3D Printing Your Supply Chain

By

Hala Jalwan
B.E. Civil and Environmental Engineering, American University of Beirut, 2012

And

Gregory Israel
B.S. Engineering & Management, Clarkson University, 2005

Submitted to the Engineering Systems Division in Partial Fulfillment of the Requirements for the Degree of

Master of Engineering in Logistics
at the
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Signature redacted

Signature of Author ....
Master of Engineering in Logistics Program, Engineering Systems Division
May 9, 2014

Signature redacted

Signature of Author ....
Master of Engineering in Logistics Program, Engineering Systems Division
May 9, 2014

Signature redacted

Certified by ....
Alexis Hickman Bateman
Postdoctoral Associate, Center for Transportation and Logistics
Thesis Supervisor

Signature redacted

Accepted by ....
Yossi Sheffi
Director, MIT Center for Transportation and Logistics
Elisha Gray II Professor of Engineering Systems
Professor, Civil and Environmental Engineering

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ABSTRACT

Increasing the pace of product innovation in the consumer packaged goods industry can be achieved by implementing new technologies and streamlining processes. Our research is conducted primarily through extensive interviews with 3D printing experts and stakeholders in product development of a leading cosmetics manufacturer. We identify a framework where additive manufacturing technology such as 3D printing can complement the steel mold tooling used in the development of consumer product packaging. Within hours, rapid tooling technology can provide molds that are ideal for low volume production required during the preliminary stages of product design and testing. Implementing our proposed solution may reduce 14% to 26% of a company's time to market by shortening the duration of some critical path activities. The company can therefore respond to customer demand faster, strengthening its competitive advantage in the industry.

Thesis Supervisor: Alexis Hickman Bateman
Title: Postdoctoral Associate, Center for Transportation and Logistics

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Hala Jalwan

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1. INTRODUCTION

The key factor driving sales growth and margin retention in the consumer packaged goods (CPG) industry is product innovation. The ability to adapt to constantly shifting consumer trends is the key driver to a firm's success. As a result, CPG companies have increased the number of new products brought to market every year in order to remain competitive, thus straining the firms' supply chains. This thesis focuses on new product development in cosmetics, a particular segment of the CPG industry, where our partner company is a leading firm. For confidentiality purposes we reference the sponsoring company under the alias InnerBeauty Inc. In the last couple of years, the competitive CPG environment has pushed InnerBeauty to introduce three times as many products in half the timeframe. Adding to this challenge, a full year before the product even launches, the sales team at InnerBeauty must provide big retail customers with shelf-quality sales samples at sales negotiation meetings.

The objective of this thesis is to shorten the supply chain of sales samples by analyzing the product development process and identifying opportunities for improvement. In cosmetics, a product consists of two main components: the makeup formula and its primary packaging. Of the two, often the latter is the bottleneck "critical path" of product development. In order to streamline the process, we chose to explore the integration of 3D printing technology as a standard operating procedure. 3D printing technology, though invented 30 years ago, has recently been gaining notoriety for its potential in improving product development and manufacturing processes. We studied the application of the technology in the context of CPG product innovation.

Sales samples are an understudied area of product development process that are not tracked in a traditional manner. As a result, there is a lack of quantitative information and, as a result, most of the data we collected came from interviews. This study outlines and identifies opportunities where InnerBeauty is able to implement a leaner product development process, reduce the time required to provide sales samples to their retail customers and thus gain competitive advantage.

2. PROBLEM DEFINITION

InnerBeauty is a large company comprised of disparate functional silos that may not always align with the company's overall strategy. In order to identify improvements in the product launch process, we first identified and interviewed all of the stakeholders in the process and gained an understanding of the context of the problem. It is worth noting that each stakeholder works on sales samples in parallel with their daily functional responsibilities. The interviews summarized below pertain only to their roles in sales samples development as opposed to overall product development.

<u>Design:</u> There is a significant bottleneck at the senior leadership level to "freeze" the plans for a new product, sometimes requiring several weeks to approval of a final proof of a concept. The inability to lock the design creates uncertainty in the downstream supply chain.

<u>Sales and marketing:</u> Sales samples are the critical foundation to driving sales growth as the retailer buyers make their purchasing decisions based on their initial experience with the product.

<u>Packaging:</u> Samples' packages are complicated to manage as they are manufactured globally (China, France, Germany, Italy, Ireland). This poses several physical, informational, financial and import constraints. The packaging team is responsible for coordinating the timing between the formula contents and the packaging.

<u>Manufacturing:</u> The main manufacturing facility and the R&D pilot lab are used for the production and final assembly of sales samples. Relatively small batch sales samples production often disrupts manufacturing schedules. For instance, processes such as filling, packaging and labeling, run three shifts with changeovers averaging 20-30 minutes on typical two hour runs. As a result, any disruption affects these tight schedules.

Research and development: In addition to developing the new product, InnerBeauty uses R&D to facilitate the production and final assembly of sales samples. This stifles innovation by focusing specialized resources away from their core competencies. R&D also hires temporary employees to handle peak loads of product assembly, further distracting them from their primary responsibility.

Regulatory: As sales samples are designed for human use, the partner company enforces the same stringent standards as with full-scale production. In this way, original formula and packaging must undergo extensive testing and approval from their corporate regulatory body. Thus, documentation approval lead time is a rigid constraint in the overall process.

Finance: Procurement costs, headcount resources and exceptional expenses are poorly tracked, maintained only at a high-level cost center. An explicit budget for sales samples does not exist, and so expenses are shared amongst various departments. This environment creates misaligned incentives and conflicts of interest amongst the cross-functional teams.

Program manager: Sales samples represent only a fraction of the program manager's responsibilities and their time is thus allocated proportionally. They lead definition of a sales samples plan which is then handed off to execution by multiple function. The lack of a single contact point creates miscommunication and mistakes. There are opportunity to streamline the process through improved planning and communication.

Each function has a unique set of incentives, priorities, budgets and cultures that may conflict, jeopardizing the timely delivery of sales samples to customers. Given this understanding of sales samples at InnerBeauty, we were able to prioritize which aspects of the problem should be the focus of our research and analysis.

3. LITERATURE REVIEW

Prior to gathering data from InnerBeauty, we studied the topics most pertinent to the stated problem. Though literature regarding the specific sales samples process is scarce, there is an abundance of published information regarding product innovation, 3D printing and current trends in CPG product development. The literature review first explores the current state of the cosmetics sector to understand the pressure on product innovation. Second, we introduce an overview of CPG product packaging, an identified focus of our analysis. The third section is a brief explanation of the supply chain structure of the cosmetics industry in the context of launching a new product. Next, we present an overview of additive manufacturing and 3D printing technology, identifying its prospects and challenges in product development. Finally, we provide an academic understanding of dual sourcing strategies as it pertains to balancing efficiency versus responsiveness.

3.1. Trend toward innovation and customer markets in the cosmetics industry

As competitiveness in cosmetics increases, industry players are increasingly introducing new features and functionality to differentiate their products. Technology advancements in formulas and packaging have introduced further pressure to innovate faster than ever before.

