely to affect the total cost of printing labels, such as average annual volume (V). Therefore, the model also incorporates average annual volume as the eighth variable and treats it as an independent variable. In addition, in order to account for the additional factors that may be influential as probable independent factors, an error term is used. Therefore, the error percentage term introduced previously in this chapter addresses the additional factors that may not have been taken into account.

## CONCLUSION

In this chapter, the groundwork for developing an economic model for package label printing in pharmaceutical industry is described. The next chapter presents the data analysis according to the methodology explained above.

# CHAPTER IV

# DATA ANALYSIS

A total of seven case study interviews are conducted for identifying the representative minimum, mode, and maximum values for each product factor and all cost variables that compose the cost factors which, when added, make up the total cost (see equation 3.1). Appendix A lists the interview questions and discussion points that were addressed by the case study participants. Data on some of the cost variables was not available due to confidentiality or difficulty in compiling the data especially when multiple departments were involved. However, the case study interviews are used to identify the representative ranges of the data set, which is not intended to symbolize any one specific case.

The simulation model is run based on the data as gathered and utilized to set the representative ranges of the variables. After the simulation of the model, sensitivity analysis is performed to measure the scale of significance for each product factor.

This chapter presents the data analyses as explained in the cost simulation section of Chapter III and the results for each product factor and the multiple variable data analysis to isolate the product factors with the significant impact on total cost for printing package labels in the pharmaceutical industry.

As a summary, the data collected through the case study interviews are used to establish the representative ranges of values for the cost factors, the variables that are used to calculate them, and the product factors. A combination simulation-regression analysis is conducted using the data obtained through the case study interviews. The simulation model is developed to observe the impact of all the independent variables on the package labeling system cost difference between digital and conventional printing. A negative result indicates that digital (plateless) printing provides cost reduction with respect to conventional (plate) printing. Observations on over-the-counter (OTC) drug, prescription drug, and surgical equipment products are captured during the interview process and are used to create different scenarios for the sensitivity analysis.

Multiple regression analysis is executed in order to identify the independent variables with statistical significance on the dependent variable, namely the difference of total cost of printing labels digitally versus conventionally ($T_c$). The independent variables analyzed include the seven product factors (i.e., $F_{rc}$, $F_{mc}$, $F_{pc}$, $V_p$, $N_b$, $N_m$, and $N_{pr}$) and the average annual volume (V). A package labeling supply chain system profile is developed to reveal when savings can be achieved.

The effects of postponement on each of the seven product factors are explored with a focus on minimizing total cost utilizing the spreadsheet model.

Finally, the relative importance of the product factors is examined. As a result, the product factors are ranked in descending order of impact on the difference of total cost of printing labels digitally versus conventionally.

## EFFECT OF FREQUENCY OF REGULATORY CHANGES

Figure 4.1 illustrates the one thousand observations of the independent variable frequency of regulatory changes ($F_{rc}$) with respect to the dependent variable the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$). The multiple variable regression analysis illustrated in Table 4.1 indicates that $F_{rc}$ with a p-value of 0.579069861 (higher than 0.05) is NOT a significant factor affecting the total cost of printing labels.

This result could be due to the fact that the ranges of values for $F_{rc}$ are not high compared to $F_{mc}$, which is statistically significant, as explained in the next section. This is tested with a sensitivity analysis, where the values of the product factors with high p-values are increased, for example, doubled. When this analysis is performed, $F_{rc}$ becomes a significant variable affecting the total cost of printing labels. The resulting multiple variable regression analysis is presented in Table 4.2a. The simulation and multiple variable regression analysis confirm significance when the ranges of values for $F_{rc}$ are otherwise increased, such as making the values equal to the ranges of values for $F_{mc}$.

**TABLE 4.1**

Multiple Variable Regression Analysis

| *Regression Statistics* | | | |
|---|---|---|---|
| R Square | .727 | | |
| | *Coefficients* | *t Stat* | *P-value* |
| Intercept | 229422.891 | 11.422 | .000 |
| $F_{rc}$ | -2625.589 | -.555 | .579 |
| $F_{mc}$ | -7598.251 | -3.262 | .001 |
| $F_{pc}$ | -2753.274 | -.566 | .571 |
| $V_p$ | -2232.136 | -.361 | .718 |
| $N_b$ | -14771.437 | -22.405 | .000 |
| $N_m$ | -15943.307 | -5.071 | .000 |
| $N_{pr}$ | -8762.946 | -46.370 | .000 |
| V | .000 | .991 | .322 |

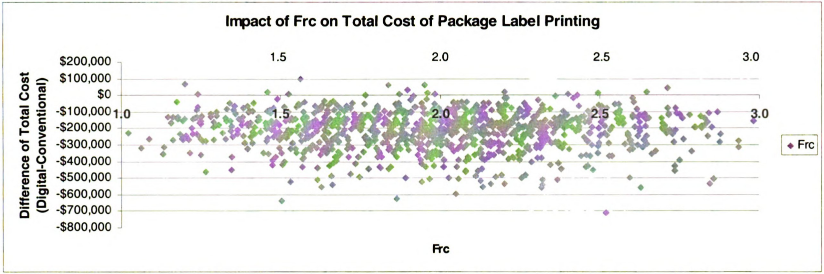
**TABLE 4.2a**

Multiple Variable Regression Analysis: $F_{rc}$ ranges of values doubled

| *Regression Statistics* | | | |
|---|---|---|---|
| R Square | .740 | | |
| | *Coefficients* | *t Stat* | *P-value* |
| Intercept | 273545.524 | 14.181 | .000 |
| $F_{rc}$ | -6415.972 | -2.613 | .009 |
| $F_{mc}$ | -4838.225 | -1.959 | .050 |
| $F_{pc}$ | -8882.011 | -1.836 | .067 |
| $V_p$ | -19886.992 | -3.190 | .002 |
| $N_b$ | -16871.899 | -26.446 | .000 |
| $N_m$ | -14801.946 | -4.867 | .000 |
| $N_{pr}$ | -8622.966 | -45.747 | .000 |
| V | .000 | -.127 | .899 |

**FIGURE 4.1**

**Impact of Frequency of Regulatory Changes on Total Cost of Package Label Printing**




1,000 observations of frequency of regulatory changes ($F_{rc}$) with respect to the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$).

## EFFECT OF FREQUENCY OF MARKETING CHANGES

Figure 4.2 illustrates the one thousand observations of the independent variable frequency of marketing changes ($F_{mc}$) with respect to the dependent variable the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$). The multiple variable regression analysis illustrated in Table 4.1 indicates that $F_{mc}$ with a p-value of 0.001146057 (lower than 0.05) IS a significant factor affecting the total cost of printing labels.

As displayed in Table 4.2a, doubling the variable ranges for $F_{rc}$ renders $F_{mc}$ as insignificant only marginally, (p-value of 0.050348782). However, when the variable ranges for $F_{mc}$ and $F_{rc}$ are made equal (i.e. 1, 3, 5), then both variables become significant. The resulting regression analysis is displayed in Table 4.2b. This indicates that under certain value ranges, the variables become insignificant factors affecting the total cost of printing labels.

**TABLE 4.2b**

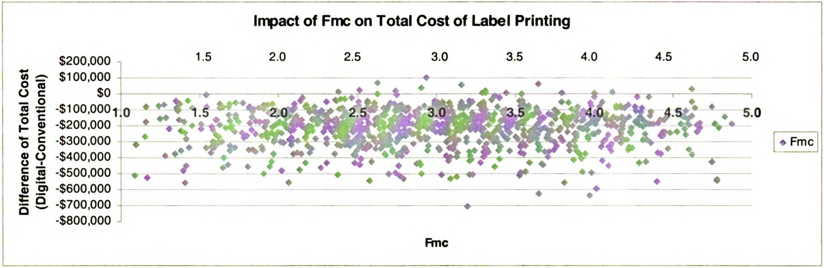
Multiple Variable Regression Analysis:

$F_{rc}$ ranges of values increased to equal to $F_{mc}$ ranges of values

| *Regression Statistics* | | | |
|---|---|---|---|
| R Square | .730 | | |
| | *Coefficients* | *t Stat* | *P-value* |
| Intercept | 215371.178 | 11.785 | .000 |
| $F_{rc}$ | -10938.540 | -4.518 | .000 |
| $F_{mc}$ | -5145.315 | -2.192 | .029 |
| $F_{pc}$ | -3626.316 | -.782 | .434 |
| $V_p$ | 1545.241 | .244 | .808 |
| $N_b$ | -14658.612 | -23.235 | .000 |
| $N_m$ | -10593.274 | -3.438 | .001 |
| $N_{pr}$ | -8255.826 | -45.667 | .000 |
| V | .000 | -1.0197 | .308 |

**FIGURE 4.2**

**Impact of Frequency of Marketing Changes on Total Cost of Package Label Printing**




1,000 observations of frequency of marketing changes ($F_{mc}$) with respect to the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$).

## EFFECT OF FREQUENCY OF PACKAGE ENGINEERING CHANGES

Figure 4.3 illustrates the one thousand observations of the independent variable frequency of package engineering design changes ($F_{pc}$) with respect to the dependent variable the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$). The multiple variable regression analysis illustrated in Table 4.1 indicates that $F_{pc}$ with a p-value of 0.571438514 (higher than 0.05) is NOT a significant factor affecting the total cost of printing labels.

Similar to the argument made previously for $F_{rc}$, this result could be due to the fact that the ranges of values for $F_{pc}$ are not high compared to $F_{mc}$, which is statistically significant. Once again, the simulation and multiple variable regression analysis confirm significance when the ranges of values for $F_{pc}$ are increased, such as making the values equal to the ranges of values for $F_{mc}$. When this analysis is performed, $F_{pc}$ becomes a significant variable affecting the total cost of printing labels. The resulting multiple variable regression analysis is presented in Table 4.2c.

**TABLE 4.2c**

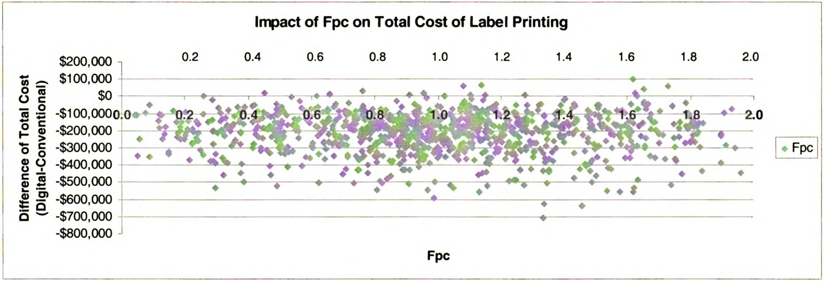
Multiple Variable Regression Analysis:

$F_{pc}$ ranges of values increased to equal to $F_{mc}$ ranges of values

| *Regression Statistics* | | | |
|---|---|---|---|
| R Square | .739 | | |
| | *Coefficients* | *t Stat* | *P-value* |
| Intercept | 268768.302 | 13.379 | .000 |
| $F_{rc}$ | -7296.102 | -1.599 | .110 |
| $F_{mc}$ | -12543.999 | -5.239 | .000 |
| $F_{pc}$ | -8768.439 | -3.710 | .000 |
| $V_p$ | -2684.772 | -.437 | .662 |
| $N_b$ | -15257.203 | -23.548 | .000 |
| $N_m$ | -16418.177 | -5.165 | .000 |
| $N_{pr}$ | -8633.146 | -46.764 | .000 |
| V | .000 | -.538 | .591 |

**FIGURE 4.3**

**Impact of Frequency of Package Engineering Design Changes on Total Cost of Label Printing**




1,000 observations of frequency of package engineering design changes ($F_{pc}$) with respect to the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$).

## EFFECT OF VALUE OF PRODUCT-PACKAGE SYSTEM

Figure 4.4a illustrates the one thousand observations of the independent variable value of product-package system ($V_p$) with respect to the dependent variable the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$). The multiple variable regression analysis illustrated in Table 4.1 indicates that $V_p$ with a p-value of 0.71790182 (higher than 0.05) is NOT a significant factor affecting the total cost of printing labels.

Similar to the arguments made for the other product factors that turned out to be insignificant, this result is likely due to the fact that the ranges of values for $V_p$ are not high enough to render it significant. When tested with a sensitivity analysis by increasing the ranges of values, $V_p$ is rendered significant. This succeeded in depicting $V_p$ as significant only when the ranges of values were increased by about a couple hundred folds (i.e., $5, $500, and $10,000 as minimum, mode, and maximum respectively). The scenario under which these types of values could be justified is in the case of surgical implants, or highly complex pharmaceuticals such as cancer treatment drugs, because the $V_p$ values for such products tend to be much higher than more common pharmaceutical products. The resulting multiple variable regression analysis is presented in Table 4.2d.

**TABLE 4.2d**

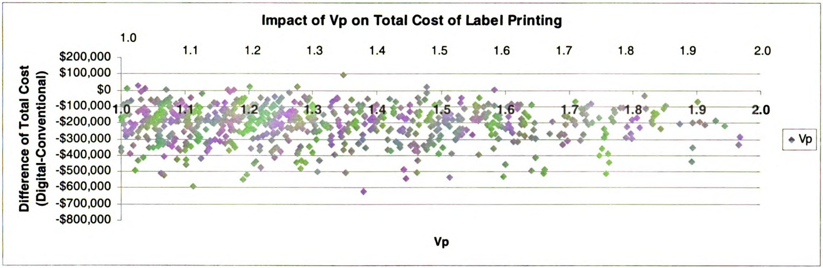
Multiple Variable Regression Analysis:

$V_p$ ranges of values increased to 5, 500, and 10,000

| *Regression Statistics* | | | |
|---|---|---|---|
| R Square | .018 | | |
| | *Coefficients* | *t Stat* | *P-value* |
| Intercept | 3671293.261 | .630 | .529 |
| $F_{rc}$ | -1499685.226 | -.981 | .327 |
| $F_{mc}$ | -397873.461 | -.520 | .604 |
| $F_{pc}$ | 912345.208 | .589 | .556 |
| $V_p$ | 649.818 | 2.433 | .015 |
| $N_b$ | 152168.275 | .733 | .464 |
| $N_m$ | -1745911.809 | -1.740 | .082 |
| $N_{pr}$ | -76777.932 | -1.284 | .199 |
| V | .071 | 2.425 | .016 |

## FIGURE 4.4a

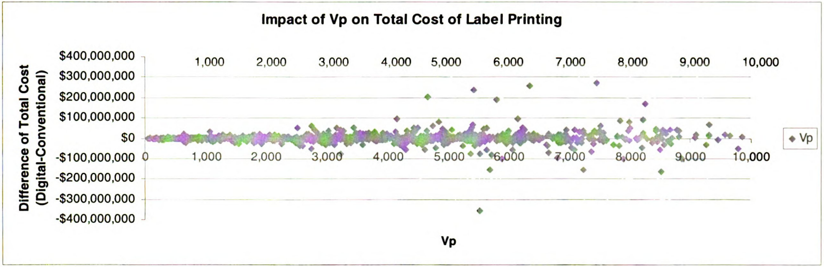
## Impact of Value of Product-Package System on Total Cost of Label Printing




1,000 observations of value of product-package system ($V_p$) with respect to the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$).

**FIGURE 4.4b**

**Impact of Value of Product-Package System on Total Cost of Label Printing ($V_p$ value range \$5, \$500, \$10,000)**




1,000 observations of value of product-package system ($V_p$) with respect to the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$).

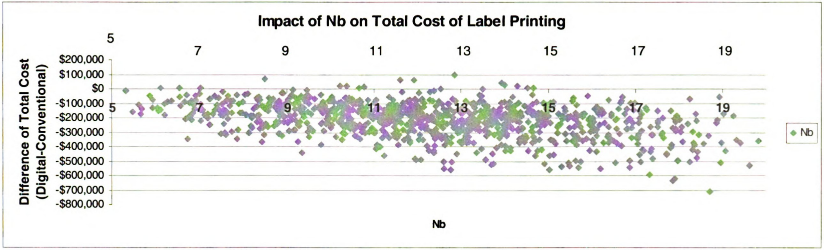
## EFFECT OF NUMBER OF BRANDS

Figure 4.5 illustrates the one thousand observations of the independent variable number of brands ($N_b$) with respect to the dependent variable the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$). The multiple variable regression analysis illustrated in Table 4.1 indicates that $N_b$ with a p-value of 4.72474E-07 (much lower than 0.05) IS a significant factor affecting the total cost of printing labels.

As displayed in Tables 4.2a through 4.2d, $N_b$ remains significant under all the scenarios tested for sensitivity of the model. This indicates that for all of the value ranges tested, the variable $N_b$ depicts statistical significance in affecting the total cost of printing labels. In addition, as seen in Figure 4.5, digital printing becomes increasingly favorable with respect to conventional printing as the number of brands increases.

## FIGURE 4.5

### Impact of Number of Brands on Total Cost of Label Printing




1,000 observations of number of brands ($N_b$) with respect to the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$).

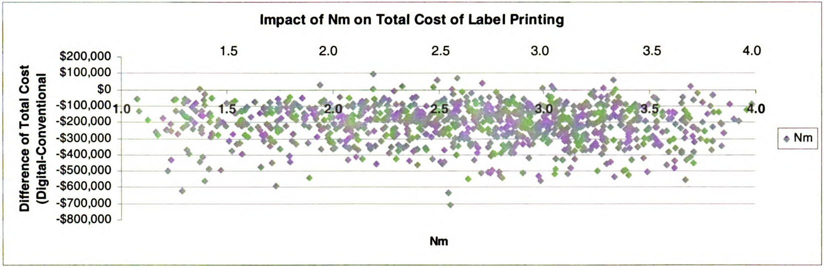
## EFFECT OF NUMBER OF GLOBAL MARKETS

Figure 4.6a illustrates the one thousand observations of the independent variable number of global markets ($N_m$) with respect to the dependent variable the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$). The multiple variable regression analysis illustrated in Table 4.1 indicates that $N_m$ with a p-value of 2.83556E-90 (much lower than 0.05) IS a significant factor affecting the total cost of printing labels.

Similar to $N_b$, $N_m$ remains significant under the business scenarios tested for sensitivity of the model. This indicates that $N_m$ is effective in the scenarios tested for sensitivity of the model. This designates that for all of the value ranges tested, the variable $N_m$ depicts statistical significance in affecting the total cost of printing labels. However, distribution does not display a strong trend such as the $N_b$ plot does (i.e., digital printing becomes increasingly favorable with respect to conventional printing as the number of brands increases). This is due to the range of values (i.e., 1, 3, and 4) taken as representative for $N_m$. When a product is marketed to a range of one, 15, and 20 global markets for example, the trend becomes pronounced as seen in Figure 4.6b (i.e., digital printing becomes increasingly favorable as the number of global markets increases).