The cosmetics industry is expected to grow at an annual rate of 5.8% through 2018. Of the current $48.5 billion cosmetics and beauty market, the U.S. comprises the largest share of the market at 20%, or $9.7B. The cosmetics sector itself accounts for 18.6%, or $9.02B of the total beauty industry. Since the 2008 recession, the industry sustained profit levels of 13% through cost saving measures, for instance by reducing its workforce by 2.1%. Industry players are expected to increase employment by 4.1% over the next five years, driven by a need to develop new products. The beauty and cosmetics industry is viewed as a growth industry due to:

- Sustained 4.2% growth compared with U.S. GDP growth of 2.1%.
- Continued innovation and frequent product releases.
- New companies regularly entering the market: the number of companies is expected to grow 3.5% through 2018 (Phillips, 2013).

In an Accenture study (2009) regarding CPG innovation and growth, 10% of sales is spent on R&D. IBISWorld reports that "as the industry has grown more competitive, product innovation and reformulation have become more important to companies looking to expand their market share" (Phillips, 2013, p. 36).

Nearly 86% of CPG companies think that consumer insights are very important in the design phase of the product lifecycle (Accenture & (GMA), 2009). In the same study, 45 respondents from 20 companies provided feedback regarding their firm's capabilities in product lifecycle management. The results point to various inconsistencies in each firm's ability in bringing new products to market. There was, however, common agreement regarding the increasing use of data analytics to better understand consumer preferences. In figure 1 below, it is clear that gaining insights from consumers is absolutely critical in the earliest phases of product development. The top four categories of Innovation, Idea Management, Product Development and Concept Development all rely heavily on input from end-market consumer feedback.

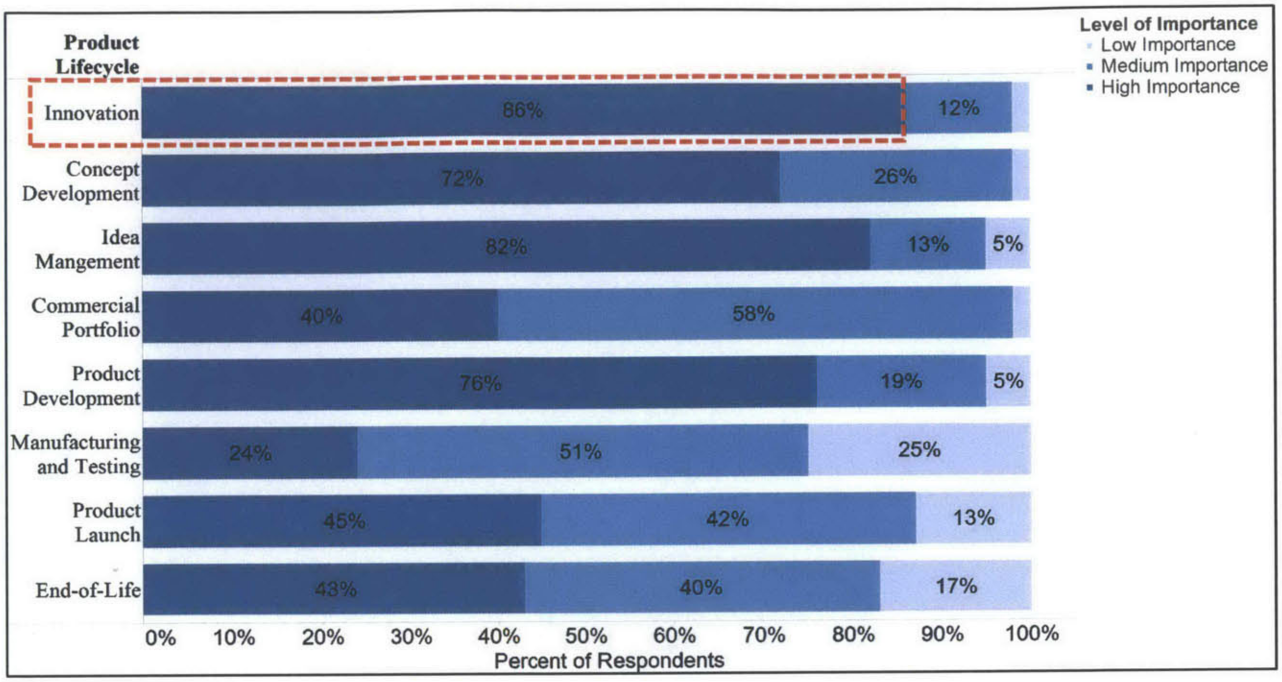

Figure 1: Importance of consumers' feedback in the different lifecycle of a product (Accenture & (GMA), 2009)

Furthermore, according to this same Accenture research, almost 60% of respondents believe the Go/No Go decision of a new product launch is ineffectively executed. Risk aversion, indecisiveness, and lack of confidence jeopardize a firm's ability to launch new products.

This study provide insights to the problems faced by InnerBeauty when launching new products. Having the ability to provide a shelf-ready product for consumer feedback would improve a firm's confidence in a new product's design, thus mitigating the risk of failure, accelerating design freeze and hastening the pace of product launches.

The design phase of new product development is a critical and time-consuming aspect in the product lifecycle. Capturing more accurate consumer data while reducing the time spent in consumer testing is a tremendous opportunity for CPG firms.

3.2.Market trends and challenges in CPG packaging

Developing novel, innovative products and packages is the driving force in cosmetics. As Cook & Georgiadis (1997) note, "…the future health and growth of the Consumer Packaged Goods industry will critically depend on its ability to expand sales through innovation and successful commercialization of these innovations" (as cited in Gielens & Steenkamp, 2007, p. 2). This reaffirms that product innovation and the rapid launching of new products to market is a strategic area of focus for the CPG space.

In the cosmetics industry, packaging is often referred to as the "silent salesman," acting as the front-line spokesperson for the formula inside, playing a key role in the purchasing decision of the consumer (Palekar-Shanbhag, 2013). Additionally, the packaging may cost manufacturers three times as much as the formula contained within it (Poulter, 2007). This highlights the importance of packaging in the industry and explains the reason for our focus on it. For instance, packaging vendor Anomatic Corporation recently built a design and innovation center leveraging state of the art prototyping technology, delivering working models in days as opposed to the typical months. (Penning, 2013). In another example, L'Oreal is working with Siemens on software that will optimize the packaging development process by improving time to market, product innovation and quality (Siemens, 2014). In 2013, P&G specifically recognized the importance of packaging by awarding the title of "External Business Partner of the Year" to eight packaging vendors in their top 15 supplier partners, out of a total of 82,000 suppliers (P&G Recognizes the Excellence of Supplier Partners, 2013). These examples indicate how product packaging is a significant opportunity for CPG participants to focus on innovating.

3.3.Supply chain structure and distribution channels

Mass merchandisers/groceries and pharmacies account for 23.8% and 13% of the cosmetics industry revenue respectively (Phillips, 2013). For InnerBeauty, the top four retailers account for 75% of total cosmetics sales. Large cosmetics manufacturers gain market advantage by leveraging large volumes and efficient economies of scale, while distributing directly to large retailers. To meet the stringent requirements of these retailers, the large cosmetics firms are under pressure to provide both process efficiency and product innovation.

Geographically speaking, the U.S. Mid-Atlantic region is the most popular for cosmetics producers because of its proximity to chemicals suppliers and a densely populated consumer market. As a result, 65% of packaging establishments are located in areas surrounding the mid-Atlantic. According to Phillips' research (2013), the production of cosmetics in the US may be advantageous simply by its close proximity to the high local demand, around 31.5% of the global market. This on-shoring will also shorten the time frame for innovation which is a critical aspect in this industry.