**FIGURE 4.6a**

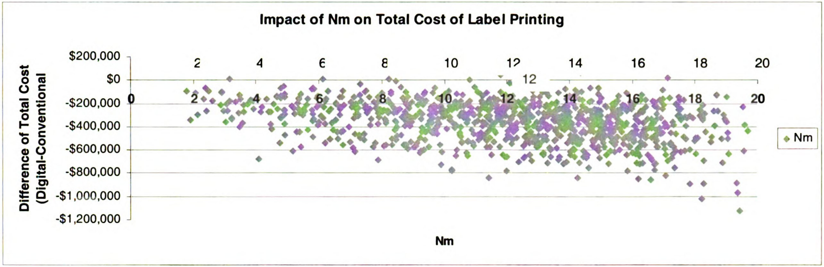
**Impact of Number of Global Markets on Total Cost of Label Printing**




1,000 observations of number of global markets ($N_m$) with respect to the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$).

**FIGURE 4.6b**

**Impact of Number of Global Markets on Total Cost of Label Printing**
**$N_m$ ranges of values increased to 1, 15, and 20**




1,000 observations of number of global markets ($N_m$) with respect to the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$).

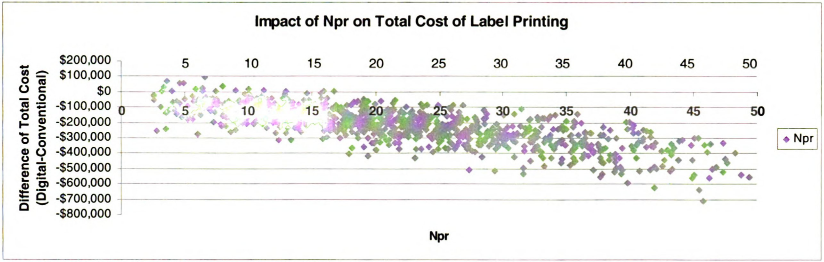
## EFFECT OF NUMBER OF ANNUAL PRODUCTION RUNS

Figure 4.7 illustrates the one thousand observations of the independent variable number of annual production runs ($N_{pr}$) with respect to the dependent variable the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$). The multiple variable regression analysis illustrated in Table 4.1 indicates that $N_{pr}$ with a p-value of 1.7136E-250 (much lower than 0.05) IS a significant factor affecting the total cost of printing labels.

Similar to $N_b$ and $N_m$, $N_{pr}$ remains significant under all the scenarios tested for sensitivity of the model. This indicates that for all of the value ranges tested, the variable $N_{pr}$ depicts statistical significance in affecting the total cost of printing labels. As the number of annual production runs increases, the chances of being able to incorporate any regulatory change, marketing change, or packaging change into the already scheduled production changeovers increase. Therefore, the greater the number of annual production runs, the easier it is for companies to accommodate changes such as regulatory ones with less impact on total cost. Similar to the analysis on $N_b$, digital printing becomes increasingly favorable with respect to conventional printing as the number of annual production runs increases.

**FIGURE 4.7**

**Impact of Number of Annual Production Runs on Total Cost of Label Printing**




1,000 observations of number of annual production runs ($N_{pr}$) with respect to the difference of total cost of printing labels using digital versus conventional printing technology ($T_c$).

## MULTIPLE VARIABLE REGRESSION ANALYSIS

Four of the seven product factors are proven to have an impact on the total cost of printing package labels in the pharmaceutical industry. These four are the frequency of marketing based design changes ($F_{mc}$), number of brands ($N_b$), number of global markets ($N_m$), and number of annual production runs ($N_{pr}$). Table 4.1 illustrates the p-values of each of the seven independent variables and annual average volume (V).

In order to examine the contribution of each independent variable to the regression model, backward elimination method is used as part of the sequential search method under the multiple variable regression analysis framework (Hair, et. al., 1998). This procedure computes a regression analysis with all the independent variables and then deletes the independent variables that do not contribute significantly (Hair, et. al., 1998). Therefore, multiple regression analysis is exercised continuously by taking the independent variable with the highest p-value out of the simulation system and running the multiple regression analysis with the remaining independent variables. This process is repeated until there are no independent variables left with a p-value higher than 0.05. The independent variables are taken out of the regression analysis in the following order: $V_p$, $F_{rc}$, $F_{pc}$, and finally V.

Consequently, four independent variables (i.e., $F_{mc}$, $N_b$, $N_m$, and $N_{pr}$) prove to have a statistically significant impact on the total cost of package label printing. Tables 4.4 through 4.7 illustrate the multiple regression analyses following the procedure described above. Table 4.1 displays the regression results for all independent variables tested and highlights the four independent variables that have a statistically significant effect on the total cost of printing labels. The resulting regression analysis is displayed in Table 4.3, where $V_p$, $F_{rc}$, $F_{pc}$, and V are removed from the model confirming the statistical validity of the final set of independent variables $F_{mc}$, $N_b$, $N_m$, and $N_{pr}$.

**TABLE 4.3**

Multiple Variable Regression Analysis:

Independent Variables Taken out of the Analysis: $V_p$, $F_{rc}$, $F_{pc}$, and V

| *Regression Statistics* | | | |
|---|---|---|---|
| R Square | .727 | | |
| | *Coefficients* | *t Stat* | *P-value* |
| Intercept | 221921.236 | 15.401 | .000 |
| $F_{mc}$ | -7515.277 | -3.231 | .001 |
| $N_b$ | -14793.221 | -22.539 | .000 |
| $N_m$ | -15814.916 | -5.039 | .000 |
| $N_{pr}$ | -8758.064 | -46.412 | .000 |

## EXAMINATION OF RELATIVE IMPORTANCE OF PRODUCT FACTORS

The Cohen, Cohen, West, and Aiken (2003) procedure was used to test the differences between the four beta coefficients (i.e., $F_{mc}$, $N_b$, $N_m$, and $N_{pr}$) in the multiple regression equation that were found to be significant predictors on the criterion (dependent) variable, namely the difference of total cost of printing labels digitally versus conventionally ($T_c$). In this case, the standard error of the difference between the beta coefficients $\beta_I - \beta_j$ is given by

$$SE_{\beta i-\beta j} = \sqrt{\frac{1 - R^2{}_{y.12...k}}{n-k-1}(r^{ii} + r^{jj} - 2r^{ij})} \,. \tag{4.1}$$

The observed difference is then given by

$$t = \frac{\beta_i - \beta_j}{SE_{\beta i-\beta j}}, \tag{4.2}$$

with the degrees of freedom (df) = n-k-1.

Table 4.4 displays the inverse of the correlation matrix for each of the product factors and the dependent variable, namely the difference of total cost of printing labels digitally versus conventionally ($T_c$).

**TABLE 4.4**

Inverse of the Correlation Matrix

| | $F_{rc}$ | $F_{mc}$ | $F_{pc}$ | $V_p$ | $N_b$ | $N_m$ | $N_{pr}$ | $T_c$ |
|---|---|---|---|---|---|---|---|---|
| $F_{rc}$ | 1.003 | | | | | | | |
| $F_{mc}$ | -.007 | 1.014 | | | | | | |
| $F_{pc}$ | .011 | -.017 | 1.001 | | | | | |
| $V_p$ | -.002 | .013 | .010 | 1.003 | | | | |
| $N_b$ | .015 | .022 | .006 | .056 | 1.512 | | | |
| $N_m$ | .016 | .038 | -.002 | .015 | .133 | 1.026 | | |
| $N_{pr}$ | .081 | .168 | -.034 | .091 | 1.076 | .204 | 3.182 | |
| $T_c$ | .063 | .191 | -.014 | .082 | 1.363 | .304 | 2.822 | 3.657 |

Six comparisons were assessed (i.e., $F_{mc}$ vs. $N_b$, $F_{mc}$ vs. $N_m$, $F_{mc}$ vs. $N_{pr}$, $N_b$ vs. $N_m$, $N_b$ vs. $N_{pr}$, and $N_m$ vs. $N_{pr}$) using the inverse of the correlation matrix and the regression results as input. We found differences between $F_{mc}$ vs. $N_b$ (t-value = 12.28, df = 992, $p < .01$), $F_{mc}$ vs. $N_{pr}$ (t-value = 22.091, df = 992, $p < .01$), $N_b$ vs. $N_m$ (t-value = 11.598, df = 992, $p < .01$), $N_b$ vs. $N_{pr}$ (t-value = 15.085, df = 992, $p < .01$), and $N_m$ vs. $N_{pr}$ (t-value = 21.511, df = 992, $p < .01$), but no such difference between $F_{mc}$ vs. $N_m$ (t-value = 1.652, df = 992). Thus, the four significant predictor variables can be "ranked" in order of importance as ($F_{rc}$, $F_{pc}$, and $V_p$ were not significant predictors in the regression equation and were thus excluded form the Cohen et al. test):

**Ranking**

Number 1: $N_{pr}$
Number 2: $N_b$
Number 3 (Tied): $N_m$
Number 3 (Tied): $F_{mc}$

Table 4.5 demonstrates the results of the regression analysis for each of the product factors.