3.4.Introduction to additive manufacturing and 3D printing

In addition to the aforementioned examples of packaging innovation, one of the most promising innovations in the plastic packaging space is 3D printing[1]. Additive manufacturing is the process of joining materials to make objects from 3D designs data to build up a component in layers by depositing material (International Committee F42 for Additive Manufacturing Technologies, ASTM). Different metals, plastics and composite materials can be used. As a result of avoiding

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[1] 3D printing has been recently set as the prevailing synonym implying all types of additive manufacturing. For the intent of unambiguous communication, each type of additive manufacturing is used explicitly as defined above.

traditional manufacturing methods and burdensome design changes, the main advantages of additive manufacturing are reduced speed and cost.

Additive manufacturing can be achieved through different technologies, classified into four main categories:

1. Fused Deposition Modeling (FDM)[2] is a process used to make 3D parts through the deposition of heat sensitive plastic material layer by layer through heated nozzle that moves horizontally and vertically guided by a computer, as seen in figure 2. This technology is usually used for prototyping and modeling purposes.

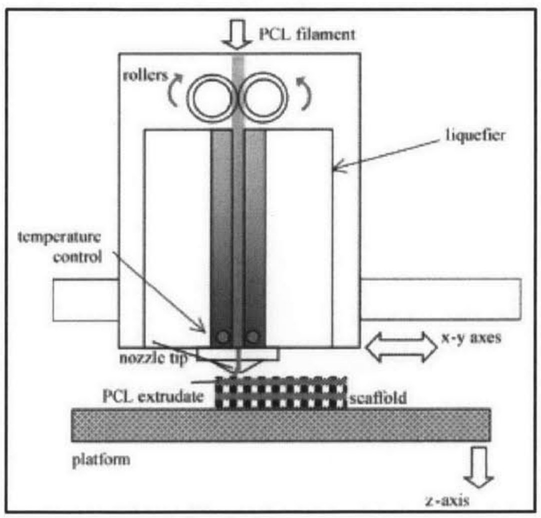

Figure 2: Fused Deposition Modeling process (Zein, Hutmacher, Tan, & Teoh, 2001)

2. Stereolithography[3] (SLA) is a process used to make 3D printed parts from a light sensitive liquid polymer that harden when contacted by a computer-controlled moving laser beam as seen in figure 3.

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[2] According to the ASTM definition, FDM is "a material extrusion process used to make thermoplastic parts through heated extrusion and deposition of materials layer by layer" (2012,2)

[3] According to the ASTM definition SLA is "a vat photopolymerization process used to produce parts from a light sensitive plastic material in a liquid state using lasers to cure to a predetermined thickness and harden the material into shape layer upon layer" (2012,2).

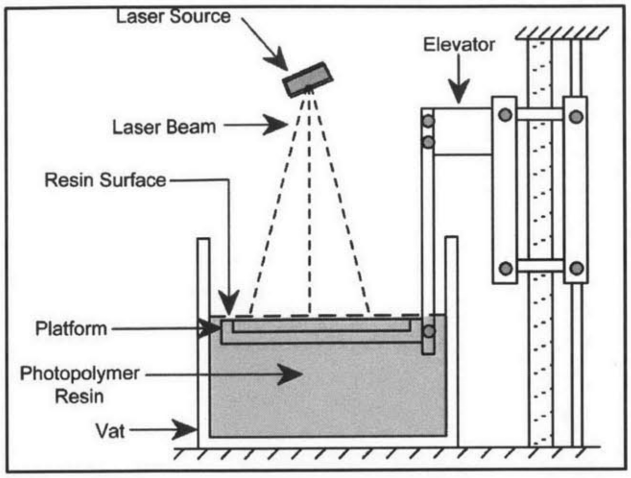

Figure 3: Stereolithography (SLA) process (3D printing techical revolution, 2011)

3. Selective Laser Sintering (SLS)[4] is a process used to make 3D printed part from powdered material by fusing the particles together through a computer controlled moving laser, as seen in figure 4.

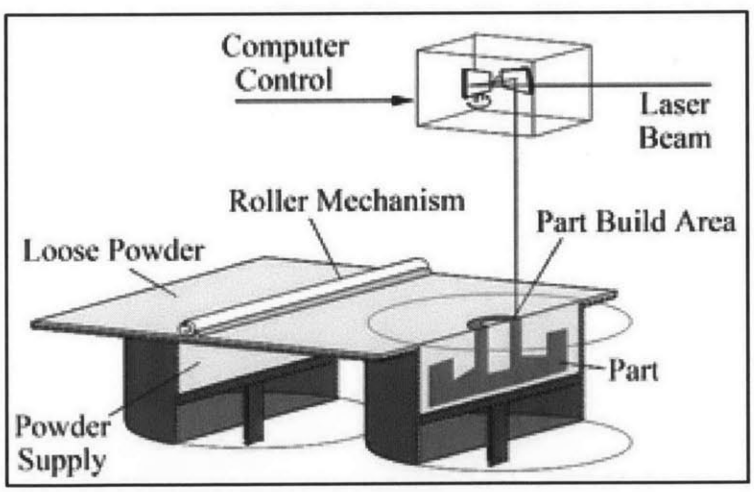

Figure 4: Selective Laser Sintering (SLS) (Lou & Grosvenor, 2011)

4. 3D printing is described by ASTM as the fabrication of objects through the deposition of a material using a print head, nozzle or another printer technology. 3D printing is similar

[4] According to the ASTM definition SLS is" a powder bed fusion process used to produce objects from powdered materials using one or more lasers to selectively fuse or melt the particles at the surface, layer by layer, in an enclosed chamber" (2012,2).

to a standard inkjet printer in that it utilizes powder or liquid resin deposited in layers and then cured with ultraviolet light and/or heat. Typical materials used in 3D printing include ABS plastic, polyamide, resin, titanium, stainless steel, silver, gold, bronze, ceramics, rubber, wax, photopolymers, and polycarbonate as seen in figure 5.

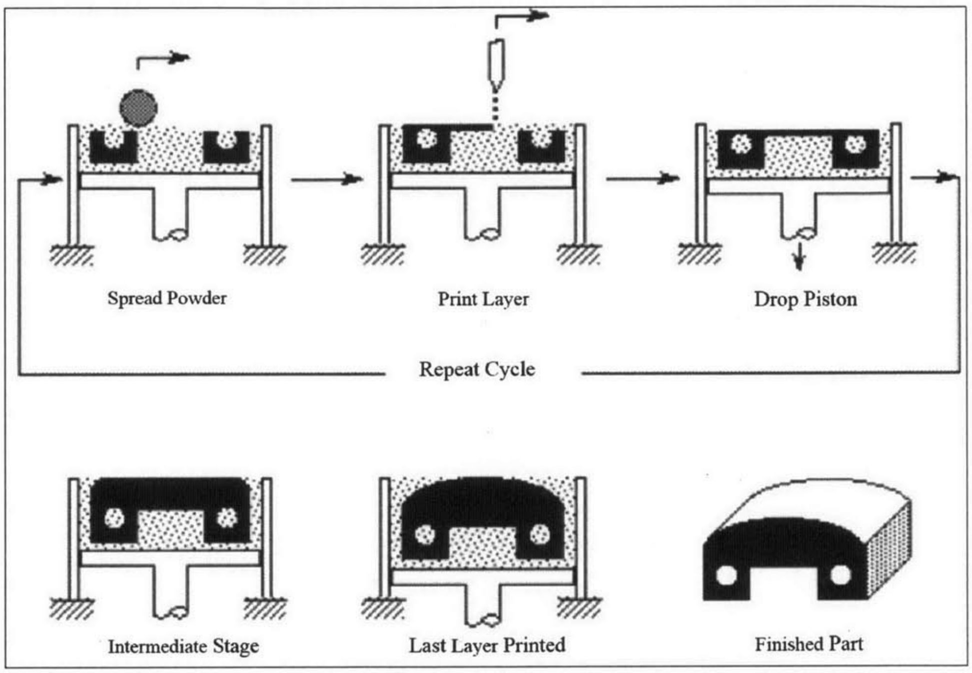

Figure 5: 3D printing process (An Introduction to Rapid Prototyping, n.d.)

Formed in 2009, the ASTM International Committee F42 on Additive Manufacturing Technologies have classified the different processes of additive manufacturing into seven classes, as described in table 1 (Scoot, Nayanee Gupta, Newsome, & Wohlers, 2012). Each class of additive manufacturing has traditionally supported prototyping applications. However, vendors have recently applied these methods to various applications and as a result of technical advancements in the technology.

Table 1: Leading companies in the 3D printing industry and their primary applications. (Scoot et al., 2012)

Process	Example Companies	Materials	Application
Vat Photopolymerization	3D Systems (US), Envisionetec (Germany)	Photopolymers	Prototyping
Material Jetting	Object (Israel) 3D Systems (US)) Solidscape (US)	Polymers Waxes	Prototyping Casting Patters
Binder Jetting	3D Systems (US) ExOne (US) Voxeljet (Germany)	Polymers Metals Foundry Sand	Prototyping Casting Molds Direct Part
Material Extrusion	Bits from Bytes RepRap	Polymers	Prototyping
Powder Bed Fusion	EOS (Germany) 3D Systems (US) Arcam (Sweden)	Polymers Metals	Prototyping Direct Part
Sheet Lamination	Fabrisonic (US) Mcor (Ireland)	Papers Metals	Prototyping Direct Part
Direct Energy Deposition	Optomec (US) POM (US)	Metals	Repair Direct Part

The four major markets targeted by additive manufacturing companies are rapid prototyping, rapid tooling, repair parts and the integrated manufacturing process, which are described below (Scoot et al., 2012).

- Rapid prototyping: Additive manufacturing was first created to produce prototypes in the early development phase of a product to reduce the time and cost of reaching the final design. Today, this technology is a standard practice for many manufacturing companies.
- Rapid tooling: Additive manufacturing technology can be used to quickly manufacture quickly tools or tooling components. This trend has been widely observed in 3D printing where tools such as molds and dies are used in various manufacturing processes.
- Repair parts: The use of additive manufacturing is useful in the repair of damaged parts, especially those with a long lead time or high cost of procurement.
- Integrated manufacturing process: Integration with production has become the fastest growing application for additive manufacturing. In 2003, this category was only 4% of

the total additive manufacturing revenues, reaching almost 20% of revenues in 2010, according to a Wholers 2011 report (as cited in Scoot et al., 2012).

3.5.Maturity of additive manufacturing technology

Despite being 30 years old, 3D printing technology is still quickly maturing. Our proposed solution involves rapid tooling technology to produce an injection molding tool. This approach is becoming common in industry as many companies are finding tremendous advantage in cutting the lead time required in the production of a steel mold. A study by the consulting firm Roland Berger (2013) has rated the maturity of 3D printing in tooling as transitioning from a production environment to a pilot tooling application as described in figure 6 below.

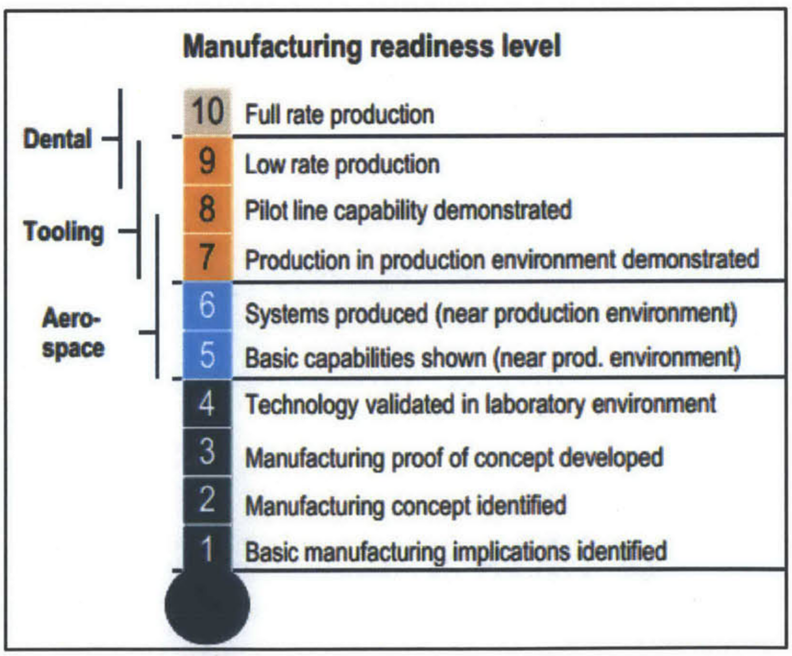

Figure 6: Manufacturing readiness level (Roland Berger, 2013)

The application of 3D printing is very much on the cutting edge and still requires several more years of maturity to be a fully comprehensive method of manufacturing. The thesis highlights some of the opportunities and technical challenges of 3D printing.

3.6.The relationship between 3D printing and product development in the CPG industry

As a response to the increase in customers' expectations, product development has accelerated since the late 2000's. Companies must increase the pace at which they release new products in order to stay competitive. Recently, consumer goods companies have been investing in flexible packaging, where a compounded annual growth rate (CAGR) of 5.1% is expected in the next five years. In the cosmetics industry, companies are specifically focused on innovation in order to increase their market shares, as the European and North American markets are already mature (Phillips, 2013). Through new technological advancements in additive manufacturing, prototypes now closely resembles the final product. In a 2012 conference of the Society of Manufacturing Engineers (SME), Terry Wolhers, the keynote speaker, stated that "3D printing and 3D imaging are causing design and manufacturing professionals to rethink their approach to new product development" (as cited by MCue, 2012, paragraph 3)

According to a study performed by the German consulting company Roland Berger, the market for systems, services and materials for additive manufacturing was estimated to be $2.34 billion and is estimated to quadruple over the next 10 years. Another study by the consulting firm Deloitte (2012) has valued the market of 3D printers to approach $5 billion in 2017 (p. 5).

Based on the aforementioned research and interviews with industry experts, figure 7 summarizes the different markets, levels of maturity and sales samples relevance from a 3D printing perspective.