**TABLE 4.5**

Results of the Regression Analysis:

$T_c$ Digital-Conventional Criterion Variable

| **Predictors** | β | **B** | **Std. Error** | **t-value** | **Sign (p)** |
|---|---|---|---|---|---|
| $F_{rc}$ | -.017 | -3973.897 | 3846.175 | -1.033 | .302 |
| $F_{mc}$ | -.052 | -6912.782 | 2206.031 | -3.134 | .002 |
| $F_{pc}$ | .004 | 907.415 | 4008.207 | .226 | .821 |
| $V_p$ | -.022 | 6591.410 | 4892.573 | -1.347 | .178 |
| $N_b$ | -.373 | 14707.210 | 656.657 | -22.397 | .000 |
| $N_m$ | -.083 | 15725.395 | 3144.292 | -5.001 | .000 |
| $N_{pr}$ | -.772 | 8788.041 | 189.378 | -46.405 | .000 |

$R^2$ = .727, Adjusted $R^2$ = .725. [1]β = standardized beta and "b" = unstandardized beta. $R^2$ is the total $R^2$ for the equation. Adjusted $R^2$ is the total $R^2$ for the equation taking into account the number of predictor variables and the sample size.

The next chapter presents the results of the data analysis. Each of the hypotheses is reviewed and the outcomes are revealed with explanations in which digital versus conventional methods of printing are favored with respect to each scenario.

# CHAPTER V

# RESULTS

This study set out to analyze package labeling cost structure in the implementation of postponement strategies. First, digital printing is identified as an enabler to postponement. Then, product factors that affect the decision to implement postponement strategies are revealed. Next, the typical value ranges for these product factors are identified through case study interviews. The effect of each factor on the total cost for label printing and the decision to postpone is analyzed. Finally, the product factors that have the most significant impact on the total cost for label printing and the decision to postpone label printing to the distribution center level are identified.

In this chapter, the effect of each product factor on the total cost of package label printing for the pharmaceutical industry is analyzed and the results are presented. The combination simulation-regression analysis conducted on the total cost model represents the value ranges of the pharmaceutical industry data. The one thousand observations create a large sample size and help generalize the results. Four of the seven product factors are proven to be effective on the total cost of printing package labels in the pharmaceutical industry. It is also observed that in the majority of the one thousand observations, digital printing proved to be advantageous compared to conventional printing from a total cost perspective.

The product factors that are found to have a significant effect on the total cost of printing labels are $F_{mc}$, $N_b$, $N_m$, and $N_{pr}$; and $F_{rc}$ and $F_{pc}$ are also found to have a significant effect on the total cost of printing package labels when the range of values are increased. Employing the simulation model on their respective data enables companies to assess whether or not they should print using digital technologies and therefore postpone labeling to the distribution center level. In other words, when minimum, mode, and maximum ranges of values are set into the model, the model suggests a type of printing technology to be used (i.e., digital or conventional) based on the total cost of package label printing. As seen in Figures 4.1 through 4.7, the representative ranges of values used in this study favor digital printing methods to be used over conventional methods.

Next, the hypotheses for this research are presented with the observations derived from the model.

## EFFECT OF FREQUENCY OF REGULATORY CHANGES

A. The HIGHER the frequency of regulatory changes ($F_{rc}$), the GREATER the incentive to postpone labeling to the distribution center level, and the GREATER the cost of obsolescence and the cost of printing runs (most upgrades involve more information to be put on labels).

With the representative value ranges presented in Chapter III, $F_{rc}$ is rendered insignificant in terms of its effect on the total cost of package label printing. However, as the value ranges are increased, the significance of this factor surfaces. As Figure 4.1 indicates, a large majority of the one thousand iterations on the simulation model favor digital printing over conventional printing. As indicated previously, digital printing is an enabler to postponement strategies, and therefore there is a greater incentive to postpone labeling to the distribution center level.

## EFFECT OF FREQUENCY OF MARKETING CHANGES

B. The HIGHER the frequency of marketing based changes ($F_{mc}$), the GREATER the cost of obsolescence and the cost of printing runs (most changes involve more color to be put on labels; or more expensive colorant, such as metallic ink).

With the representative value ranges presented in Chapter III, $F_{mc}$ is found to be significant in terms of its effect on the total cost of package label printing. As Figure 4.2 indicates, a large majority of the one thousand iterations on the simulation model favor digital printing over conventional printing. Therefore, as $F_{mc}$ increases, there is a greater incentive to postpone labeling to the distribution center level.

## EFFECT OF FREQUENCY OF PACKAGE ENGINEERING CHANGES

C. The HIGHER the frequency of packaging engineering design changes ($P_{pc}$), the GREATER the cost of obsolescence and the cost of printing runs (most changes involve more complicated designs such as folding to better prevent shock and vibration damage).

Similar to $F_{rc}$, $F_{pc}$ is rendered insignificant in terms of its effect on the total cost of package label printing. However, as the value ranges are increased, the significance of this factor is revealed. As Figure 4.3 indicates, a large majority of the one thousand iterations on the simulation model favor digital printing over conventional printing. As noted previously, digital printing is an enabler to postponement strategies, and therefore there is a greater incentive to postpone labeling to the distribution center level.

**EFFECT OF VALUE OF PRODUCT-PACKAGE SYSTEM**

D. The GREATER the value of product-package system ($V_p$), the GREATER the incentive to postpone labeling to the distribution center level (generally, as the value of product-package system increases, the cost of printing labels increases).

Similar to $F_{rc}$ and $F_{pc}$, $V_p$ is rendered insignificant in terms of its effect on the total cost of package label printing. However, as the value ranges are increased to the levels of 5, 500, and 10,000, the significance of this factor surfaced. As Figure 4.4a indicates, a large majority of the one thousand iterations on the simulation model favor digital printing over conventional printing with the representative value ranges gathered through the case study interviews initially. However, in the case of very specialized pharmaceutical treatments, such as cancer, or in the case of surgical implants, the $V_p$ ranges could be very high. The second simulation observed the effect of those cases. As demonstrated in

Figure 4.4b, it is very hard to suggest one printing method over the other. Therefore, this hypothesis does not hold true.

## EFFECT OF NUMBER OF BRANDS

E. The GREATER the number of brands ($N_b$), the GREATER the incentive to postpone labeling to the distribution center level.

Similarly, $N_b$ is found to be significant in terms of its effect on the total cost of package label printing. As Figure 4.5 indicates, a large majority of the one thousand iterations on the simulation model favor digital printing over conventional printing. Therefore, as $N_b$ increases, there is a greater incentive to postpone labeling to the distribution center level.

## EFFECT OF NUMBER OF GLOBAL MARKETS

F. The GREATER the number of global markets ($N_m$), the GREATER the incentive to postpone labeling to the distribution center level.

$N_m$ renders to be significant in terms of its effect on the total cost of package label printing. As Figure 4.6 indicates, a large majority of the one thousand iterations on the simulation model favor digital printing over conventional printing. Therefore, as $N_m$ increases, there is a greater incentive to postpone labeling to the distribution center level.

## EFFECT OF NUMBER OF ANNUAL PRODUCTION RUNS

G. The GREATER the number of annual production runs ($N_{pr}$), the LOWER the incentive to postpone labeling to the distribution center level.

$N_{pr}$ is found to be significant in terms of its effect on the total cost of package label printing. As Figure 4.7 indicates, a large majority of the one thousand iterations on the simulation model favor digital printing over conventional printing. Therefore, as $N_{pr}$ increases, there is a GREATER incentive to postpone labeling to the distribution center level. This is probably the result of digital printing supporting more production changeovers compared to conventional printing, from a total cost perspective. Therefore, the relationship found between $N_{pr}$ and the dependent variable is in the OPPOSITE direction of the hypothesis, hence the hypothesis has been disproved.

# CONCLUSION

The number of annual production runs ($N_{pr}$) is the number one factor impacting the difference of total cost of printing labels digitally versus conventionally. Number of brands ($N_b$) is the second factor impacting the difference of total cost of printing labels digitally versus conventionally. Finally, number of global markets ($N_m$) and frequency of marketing based graphic design changes ($F_{mc}$) are tied up as the third factors.

Three of these factors, namely $N_b$, $N_m$, and $F_{mc}$, stem from strategy-based managerial decisions. The greatest impact is attained by $N_{pr}$, which suggests that the decision of running productions weekly versus monthly has significant bearing on total cost of printing labels. In addition, the pronounced trend line observed from the simulation results indicate that the cost savings realized through digital printing increases progressively as the production schedule moves from for example, monthly to weekly.

# CHAPTER VI

# DISCUSSION AND IMPLICATIONS

This chapter discusses the implications of this research and the areas where further research is needed. In light of the results presented in Chapter V, this study develops a total cost model that succeeds in generalizing the different scenarios when different printing technologies could be employed and postponement strategies implemented.

For a blockbuster drug (over $1 billion in sales per year), a one-day delay of the initial launch of a new product costs up to $3 million (Trombley, 2003). The difference of timing may be as much as a couple of days if the labels are printed digitally. So, digital printing could possibly save a pharmaceutical company as much as $6 million in the beginning of a product launch (Trombley, 2003).

This study also develops a simulation model based on total cost considerations for package label printing for the pharmaceutical industry. The model identifies the product factors that have a statistically significant impact on the total cost for printing labels and compares digital versus conventional printing methods. The simulation model reveals the product factors that have a significant affect on total cost of package label printing. When minimum, mode, and maximum ranges of values are put into the model, the model suggests a type of printing technology to be used (i.e., digital or conventional) based on the total cost of package label printing. The representative ranges of values used in this study favors digital printing methods to be used over conventional methods.

## RESEARCH LIMITATIONS

From a business perspective, the motivation to postpone is to maximize profits primarily through inventory reduction. In a general sense, profits equal revenues minus total cost. For the purposes of this study, revenues are assumed constant. However, it is also important to recognize the fact that postponement also has effects on revenue. For example, due to the simple fact that by utilizing postponement strategies, companies are able to customize certain products according to customers' needs, and therefore, have the customer pay more for the product than a generic counterpart.

From the pharmaceutical industry point of view, the revenue gain will be realized through faster launch of patented products once approvals are received. The subject under investigation, postponement-speculation, has diverse effects on the speed of launch of a particular product. For example, assuming that the label wording will need to be changed per FDA approval, a company that postpones label printing until product approvals are received may actually shorten the product's time to market. On the other hand, a disastrous situation may occur when labels are printed prior to receiving the approvals with a speculative approach on the label requirements and then having the labels and/or inserts re-printed with accurate information.

Another business scenario is to print the labels with speculative wording and actually end up gaining time in launching the product if the approval is received without any changes in label wording. There are situations where pharmaceutical companies make such decisions based on experience. The case where materials are printed before approval is described as "at risk," meaning that if there are any changes in the wording for the labeling, the printed materials have to be destroyed (McNeely, 2001). In addition, McNeely (2001) notes that it is sometimes advisable to print the inserts "at risk," since it becomes a rate-limiting step in the launch process.

However, there should be some cases where not taking such risks may also depend on the company having digital printing capabilities that boast minimal setup time, and this alone may justify the costs associated with labeling postponement. On the other hand, for this research, revenue is assumed to be constant, and therefore maximizing profit will depend solely on minimized total cost. At the same time, the study recognizes the importance of analyzing the effects of postponement on revenues, both from a purely research contribution as well as from a business perspective.

## FUTURE RESEARCH CONSIDERATIONS

As explained, for the purposes of this study the revenue function is assumed to be constant. The total cost of printing labels is a function of the seven product factors identified in this research and postponement, and total cost is assumed to be a continuous function with respect to postponement. Therefore, the study assumes that in order to maximize profits, total cost should be minimized. However, profits equal revenue minus total cost. Thus, it would be interesting to research the ways that the seven product factors (or any additional factor) affect the profit function by looking at how the profit function could be maximized.

The questions this research addresses are: What factors need to be considered in evaluating effectiveness of postponement? Under what circumstances are new technologies such as digital printing cost effective? Is there a model that could be developed to bring answers to these questions? Issues such as profitability, supply chain visibility and integration concepts have not been addressed. Customers demand more supply chain visibility, as indicated by Richardson (2000). Since printers can increase visibility into the packaging process (Richardson, 2000), could supply chain visibility be one of the efficiencies gained? For achieving increased production rates and information availability, printer applications are integrated into warehouse management systems (WMS), enterprise resource planning (ERP), and order processing systems (Richardson, 2001). What would be the effects of postponement on integration of printer applications into WMS and ERP for increased production rates and supply chain visibility? Addressing these questions in one or more research projects would contribute greatly to the scholarly puzzle of packaging supply chain.

As the printing technologies advance, the dynamics of the supply chain could change. For example, recent developments in lithographic printing technology include utilizing computer to plate processing. This advancement reduces setup time (and costs) however, currently ends up costing more (Ingram, 2002). Nevertheless, as technological advancements occur, there is great potential for the cost model for package label printing to change. Further research updates are necessary in order to document such alterations.

Another area that warrants further research is the effect of product tracking technologies on the total cost of package label printing. Barcode and, more recently, radio frequency identification

(RFID) technologies have revolutionized the supply chain by providing on-time and accurate information regarding the product; in some cases including the temperatures that the product has been exposed to. Through RFID, the quality of information provided varies tremendously and the quantity increases as the technological advancements take place at ever increasing rates. This not only affects the cost of printing labels, but may also dictate certain changes in the supply chain for printing labels and packaging.

Finally, additional research could be conducted for different stages of the pharmaceutical product life cycle. For example, the ranges of values for the product factor frequency of regulatory changes vary depending on where the product is in its life cycle. In the first year of the patent, the regulatory changes tend to be much more frequent. Similarly, some of the cost components may change depending on where the product is in its life cycle. Therefore, developing a total cost model of pharmaceutical products by observing the different stages of the product life cycle may uncover diverse results.

## MANAGERIAL IMPLICATIONS

There remains one last question to be addressed: What are the implications of this total cost simulation model for management? The model creates a tool for evaluating the economic impact of digital versus conventional printing for a particular product line in the pharmaceutical industry. This study treats digital printing as an enabler to postponement, therefore a negative cost difference between printing labels digitally versus conventionally indicates cost savings realized through digital printing, and hence incentive for postponement. Consequently, the research establishes the groundwork under which postponement becomes viable from a total cost savings perspective. In addition, the total cost model suggests using one printing method over the other (i.e., digital versus conventional) based on the economical justification. The analyses of the following business situations demonstrate the generalizations with respect to management decisions under which digital printing (i.e., postponement) is economically justified.

Four of the seven product factors are proven to be effective on total cost savings achieved through digital printing technology for printing package labels in the pharmaceutical industry. As a result, only one of the hypotheses (i.e., the effect of value of the product-package system) is proven inconclusive, and one was disproved (i.e., found to be in the opposite direction of the hypothesis relating number of annual production runs to the total cost model). The product factors that are found to have a significant effect on the total cost savings realized through digital printing technology for printing labels are frequency of marketing changes ($F_{mc}$), number of brands ($N_b$), number of global markets ($N_m$), and annual number of production runs ($N_{pr}$); and frequency of restriction changes ($F_{rc}$) and frequency of package engineering design changes ($F_{pc}$) when the range of values are increased.

In addition, it is observed that for the majority of the one thousand observations created by the minimum, mode, and maximum representative values, digital printing proved to save total cost compared to conventional printing.

Total cost savings achieved through the use of digital printing becomes significant if a particular pharmaceutical product label goes through regulatory changes ($F_{rc}$) on average three times a year, with a range of one to five times. Based on this study, this also indicates that the decision to postpone labeling to the distribution center level is economically justified. However, if the $F_{rc}$ values are between one and three and average at two for that product, then the cost saving is not conclusive. As the frequency of regulatory changes increase annually, the significance on the effect of cost savings continues to hold.

As presented in Chapter IV, $F_{mc}$ is an important variable in the decision to postpone labeling to the distribution center level, when marketing changes occur one to five and average at three times a year. When the representative values for $F_{rc}$ are increased to equal the values of $F_{mc}$, both become effective factors in the decision to postpone. Consequently, the frequency of marketing based design changes a product label goes through affects the cost savings realized through using digital printing technologies. As $F_{mc}$ increases, greater cost savings are achieved through the use of digital printing technologies, and therefore, postponing labeling to the distribution center level.

Similar to $F_{rc}$, $F_{pc}$ becomes a significant factor affecting the total cost of printing labels, hence the decision to postpone labeling, when the representative values are increased to equal $F_{mc}$ values (i.e., one to five and average at three). Therefore, under the business circumstances presented previously, postponing package labeling to the distribution center is justified when the number of annual package engineering changes vary between one and five and average at three.

When the simulation model is run holding everything constant and varying the value of product-package system ($V_p$) values between

$5, $500, and $10,000, the difference of cost between digital and conventional printing appear evenly distributed (Figure 4.4.b). Hence, in the case of high-end pharmaceutical products such as surgical implants, total cost and/or postponement implications for label printing is inconclusive. Similarly, other values that are tested with this model, proved the value of product-package system to be inconclusive in terms of its effect on realizing total cost savings through the employment of digital printing technologies, and postponing labeling to the distribution center level in the supply chain.

The variable $N_b$ depicts statistical significance in affecting the total cost of printing labels. As the number of brands increase, digital printing becomes increasingly favorable with respect to conventional printing. The model is tested for the number of brands ranging from five to 20 and averaging at 12 and demonstrates that the factor is an important variable in the postponement decision.

Similarly, the variable $N_m$ portrays significance in the decision to postpone. If a product line is marketed in one to 20 global markets, digital printing becomes increasingly favorable from a total cost perspective compared to conventional printing, as the number of global markets increase. Consequently, total cost savings achieved through digital printing technologies become increasingly greater if a particular pharmaceutical product line is marketed in 15 global markets on average, and ranging from one to 20. This indicates that in such cases, postponing the labeling function to the distribution center level is economically justified.

$N_{pr}$ depicts statistical significance in affecting the difference of total cost between digital and conventional printing, hence the decision to postpone labeling to the distribution center level. As the number of annual production runs increases, the chances of being able to incorporate any regulatory change, marketing change, or packaging change into the already scheduled production changeovers increase. Therefore, the greater the number of annual production runs, the easier it is for companies to accommodate changes, such as regulatory. In addition, this relationship also indicates that on the contrary to what was hypothesized, the inventory savings turned out to be greater than stock-out costs. Similar to the analysis on $N_b$, digital printing becomes increasingly favorable with respect to conventional printing as the number of brands increases.