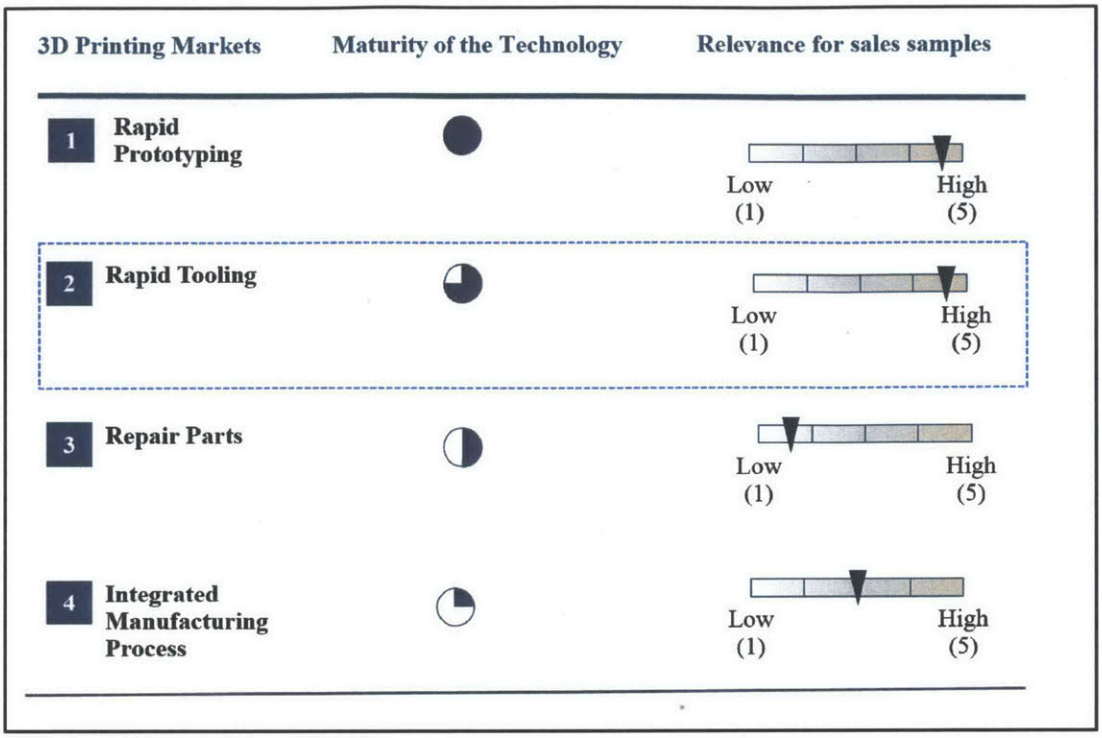

Figure 7: Different markets for 3D printing and relevance for sales samples

In summary, there is an opportunity for additive manufacturing and in particular rapid tooling, to play a significant role in packaging development. One major advantage of rapid tooling over rapid prototyping is that the same plastic material used in shelf-ready packaging can also be used in the 3D printed mold, enabling for virtually identical results.

3.7.Dual sourcing strategies

David Simchi-Levi (2003-2007) claims that successful firms are able to apply different supply chain strategies based on each product's unique characteristics. Most large CPG companies tend to apply the same efficiency-driven supply chain across their entire product portfolio. Research into product innovation processes suggest that new product launches require a responsive supply chain very different from that of their mass-production counterparts.

According to Marshall Fisher (2011), firms are increasingly introducing new products, shifting from functional to innovative products in order to increase margins. This holds true in the CPG cosmetics industry where a firm's success lies precisely in its ability to innovate and differentiate from the competition. While a firm may be successful at product innovation, it may fail to adapt an appropriately paired supply chain. Many continue to use the same "efficient" supply chain despite the fact that innovative products require vastly different supply chain.

Table 2 demonstrates this phenomenon: firms tend to reside in the upper half "efficient" supply chain quadrants, entirely focused on driving out costs. When firms attempt to use their efficient supply chain for new product development, they end up in the top-right quadrant, failing to quickly respond to downstream signals. As a result, a cosmetics CPG firm will take far too long to bring a new product to market, jeopardizing its ability to respond to rapidly changing fashion trends. In the case of sales samples, not being able to provide a trendy new product to a large customer can mean the loss of sales. The stakes are too big to have a mismatched *efficient* supply chain with an *innovative* product.

Table 2: Matching Supply Chains with Product (Fisher, 2011)

Supply Chain Strategy	**Functional**	**Innovative**
Efficient	Match	Mismatch
Responsive	Mismatch	Match

The reason why firms tend to stay the in upper right efficient-innovative quadrant likely has to do with historical context. One example provided by Fisher (2011) is related to the personal computer (PC) industry: since their beginning, PC manufacturers focused on performance metrics such as plant and inventory utilization. Once they transformed their business from mainframes to PCs, they retained the same metrics. By focusing solely on efficiency, they were unable to respond to highly volatile demand. We believe this same context exists in the large CPG industry where manufacturers have historically relied on economies of scale to compete. These firms are now proliferating innovation across their product portfolios but are still trying to constantly trim costs.

In summary, the research indicates that the key driving force in the cosmetics CPG space is new product innovation. Intuitively we see conflict arise in that CPG is a traditionally mass-market, economy of scale-focused industry. While the largest players in the market must stay focused on mass production efficiencies, they must also be nimble enough to quickly produce "mass-prototypes" to the market. Our work with the partner company, InnerBeauty, identifies new strategies in rapidly bringing new sales samples to market by applying rapid tooling technology to injection molding[5] and blow molding[6], as these are the two primary methods used to create cosmetic packaging.

[5] "Injection molding is the process in which resin is heated in a barrel and then injected into a mold by a reciprocating screw. The resin then cools in the mold and is ejected as a solid part" ((ASTM International), 2012).

[6] "Blow molding is the process of forming a hollow, one piece article (bottles, cans, jars) by expanding the parison (hot plastic) against the surface of a heated two-piece mold with compressed air" (ToolingU, 2013).

4. METHODOLOGY

The product sales samples process has historically been an afterthought for the CPG industry. Due to the low volume and short lifecycle of these products, there is little focus, expertise, quantitative tracking, or industry benchmarking available. Despite InnerBeauty's industry leadership, there tends to be poor execution of the sales samples process as compared to their mass production capability. Furthermore, there are few resources specifically allocated to the sales samples process and thus little data to support the analysis. Information that is available tends to be qualitative in nature, lacking substantive, quantitative supporting data. Consequently, the data collection consists of a variety of alternative inputs including a site visit to InnerBeauty's headquarters, weekly interviews with company stakeholders, a real-time tracking of individual products, a series of tracker documents and an exploration of 3D printing vendors.

4.1. Site Visit to Partner Company Headquarters and Weekly Stakeholder Interviews

We initially conducted a site visit to InnerBeauty's headquarter campus, holding a series of interviews with representatives of nine functional areas to gain a better understanding of the sales samples process. These groups included design, sales, marketing, packaging, manufacturing, research and development (R&D), regulatory, finance and project management. It quickly became apparent that key bottlenecks existed in the design and production of packaging, specifically regarding the outsourced and offshored mold production process. This element presented a key opportunity and focal point for our analysis.

An additional site visit was conducted to a sister division of InnerBeauty which currently uses 3D printing technology for rapid prototyping applications. This visit provided further insight into the challenges and opportunities for 3D printing technology in the CPG industry.

In addition to the site visits, weekly phone interviews were held with various InnerBeauty stakeholders. Through these discussion with a project manager, an IT systems manager, a packaging engineering manager and a contract project manager of sales samples, we gained a thorough appreciation of the product development process from the people who experience it firsthand. Each individual provided detailed process activities and figures as it relates to project execution.

4.2.Analysis Method to analyze the collected process data

According to the process analysis expert, Ann Langley (1999), there are two primary means of gathering process data: historical time-series events and real-time collection of detailed data. The first method is to determine a priori process and then support it based on detailed historical time series data. The second method is a posteriori process where data is collected first, whether historical or real time data and then a theory is formulated based on the observation and information gathered. Since research regarding the development of sales samples is very limited, it was difficult to develop a theoretical framework for it. Therefore, we decided to choose inductive reasoning and followed the a posteriori method. Ideally, we preferred collecting both real time and historical data. However, as the duration of product introductions exceeds the timeframe in which we studied them, we instead gathered information mainly from InnerBeauty historical documentation.