The relative importance of the independent variables that are found to be statistically significant in impacting the difference of total cost of printing labels digitally versus conventionally is also analyzed. The results indicate that the number of annual production runs is the number one factor in terms of its importance. Therefore, production scheduling is the biggest factor that management should look at in making the decision to print labels digitally versus conventionally. In addition, the simulation model demonstrates that as the production schedule moves from, for example, monthly to weekly, cost savings realized using digital printing becomes increasingly more. The second factor that is most important from a cost savings perspective is the number of global brands. Cost savings realized through digital printing technologies increase progressively more, as the number of brands increase for a particular compound. Similarly, the number of global markets a pharmaceutical product is marketed in, as well as the frequency of marketing based design changes that a label for a particular product is exposed to, impact the total cost savings realized through using plateless printing technologies.

The four cost drivers identified in this study are printing run, inventory, stock-out, and obsolescence. The cost drivers that are shown to have a significant impact on the total cost savings achieved through the use of digital printing are printing run, inventory, and obsolescence. The variable, number of annual production runs, also indicates that the inventory cost savings realized through plateless printing are higher than the cost of stock-outs.

The pharmaceutical industry could benefit tremendously from further research in the aforementioned matters. Several smaller scale research topics could cover different niche market segments within the pharmaceutical industry, such as over-the-counter drugs, surgical implants, medical equipments, and prescription drugs in more detail. Similarly, additional investigations could be conducted to research other industries, such as food and beverage industry.

As a conclusion, this study paves the way for research opportunities to serve the scholars, businesses, and government agencies in identifying factors that affect total cost and profit functions of package label printing for diverse industries. Addressing these factors would greatly benefit the businesses and academia in respective industries.

# APPENDIX A

# INTERVIEW QUESTIONS

## QUESTIONS REGARDING PRODUCT FACTORS

1. **Frequency of Regulatory Changes ($F_{rc}$)**

| Frc | Minimum: | Mode: | Maximum: |
|---|---|---|---|

Comments:

2. **Frequency of Marketing Based Design Changes (Fmc)**

| Fmc | Minimum: | Mode: | Maximum: |
|---|---|---|---|

Comments:

3. **Frequency of Package Engineering Design Changes (Fpc)**

| Fpc | Minimum: | Mode: | Maximum: |
|---|---|---|---|

Comments:

4. **Value of Product-Package System (Vp)**

| Vp | Minimum: | Mode: | Maximum: |
|---|---|---|---|

| Vp (digital) | Minimum: | Mode: | Maximum: |
|---|---|---|---|

Comments:

5. **Number of Brands (Nb)**

| Nb | Minimum: | Mode: | Maximum: |
|---|---|---|---|

Comments (different range of values if the labels are printed digitally?):

6. **Number of Global Markets (Nm)**

| | | | |
|---|---|---|---|
| Nm | Minimum: | Mode: | Maximum: |

Comments (different range of values if the labels are printed digitally?):

7. **Number of Annual Production Runs (Npr)**

| | | | |
|---|---|---|---|
| Npr | Minimum: | Mode: | Maximum: |

| | | | |
|---|---|---|---|
| Npr (digital) | Minimum: | Mode: | Maximum: |

Comments:

8. **Comments about product factors in general**

## QUESTIONS REGARDING COST FACTORS

$T_c$=PR+INV+STO+OBS

### 1. Cost of Printing Run (PR)

OQ = Average Annual Order Quantity
V = Average annual volume = OQ x ($N_{pr}$ /2)
PR = PS + $CONST_{PR}$ x V
PS = $N_b$ x $N_m$ x $CONST_{PS}$
PR = ($N_b$ x $N_m$ x $CONST_{PS}$) + ($CONST_{PR}$ x V)
= ($N_b$ x $N_m$ x $CONST_{PS}$) + ($CONST_{PR}$ x (OQ x ($N_{pr}$ /2)))
$CONST_{PR}$ = Annual expenses on substrate usage, colorant usage, parts replacement, etc. divided by the #of annual setup changes. $CONST_{PR}$ has two different values for the case of digital and conventional printing, $7 per day for conventional and $30 per day for digital (Emden, 2001-2003).
$CONST_{PS}$ = Annual expenses on labor and materials for setup (double sided tape in the case of conventional printing and color setup mostly in the form of labor in digital)

| | | | |
|---|---|---|---|
| V | Minimum: | Mode: | Maximum: |

| | | | |
|---|---|---|---|
| V (digital) | Minimum: | Mode: | Maximum: |

| | | | |
|---|---|---|---|
| OQ | Minimum: | Mode: | Maximum: |

| | | | |
|---|---|---|---|
| OQ (digital) | Minimum: | Mode: | Maximum: |

| | | | |
|---|---|---|---|
| $CONST_{PR}$ | Minimum: | Mode: | Maximum: |

| | | | |
|---|---|---|---|
| $CONST_{PR}$ (digital) | Minimum: | Mode: | Maximum: |

| | | | |
|---|---|---|---|
| $CONST_{PS}$ | Minimum: | Mode: | Maximum: |

| | | | |
|---|---|---|---|
| $CONST_{PS}$ (digital) | Minimum: | Mode: | Maximum: |

Comments:

## 2. Cost of Inventory (INV)

INV = Product-Package System Value (Price) = $V_p$ x $CONST_{ICC}$ x V
SS = Safety Stock
$CONST_{ICC}$ = Inventory carrying cost percentage factor (constant)
$CONST_{ICC}$ = 1.5% (time value of money tied up in inventory on a monthly basis)

Unit cost of printing a single label = $U_T$

INV= (((V / $N_{pr}$) + SS) x $U_T$ x $CONST_{PS}$) x $CONST_{ICC}$
= (((OQ / 2) + SS) x $U_T$ x $CONST_{PS}$) x $CONST_{ICC}$

| $CONST_{ICC}$ | Minimum: | Mode: | Maximum: |
|---|---|---|---|

| $U_T$ | Minimum: | Mode: | Maximum: |
|---|---|---|---|

| $U_T$ (digital) | Minimum: | Mode: | Maximum: |
|---|---|---|---|

| SS | Minimum: | Mode: | Maximum: |
|---|---|---|---|

| SS (digital) | Minimum: | Mode: | Maximum: |
|---|---|---|---|

Comments:

## 3. Cost of Stock-out (STO)

STO = $CONST_{STO}$ x (100 - SL) x $M_p$
$M_p$ = Profit Margin
SL = 1 – (f(k) x $CONST_{\sigma}$) / OQ
$CONST_{\sigma}$ = Volume replenishment lead time
If SL = 98% then STO = (1 - 0.98) x V
Demand Standard Deviation ($OQ_{SD}$)
Ordering Cost (OC): Including purchasing and receiving (inspection, etc.)
$STO_{pd}$ = Stock-out cost per day

| SL | Minimum: | Mode: | Maximum: |
|---|---|---|---|

| $OQ_{SD}$ | Minimum: | Mode: | Maximum: |
|---|---|---|---|

| | | | |
|---|---|---|---|
| OC | Minimum: | Mode: | Maximum: |

| | | | |
|---|---|---|---|
| OC (digital) | Minimum: | Mode: | Maximum: |

| | | | |
|---|---|---|---|
| $STO_{pd}$ | Minimum: | Mode: | Maximum: |

Comments:

## 4. Cost of Obsolescence (OBS)

$CONST_{obs}$ = Scrap Handling / Disposal Cost Constant

| | | | |
|---|---|---|---|
| $CONST_{obs}$ | Minimum: | Mode: | Maximum: |

Comments:

## 5. Error Term (Projection versus Actual Cost)

Typically, what's the range of percentage difference between your projected costs (budget) and actual costs (accrued expenses)?

| | | | |
|---|---|---|---|
| Error Term | Minimum: | Mode: | Maximum: |

Comments:

## 6. Comments about cost factors in general

# APPENDIX B
# FIRST 25 OBSERVATIONS IN SIMULATION MODEL

(Total number of observations run on the model was 1,000. This only represents a small sample of the data from the simulation model. Full data and the simulation model are available upon request.)

| | Frc min | Frc mode | Frc max | Fmc min | Fmc mode | Fmc max | Fpc min | Fpc mode | Fpc max | Vp min | Vp mode | Vp max | Nb min | Nb mode | Nb max | Nm min | Nm mode | Nm max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 2 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 3 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 4 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 5 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 6 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 7 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 8 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 9 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 10 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 11 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 12 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 13 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 14 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 15 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 16 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 17 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 18 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 19 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 20 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 21 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 22 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 23 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 24 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |
| 25 | 1 | 2 | 3 | 1 | 3 | 5 | 0 | 1 | 2 | 0.5 | 1 | 2 | 5 | 12 | 20 | 1 | 3 | 4 |

| | Npr min | Npr mode | Npr max | V min | V mode | V max | | Frc | Fmc | Fpc | Vp | Nb | Nm | Npr | V | OQ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 3 | 1.4 | 1 | 14 | 3 | 16 | 68,856,317 | 2,195,949 |
| 2 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 3 | 1.8 | 2 | 15 | 3 | 32 | 36,573,685 | 565,498 |
| 3 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 4 | 0.2 | 1 | 12 | 3 | 15 | 58,615,664 | 2,009,766 |
| 4 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 3 | 1.0 | 1 | 10 | 2 | 12 | 16,849,775 | 693,416 |
| 5 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 1 | 3 | 0.9 | 1 | 12 | 3 | 15 | 24,585,178 | 843,132 |
| 6 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 4 | 0.9 | 1 | 7 | 3 | 40 | 16,817,612 | 210,426 |
| 7 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 3 | 1 | 1.1 | 1 | 13 | 1 | 45 | 83,847,739 | 933,441 |
| 8 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 1 | 3 | 1.2 | 1 | 16 | 3 | 6 | 26,440,057 | 2,184,492 |
| 9 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 1 | 1.0 | 1 | 8 | 1 | 10 | 12,293,550 | 608,035 |
| 10 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 3 | 0.9 | 1 | 14 | 3 | 11 | 21,956,099 | 984,117 |
| 11 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 2 | 1.1 | 2 | 9 | 3 | 28 | 28,449,430 | 515,960 |
| 12 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 4 | 0.6 | 2 | 10 | 2 | 22 | 62,439,507 | 1,425,849 |
| 13 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 3 | 0.9 | 1 | 11 | 4 | 33 | 42,620,437 | 644,471 |
| 14 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 3 | 0.2 | 1 | 10 | 3 | 31 | 10,377,165 | 168,257 |
| 15 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 2 | 0.6 | 1 | 6 | 3 | 20 | 7,387,519 | 188,601 |
| 16 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 3 | 3 | 0.8 | 1 | 11 | 2 | 17 | 26,900,953 | 805,158 |
| 17 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 3 | 2 | 0.4 | 2 | 12 | 3 | 45 | 35,012,918 | 388,607 |
| 18 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 3 | 2 | 0.2 | 1 | 10 | 3 | 36 | 37,144,404 | 520,306 |
| 19 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 2 | 1.9 | 1 | 11 | 4 | 34 | 51,631,626 | 765,430 |
| 20 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 3 | 1.8 | 1 | 12 | 3 | 23 | 55,484,761 | 1,226,201 |
| 21 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 1 | 2 | 1.0 | 2 | 9 | 2 | 13 | 26,292,979 | 980,464 |
| 22 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 3 | 0.7 | 1 | 17 | 3 | 22 | 27,954,721 | 635,960 |
| 23 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 2 | 1.6 | 1 | 11 | 3 | 14 | 18,997,371 | 668,866 |
| 24 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 3 | 1.5 | 1 | 17 | 3 | 24 | 13,887,023 | 284,485 |
| 25 | 2 | 12 | 50 | 500,000 | 20,000,000 | 100,000,000 | | 2 | 2 | 0.4 | 2 | 13 | 4 | 11 | 27,193,242 | 1,202,715 |

| | CONSTps digital | CONSTps conv. | PS digital | PS conv. | CONSTpr digital | CONSTpr conv. | PR digital | PR conv. | Av. Daily Demand | Demand STD | Av. Cycle Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | $3,920 | $12,542 | $68,359 | $218,748 | $0.00016 | $0.00004 | $79,309 | $221,303 | 188,647 | 943 | 23 |
| 2 | $8,084 | $25,870 | $140,645 | $450,063 | $0.00030 | $0.00007 | $151,595 | $452,618 | 100,202 | 501 | 11 |
| 3 | $3,646 | $11,666 | $55,868 | $178,779 | $0.00019 | $0.00004 | $66,818 | $181,334 | 160,591 | 803 | 25 |
| 4 | $3,037 | $9,720 | $35,138 | $112,440 | $0.00065 | $0.00015 | $46,088 | $114,995 | 46,164 | 231 | 30 |
| 5 | $3,645 | $11,664 | $53,967 | $172,695 | $0.00045 | $0.00010 | $64,917 | $175,250 | 67,357 | 337 | 25 |
| 6 | $9,990 | $31,969 | $100,921 | $322,947 | $0.00065 | $0.00015 | $111,871 | $325,502 | 46,076 | 230 | 9 |
| 7 | $11,228 | $35,931 | $159,078 | $509,048 | $0.00013 | $0.00003 | $170,028 | $511,603 | 229,720 | 1,149 | 8 |
| 8 | $1,513 | $4,841 | $29,499 | $94,398 | $0.00041 | $0.00010 | $40,449 | $96,953 | 72,439 | 362 | 60 |
| 9 | $2,527 | $8,087 | $24,346 | $77,906 | $0.00089 | $0.00021 | $35,296 | $80,461 | 33,681 | 168 | 36 |
| 10 | $2,789 | $8,924 | $46,366 | $148,373 | $0.00050 | $0.00012 | $57,316 | $150,928 | 60,154 | 301 | 33 |
| 11 | $6,892 | $22,056 | $85,581 | $273,858 | $0.00038 | $0.00009 | $96,531 | $276,413 | 77,944 | 390 | 13 |
| 12 | $5,474 | $17,516 | $64,857 | $207,543 | $0.00018 | $0.00004 | $75,807 | $210,098 | 171,067 | 855 | 17 |
| 13 | $8,267 | $26,453 | $121,701 | $389,443 | $0.00026 | $0.00006 | $132,651 | $391,998 | 116,768 | 584 | 11 |
| 14 | $7,709 | $24,670 | $101,429 | $324,573 | $0.00106 | $0.00025 | $112,379 | $327,128 | 28,431 | 142 | 12 |
| 15 | $4,896 | $15,668 | $41,922 | $134,150 | $0.00148 | $0.00035 | $52,872 | $136,705 | 20,240 | 101 | 19 |
| 16 | $4,176 | $13,364 | $55,334 | $177,069 | $0.00041 | $0.00009 | $66,284 | $179,624 | 73,701 | 369 | 22 |
| 17 | $11,262 | $36,039 | $173,965 | $556,688 | $0.00031 | $0.00007 | $184,915 | $559,243 | 95,926 | 480 | 8 |
| 18 | $8,924 | $28,556 | $113,888 | $364,442 | $0.00029 | $0.00007 | $124,838 | $366,997 | 101,765 | 509 | 10 |
| 19 | $8,432 | $26,982 | $125,462 | $401,480 | $0.00021 | $0.00005 | $136,412 | $404,035 | 141,457 | 707 | 11 |
| 20 | $5,656 | $18,100 | $80,665 | $258,128 | $0.00020 | $0.00005 | $91,615 | $260,683 | 152,013 | 760 | 16 |
| 21 | $3,352 | $10,727 | $37,659 | $120,508 | $0.00042 | $0.00010 | $48,609 | $123,063 | 72,036 | 360 | 27 |
| 22 | $5,495 | $17,583 | $107,593 | $344,299 | $0.00039 | $0.00009 | $118,543 | $346,854 | 76,588 | 383 | 17 |
| 23 | $3,550 | $11,361 | $51,872 | $165,990 | $0.00058 | $0.00013 | $62,822 | $168,545 | 52,048 | 260 | 26 |
| 24 | $6,102 | $19,526 | $120,495 | $385,586 | $0.00079 | $0.00018 | $131,445 | $388,141 | 38,047 | 190 | 15 |
| 25 | $2,826 | $9,044 | $46,759 | $149,628 | $0.00040 | $0.00009 | $57,709 | $152,183 | 74,502 | 373 | 32 |