Of the seven strategies of "sensemaking" process data identified by Ann Langley (1999), our methodology most closely aligns with the so-called "visual mapping strategy." In this way, we used visual graphical representations of the process via Microsoft Project Gantt charts. In these visuals, we identified parallel processes, interdependencies and ultimately the critical path dictating the overall time to deliver a new product to market.

This documentation, though helpful, lacked the detail necessary to provide a complete picture. In order to fill in the gaps in the data, we used a narrative strategy, defined by Langley (1999) as "the construction of a detailed story from the raw data" (p. 695). We gathered the missing data by interviewing the process' stakeholders in order to provide context and details. Once the critical path was identified via the visual maps and interviews, we then focused our research on the specifics of the process that demonstrated opportunities for improvement. We held additional interviews with the people involved in the critical path activities and gathered further information to analyze. This documentation included a product "base plan," an overarching strategy describing the details of a new product launch, including product characteristics, product and packaging information, sourcing information, investment spending and project duration. We also studied product tracker sheets, which highlight the incremental progress of every new product in InnerBeauty's seasonal launch.

4.3.Case study of an individual product

The primary way we captured data was through the manual, real-time tracking of a key product: a new to the world mascara. Primarily through phone interviews and tracker sheets, a detailed sequential process was constructed. Closely following each stage of the product development process provided insights and opportunities for improvement. We mapped each activity and its time requirements, identifying the reasons for delays. InnerBeauty does not track detailed costs as sales samples' cost centers are integrated with mass production, thus our analysis only highlights the cost of some critical components.

4.4. Research of potential third party vendors

As packaging is a primary bottleneck of the sales samples process, we identified technology vendors with the potential to expedite the process. We found suppliers in two specialized disciplines: rapid prototyping and 3D printing technology.

Rapid prototyping suppliers: Firms that are able to design, build, prototype and mass-produce new packaging innovations in the United States have the potential to significantly reduce the packaging development time.

3D printing technology: We explored the current state of 3D printing technology as it relates to creating the packaging molds by interviewing several vendors that are capable of using 3D printing for rapid prototyping and rapid tooling. In order to better understand the technology, we conducted site visits to these vendors to meet with their engineers. They provided us with technical information regarding the challenges and limitations of this emerging technology. We also provided them with samples of cosmetics packaging to determine the feasibility of successful implementation, learning that the success of the technology depends on several factors: namely the shape, material, complexity and quantity of the packaging component.

4.5.Challenges in data gathering

We faced many challenges while gathering data due to the unique nature of the subject matter.

Lack of process traceability: There is currently no systematic way the sales samples development process is being managed. A manually maintained excel sheet, passed around via email, is prone to error, generally unreliable and not consistently updated. Therefore, capturing information from the other sources mentioned provided more clarity.

Lack of historical data: Very limited data from previous projects exists as every project is considered one-off or composed of ad hoc activities. It was therefore difficult to compare the planned schedules versus the actual outcomes.

5. DATA ANALYSIS AND RESULTS

The data analysis and results section describes the current process of product development, the proposed solution, and then demonstrate its benefits and challenges though a case study.

5.1.Process flow for sales samples

The interviews at InnerBeauty's headquarters provided insight into the end-to-end supply chain of sales samples. Every six months, 10 to 30 new products are scheduled for release to the market. There is a diverse range of requirements for each:

- Product category: Face, eyes, lips, nails
- Type of design change: Artwork, formula, primary packaging
- Newness of formula or packaging: Existing, minor modification, major modification, "new to the world"

The critical path method is defined as "a network analysis technique that predicts a project duration by analyzing which sequence of activities has the least amount of scheduling flexibility" (Glossary of Project Management terms, 2014). The thesis focuses is on activities that are on the critical path, such that any improvement will reduce the overall completion of the project. These activities are detailed below:

1. Project establishment: The process of new product development at InnerBeauty is an iterative feedback cycle between multi-functional partners (e.g. Design, Marketing, Consumer Research). In its nascent stages, the design and marketing teams spend one to two months identifying gaps in market needs. In order to identify design requirements, the team looks at specific fashion trends and the overall competitive landscape.

2. Primary design creation: Once the market requirements are confirmed, an initial artwork design is created by an outside firm. This initial concept ranges from one to two months and is then brought to a consumer testing panel for feedback. It is worth noting that upon its development, the design firm can provide a 3D Computer Aided Design (CAD) file of the concept within a day notice.
3. Initial design feedback: The next four months are spent with consumer testing groups vetting the first conceptual 2D graphic. In some cases, marketing may not be satisfied with the feedback of the graphic and may resort to a 3D printed prototype or mock-up model carved from wood. This one-off prototype is decorated by InnerBeauty's marketing team using household art supplies (spray paint, glitter, etc.), demonstrating the determination to capture such valuable user feedback. In one anecdote, a consumer testing group rejected an eye liner based solely on its excessively large bottle size. For the more major launches, these prototypes may go to large retailers such as Wal-Mart to gain further buy-in from key customers.

These examples highlight the importance of consumer feedback to cosmetics firms. As mentioned in an Accenture study (2009), 86% of CPG firms believe consumer feedback is the most important aspect in the innovation stage. The consumer panel offers insights into ideal shapes, sizes, colors, decorations and labeling that are then incorporated into subsequent design iterations.

4. Iterative design feedback cycles: Each iterative concept takes four to six weeks to develop and may occur two to four times, depending on the feedback. Until InnerBeauty feels that the design is sufficient for project confirmation, these iterations will continue,

often for upward of five additional months. According to interviews with InnerBeauty's project managers, if it was up to them, designers would require an infinite number of iterations to reach the perfect design.

5. Project confirmation: Upon the successful completion of these design iterations, a final concept is brought to InnerBeauty's general manager for approval. It is at this point when the overall business case for the product is made the design specification is frozen and a request to fund the next phase of development is submitted. Completing this milestone is an important step in the process, as it a signal that leadership has the confidence that the product will succeed and is willing to make a significant investment towards its development. Executives may hesitate to finance these projects if they suspect any chance of failure as the cost of cancelling it at this point is exponentially less than if it is abandoned later. For example, the cost of production tooling can easily reach $2,000,000, a significant capital investment for a firm of any size. The greater the uncertainty of the consumer feedback, the longer project confirmation launch may dwell, extending into additional rounds of feedback and design iterations. Overall, the span between project establishment and project confirmation lasts between four and nine months, depending on the certainty of the product's success and magnitude of investment.
6. Primary pack mold unit tool production: Once the project confirmation milestone is reached, the primary packaging unit tool is created. The primary pack contains and presents the cosmetic formula, acting as the "silent salesman" of the product (Palekar-Shanbhag, 2013). The primary pack is in direct contact with both the formula and the secondary pack, so success in its design is critical. The unit tooling is a steel casting consisting of four to eight cavities which produce roughly 50,000 shots of primary

packaging. Creating the unit tooling for the packaging takes two months to cast and one month to qualify. There can be upwards of eight different tools cast for just one product. An investment in the unit tooling may cost up to $200,000, so confidence in both the product's success and its mold design is important.

7. Delivery transit time from suppliers: Packaging is produced by various suppliers around the world, primarily China, Germany, Italy, France, UK and Ireland are the main source countries. The primary means of shipment is by sea, typically requiring a six week door-to-door delivery, or four if expedited. For urgent orders, a costly air transport option is available for two week door-to-door delivery.
8. Unit tool output objectives: 50,000 units are produced by the unit tools and are used for various activities. As a consequence of intensive testing, the unit tooling has a roughly 50% likelihood of being modified, each modification requiring an additional month.
9. Sales samples production: These are shelf-ready, decorated packaging components used to initiate sales activities with retail customers prior to full market launch. Below are details of the types of sales samples created:
    - *Full sales kits for the sales and marketing team:* In order to set up a deal with top customers, the sales team requires a full set of the new products being launched. The kit is composed of a suitcase that elaborately presents the new products. This full kit is instrumental in the negotiation meetings with top customers as they may determine the shelf space, quantity and pricing for North American and European stores. InnerBeauty provides 50 of these kits only to top customers. Combined, Wal-Mart, Target, CVS and Walgreens comprise 75% of InnerBeauty's total sales.

- *Selected SKUs for field samples*: For smaller customers, the marketing team selects a limited number of representative SKU's of the new product catalog. These additional samples are made on the order of 1,000-2,000 units and are typically mailed to customers.
- *Partial Sales kits*: Similar to full sales kits, these are custom-configured display cases highlighting a limited selection of mainly "hero" color shades of the product lines.
- *Miscellaneous:* Other uses of sales samples include marketing catalogs (i.e. photo shoots, customer flyers), advertising purposes and public relations events.

10. <u>Pre-production testing:</u> Numerous tests are required to ensure the product is ready for full market launch from a quality, safety and operational perspective.
    - *Design test:* Ensures that the shape and color of the packaging aligns with the designers' intent.
    - *Fit for use functionality test:* identifies whether the primary pack component is functional (i.e. pump-action, threading of caps, close clamps, etc.).
    - *Manufacturing test:* Units are sent to manufacturing sites to run the primary pack through an automated production line, identifying any balancing, change parts, or quality adjustments needed.
    - *Consumer feedback panels:* The initial units may be used for late-stage consumer testing using the shelf-quality primary pack, rather than design mock-ups used in the initial design panels. Allowing users to touch and feel the samples prior to full production launch allows InnerBeauty to make small modifications to the design if necessary.

- *Resin/plastic compatibility test:* Ensures the safety and stability of the formula while in contact with the primary pack.
- *Shipping/tote test:* Ensures the shape of the final packaging can be properly packed into shipping containers, both internally and retailer-specific tote specifications.

It is worth noting that shortening activities outside of the critical path will not necessarily benefit InnerBeauty. One main example is the development of new cosmetic formulas. Although the formula and its ingredients do not necessarily require FDA premarket approval, cautious cosmetics firms such as InnerBeauty still adhere to strict regulatory practices. Thus, the lead time necessary for new formula is essentially fixed by this process, so streamlining it would require a great deal of effort for minimal improvement. Similarly, shortening the duration of any non-critical activities will not affect the duration of the overall project and will therefore not be the subject of our focus.

In conclusion, our analysis of InnerBeauty's process, combined with the aforementioned research provide inputs into a framework that shortens the product development process and consequently the sales samples process. This framework can be used by the partner company as well as any CPG firm interested in streamlining their product development process.

5.2.Integration of a "pre unit mold" step as part of the product development process

InnerBeauty has recently tripled the number of products in development and halved the time to produce them, without proportionally increasing its resources. The main question is how to alleviate pressure from the project's critical path. After a broad examination of potential solutions, we believe that leveraging 3D printing technology for primary pack mold tooling is the most promising.

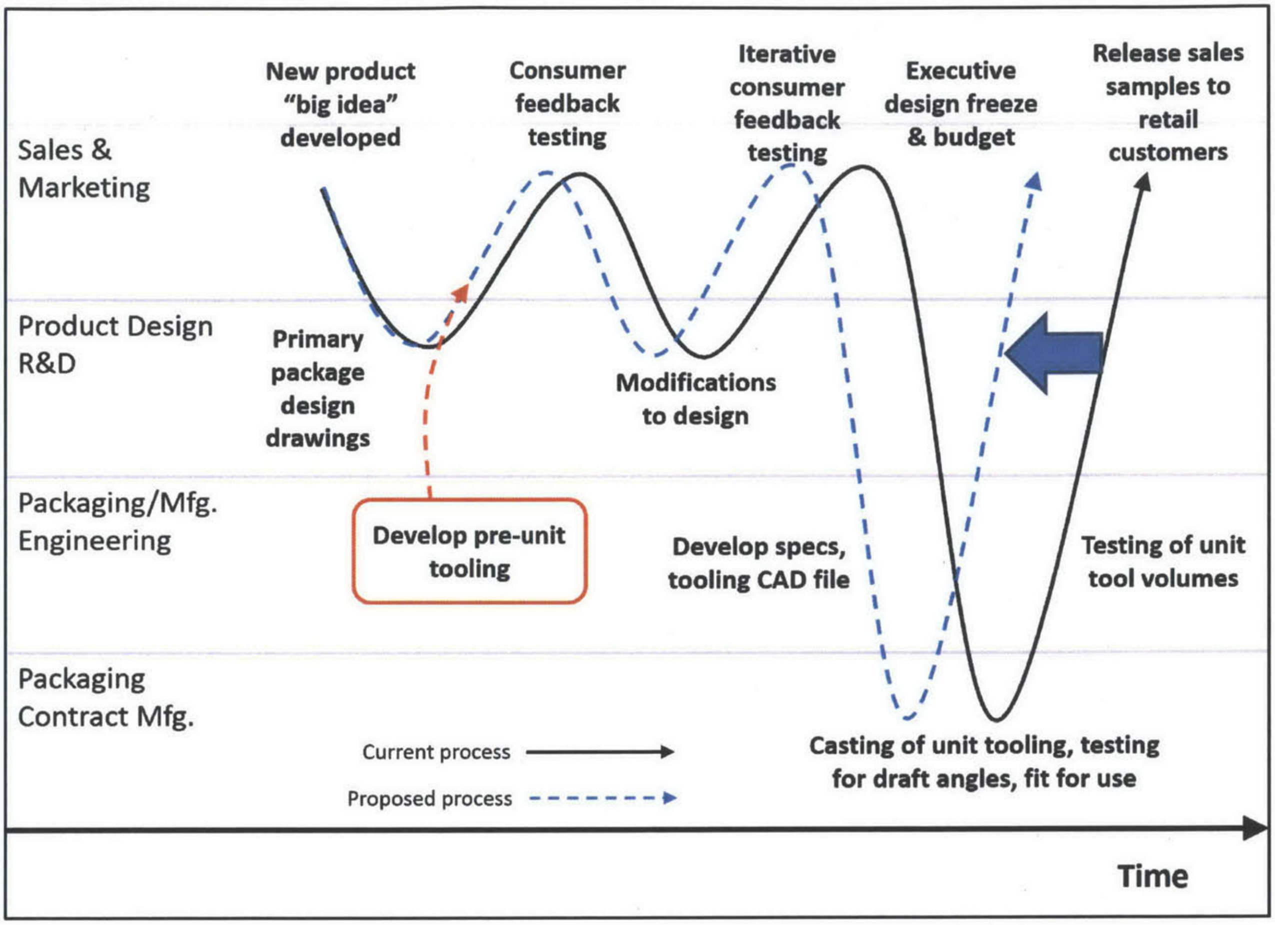

Figure 8: Illustrative process map demonstrating the proposed solution's benefits

We termed our proposed solution the "pre-unit tooling process," an intermediate phase introduced between the primary package design and initial consumer's feedback stage as shown in figure 8 above. The pre-unit tool would provide 10 to 100 shelf-quality 3D units that can be used during the consumer feedback input sessions in lieu of the 2D concept drawings or 3D mock-up prototypes. This solution has three primary benefits:

1. Fewer design iterations: Providing a fully functional, high quality, hands-on model of the product would yield more accurate feedback from consumers, resulting in fewer design iterations. Each product currently undergoes three to five design iterations, each lasting

four to six weeks. As they reside on the critical path, every design iteration removed from the sequence would shorten the project completion date by four to six weeks.