| | Cycle Time STD | STD Demand during cycle time | Order Quantity (OQ) | f(k) | k | SS | Average INV | Leadtime Demand | STD Leadtime Demand | Unit Stock Out Cost | CONSTicc | INV | SL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.1164 | 22,426 | 2,195,949 | 1.958 | 0.000 | 0 | 1,097,975 | 2,862,983 | 1,692 | $0.46 | 8% | 57,260 | 98% |
| 2 | 0.0564 | 5,900 | 565,498 | 1.917 | 0.000 | 0 | 282,749 | 1,856,759 | 1,363 | $0.46 | 8% | 37,135 | 98% |
| 3 | 0.1251 | 20,495 | 2,009,766 | 1.961 | 0.000 | 0 | 1,004,883 | 5,243,631 | 2,290 | $0.46 | 8% | 104,873 | 98% |
| 4 | 0.1502 | 7,049 | 693,416 | 1.968 | 0.000 | 0 | 346,708 | 1,543,524 | 1,242 | $0.46 | 8% | 30,870 | 98% |
| 5 | 0.1252 | 8,598 | 843,132 | 1.961 | 0.000 | 0 | 421,566 | 2,471,703 | 1,572 | $0.46 | 8% | 49,434 | 98% |
| 6 | 0.0457 | 2,216 | 210,426 | 1.899 | 0.000 | 0 | 105,213 | 563,791 | 751 | $0.46 | 8% | 11,276 | 98% |
| 7 | 0.0406 | 9,892 | 933,441 | 1.887 | 0.000 | 0 | 466,721 | 1,462,414 | 1,209 | $0.46 | 8% | 29,248 | 98% |
| 8 | 0.3016 | 22,025 | 2,184,492 | 1.984 | 0.000 | 0 | 1,092,246 | 5,005,065 | 2,237 | $0.46 | 8% | 100,101 | 98% |
| 9 | 0.1805 | 6,164 | 608,035 | 1.973 | 0.000 | 0 | 304,017 | 1,436,135 | 1,198 | $0.46 | 8% | 28,723 | 98% |
| 10 | 0.1636 | 9,990 | 984,117 | 1.970 | 0.000 | 0 | 492,058 | 1,618,802 | 1,272 | $0.46 | 8% | 32,376 | 98% |
| 11 | 0.0662 | 5,351 | 515,960 | 1.928 | 0.000 | 0 | 257,980 | 1,559,285 | 1,249 | $0.46 | 8% | 31,186 | 98% |
| 12 | 0.0834 | 14,680 | 1,425,849 | 1.943 | 0.000 | 0 | 712,925 | 4,909,883 | 2,216 | $0.46 | 8% | 98,198 | 98% |
| 13 | 0.0552 | 6,730 | 644,471 | 1.915 | 0.000 | 0 | 322,236 | 1,213,389 | 1,102 | $0.46 | 8% | 24,268 | 98% |
| 14 | 0.0592 | 1,752 | 168,257 | 1.921 | 0.000 | 0 | 84,129 | 328,499 | 573 | $0.46 | 8% | 6,570 | 98% |
| 15 | 0.0932 | 1,936 | 188,601 | 1.948 | 0.000 | 0 | 94,301 | 390,940 | 625 | $0.46 | 8% | 7,819 | 98% |
| 16 | 0.1092 | 8,234 | 805,158 | 1.956 | 0.000 | 0 | 402,579 | 1,231,210 | 1,110 | $0.46 | 8% | 24,624 | 98% |
| 17 | 0.0405 | 4,119 | 388,607 | 1.887 | 0.000 | 0 | 194,303 | 1,182,845 | 1,088 | $0.46 | 8% | 23,657 | 98% |
| 18 | 0.0511 | 5,452 | 520,306 | 1.909 | 0.000 | 0 | 260,153 | 1,336,261 | 1,156 | $0.46 | 8% | 26,725 | 98% |
| 19 | 0.0541 | 8,000 | 765,430 | 1.914 | 0.000 | 0 | 382,715 | 2,058,616 | 1,435 | $0.46 | 8% | 41,172 | 98% |
| 20 | 0.0807 | 12,636 | 1,226,201 | 1.941 | 0.000 | 0 | 613,100 | 1,687,688 | 1,299 | $0.46 | 8% | 33,754 | 98% |
| 21 | 0.1361 | 9,983 | 980,464 | 1.964 | 0.000 | 0 | 490,232 | 3,181,649 | 1,784 | $0.46 | 8% | 63,633 | 98% |
| 22 | 0.0830 | 6,548 | 635,960 | 1.942 | 0.000 | 0 | 317,980 | 1,222,735 | 1,106 | $0.46 | 8% | 24,455 | 98% |
| 23 | 0.1285 | 6,818 | 668,866 | 1.962 | 0.000 | 0 | 334,433 | 1,019,460 | 1,010 | $0.46 | 8% | 20,389 | 98% |
| 24 | 0.0748 | 2,938 | 284,485 | 1.936 | 0.000 | 0 | 142,242 | 717,729 | 847 | $0.46 | 8% | 14,355 | 98% |
| 25 | 0.1614 | 12,212 | 1,202,715 | 1.970 | 0.000 | 0 | 601,357 | 4,263,643 | 2,065 | $0.46 | 8% | 85,273 | 98% |

| | STO | CONSTobs | OBS digital | OBS conv. | PR | INV | STO | OBS | Tc digital |
|---|---|---|---|---|---|---|---|---|---|
| 1 | $628,314 | $1.5 | $32,998 | $92,076 | $79,309 | $57,260 | $628,314 | $32,998 | $857,862 |
| 2 | $333,735 | $1.5 | $30,267 | $90,368 | $151,595 | $37,135 | $333,735 | $30,267 | $579,456 |
| 3 | $534,868 | $1.5 | $26,326 | $71,444 | $66,818 | $104,873 | $534,868 | $26,326 | $736,479 |
| 4 | $153,754 | $1.5 | $22,689 | $56,612 | $46,088 | $30,870 | $153,754 | $22,689 | $255,556 |
| 5 | $224,340 | $1.5 | $23,979 | $64,734 | $64,917 | $49,434 | $224,340 | $23,979 | $341,147 |
| 6 | $153,461 | $1.5 | $19,670 | $57,233 | $111,871 | $11,276 | $153,461 | $19,670 | $298,966 |
| 7 | $765,111 | $1.5 | $19,559 | $58,852 | $170,028 | $29,248 | $765,111 | $19,559 | $922,508 |
| 8 | $241,266 | $1.5 | $36,697 | $87,958 | $40,449 | $100,101 | $241,266 | $36,697 | $424,980 |
| 9 | $112,179 | $1.5 | $16,411 | $37,410 | $35,296 | $28,723 | $112,179 | $16,411 | $191,854 |
| 10 | $200,349 | $1.5 | $27,069 | $71,279 | $57,316 | $32,376 | $200,349 | $27,069 | $322,413 |
| 11 | $259,601 | $1.5 | $15,958 | $45,696 | $96,531 | $31,186 | $259,601 | $15,958 | $418,958 |
| 12 | $569,760 | $1.5 | $22,456 | $62,237 | $75,807 | $98,198 | $569,760 | $22,456 | $739,498 |
| 13 | $388,911 | $1.5 | $22,348 | $66,040 | $132,651 | $24,268 | $388,911 | $22,348 | $515,490 |
| 14 | $94,692 | $1.5 | $17,617 | $51,282 | $112,379 | $6,570 | $94,692 | $17,617 | $216,081 |
| 15 | $67,411 | $1.5 | $13,027 | $33,682 | $52,872 | $7,819 | $67,411 | $13,027 | $131,836 |
| 16 | $245,471 | $1.5 | $26,305 | $71,284 | $66,284 | $24,624 | $245,471 | $26,305 | $340,226 |
| 17 | $319,493 | $1.5 | $18,930 | $57,251 | $184,915 | $23,657 | $319,493 | $18,930 | $591,852 |
| 18 | $338,943 | $1.5 | $18,761 | $55,154 | $124,838 | $26,725 | $338,943 | $18,761 | $526,402 |
| 19 | $471,139 | $1.5 | $23,331 | $69,104 | $136,412 | $41,172 | $471,139 | $23,331 | $726,644 |
| 20 | $506,298 | $1.5 | $29,629 | $84,306 | $91,615 | $33,754 | $506,298 | $29,629 | $650,169 |
| 21 | $239,923 | $1.5 | $16,599 | $42,023 | $48,609 | $63,633 | $239,923 | $16,599 | $362,345 |
| 22 | $255,087 | $1.5 | $31,324 | $91,652 | $118,543 | $24,455 | $255,087 | $31,324 | $470,103 |
| 23 | $173,351 | $1.5 | $22,883 | $61,392 | $62,822 | $20,389 | $173,351 | $22,883 | $268,126 |
| 24 | $126,719 | $1.5 | $33,775 | $99,734 | $131,445 | $14,355 | $126,719 | $33,775 | $323,699 |
| 25 | $248,138 | $1.5 | $21,707 | $57,243 | $57,709 | $85,273 | $248,138 | $21,707 | $373,991 |

| | PR | INV | STO | OBS | Tc conventional | Tc Digital-Conventional |
|---|---|---|---|---|---|---|
| 1 | $221,303 | $57,260 | $628,314 | $92,076 | $946,324 | -$88,462 |
| 2 | $452,618 | $37,135 | $333,735 | $90,368 | $871,073 | -$291,618 |
| 3 | $181,334 | $104,873 | $534,868 | $71,444 | $950,958 | -$214,479 |
| 4 | $114,995 | $30,870 | $153,754 | $56,612 | $390,780 | -$135,225 |
| 5 | $175,250 | $49,434 | $224,340 | $64,734 | $473,072 | -$131,925 |
| 6 | $325,502 | $11,276 | $153,461 | $57,233 | $497,393 | -$198,427 |
| 7 | $511,603 | $29,248 | $765,111 | $58,852 | $1,480,284 | -$557,776 |
| 8 | $96,953 | $100,101 | $241,266 | $87,958 | $498,055 | -$73,075 |
| 9 | $80,461 | $28,723 | $112,179 | $37,410 | $252,523 | -$60,668 |
| 10 | $150,928 | $32,376 | $200,349 | $71,279 | $477,195 | -$154,782 |
| 11 | $276,413 | $31,186 | $259,601 | $45,696 | $639,084 | -$220,125 |
| 12 | $210,098 | $98,198 | $569,760 | $62,237 | $1,010,817 | -$271,319 |
| 13 | $391,998 | $24,268 | $388,911 | $66,040 | $903,682 | -$388,192 |
| 14 | $327,128 | $6,570 | $94,692 | $51,282 | $486,863 | -$270,781 |
| 15 | $136,705 | $7,819 | $67,411 | $33,682 | $263,067 | -$131,231 |
| 16 | $179,624 | $24,624 | $245,471 | $71,284 | $505,910 | -$165,684 |
| 17 | $559,243 | $23,657 | $319,493 | $57,251 | $892,190 | -$300,338 |
| 18 | $366,997 | $26,725 | $338,943 | $55,154 | $731,906 | -$205,503 |
| 19 | $404,035 | $41,172 | $471,139 | $69,104 | $1,009,038 | -$282,394 |
| 20 | $260,683 | $33,754 | $506,298 | $84,306 | $823,918 | -$173,750 |
| 21 | $123,063 | $63,633 | $239,923 | $42,023 | $459,653 | -$97,307 |
| 22 | $346,854 | $24,455 | $255,087 | $91,652 | $749,135 | -$279,032 |
| 23 | $168,545 | $20,389 | $173,351 | $61,392 | $441,354 | -$173,227 |
| 24 | $388,141 | $14,355 | $126,719 | $99,734 | $630,607 | -$306,907 |
| 25 | $152,183 | $85,273 | $248,138 | $57,243 | $513,089 | -$139,098 |

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