2. Improved confidence in product success: Using a quasi-final product in collecting input from the consumer tests would provide more accurate and reliable data, strengthening senior executives' confidence in the product's potential market success. Based on our analysis, it is this consumer testing and senior executive "design freeze" that suspends the rest of the sales samples process. Accelerating this step and securing design freeze much earlier will shorten the critical path and launch new products to market sooner.
3. Removal of testing activities removed from critical path: Producing final product packaging earlier in the process would allow many of the testing steps to be done not only sooner but in parallel with other activities on the critical path. The pre-unit tooling is advantageous in that it is capable of injecting the plastics already being used in production, qualifying it for many of the testing activities. The feasible tests include design, fit for use functionality, manufacturing and resin/plastic compatibility. For example, shelf-quality units available on the filling line would allow industrial engineers to determine weight balancing, quality control adjustments and change parts needed for each line. Generally, it takes one week to schedule a "line trial", interrupting ongoing production in order to validate the line. There is a 50% probability of failure, and in these cases the mold is returned to the supplier for re-work. This process takes around six to eight weeks and is typically successful after one modification. Conducting much of the testing prior to the unit tool creation, may avoid the re-work step, saving around one to two months of time. Table 3 below highlights those activities which are capable of being done by the pre-unit tool, removing them from the critical path.

Table 3: Testing capabilities of the different mold tools

	Pre-unit tool	Unit tool	Production tool
Consumer testing	•	•	
Design testing	•	•	
Formula color-matching	•	•	
Fit for use functionality test	•	•	
Resin compatibility test	•	•	
Manufacturing test	•	•	•
Shipping/tote test		•	•
Sales samples		•	
Promotional photo shoots	•	•	
Full product stability test			•

In our proposed solution, the contract design firm would provide a Computer Aided Design (CAD) file of the design concept to InnerBeauty. The pre-unit tool can then be created by either a highly responsive on-shore supplier or rapid tooling technology. The details of these two methods are described below.

Contracting the primary packaging component to an on-shore supplier would not only reduce the four to six week transit time but also foster the close working relationships that encourages the development of innovative products. For example, one vendor we identified is Proto Labs, which provides a service called Protomold. This particular vendor uses a proprietary technology to quickly cut and finish an aluminum tool. Such a service guarantees delivery of both the metal alloy tooling and more than 10,000 shelf units in less than two weeks.

As mentioned, rapid tooling, is a method of using additive manufacturing used to produce a mold tool much faster than the traditional method of milling a metal alloy. Using the CAD file, rapid tooling technology can create the pre-unit tooling in a matter of hours. Depending on the characteristics of the packaging component, Fused Deposition Modeling (FDM), Stereolithography (SLA), Selective Laser Sintering (SLS), or 3D Printing can be used to develop the pre-unit tool. For example, the tooling may be a blow-molded application, with intricate shapes, using a resin with a relatively high melting point. In this scenario, a more limited set of rapid tooling methods may be technically feasible.

Once a CAD file is provided by the design firm, InnerBeauty can purchase the technology for in-house use or contract the work to an outside service provider to create the pre-unit tooling for them. Using rapid tooling as a service is an effective way to first implement the pre-unit tooling methodology without the risk an upfront capital investment. An outside vendor with expertise would enable both parties to refine the rapid tooling process until it sufficiently meets requirements. One particular vendor called RedEye, a subsidiary of Stratasys Inc., offers such a service for less than $3,000 per mold (RedEye, 2014). The downside to these providers is that they typically only provide the mold but not the actual injection/blow molding services itself. The alternative is for InnerBeauty to create the pre-unit tooling internally, then use a supplier to shoot finished primary pack units into the mold. The tradeoff between in-sourcing or outsourcing is straightforward, as the cost of a sophisticated printer can reach $250,000 versus $3,000 for a service.

Below are photos taken from a site visit with the rapid tooling vendor Stratasys. These samples demonstrate the ability to create molds using an Objet Connex 500 3D printer. The mold in figure 9 was created via rapid tooling technology then used in a blow-molding application to create the bottle inside. Similarly, the mold tool in figure 10 was created using the same technology, generating the unit inside through an injection molding application. Most common engineering-grade plastics materials can be used in this process.

Figure 9: 3D printed mold used in a blow molding application

Figure 10: 3D printed mold used in an injection molding application

After interviewing and visiting with the largest vendors in the rapid tooling industry, our overall evaluation of the pre-unit tooling concept is optimistic. In general, these vendors are capable of supporting this process especially for the more simplistic designs. For more complex designs the state of rapid tooling is still developing and will likely be more capable in the coming years. The vendors readily admit that close partnerships with clients can actually accelerate the development of the technology to meet the specific requirements of the CPG cosmetic industry. Table 4 summarizes some of the largest vendors and their core competencies.

Table 4: Summary of the largest providers of rapid tooling technology

Vendor	Location	Annual revenue ($M)	Core competency
Stratasys	Eden Prarie, MN	414.85	FDM and 3D printing
RedEye	Eden Prarie, MN	Subsidiary of Stratasys	Additive manufacturing as a service
3D Systems	Rock Hill, SC	513.40	SLA, SLS, 3D printing
ProtoLabs	Minneapolis, MN	44.04	Rapid metal alloy tooling

5.3.Benefits and challenges of rapid tooling compared to traditional metal alloy tooling

The metal alloy cast mold used in blow and injection molding requires extensive processing, including cutting, computer numerical control (CNC) precision processing, pin drilling, polishing and customization. Consequently, creating the cast mold tooling requires long lead times and high costs. Additionally, when developing a new product, multiple iterations of the tool may be needed to ensure the output injection shot is successful. Many considerations must go into the design of the tool, enabling it to produce high-volume, high-quality parts consistently. Therefore, the time and resource required for tooling is one of the most challenging and time consuming activities in the entire product development process.

Currently InnerBeauty uses two types of molds, depending on time constraints. Typically, steel unit tooling can take up to three months to develop and cost as much as $200,000. In instances where project deadlines are at risk, InnerBeauty will resort to an aluminum tool, requiring a three week lead time at a cost of around $20,000. The downside of this method are the fewer number of units capable of being produced as compared with the steel tool. Table 5 below highlights these tradeoffs:

Table 5: Comparison of time, cost and quantities for the three type of molds

Mold type	Approximate cost	Lead Time to produce	Quantity of units produced
Pre-unit tool	$3,000	10 hours	0 to 100
Aluminum Mold	$5,000 to $20,000	2 to 3 weeks	0 to 10,000
Steel Mold	$100,000	3 – 4 weeks	0 to 1,000,000+

The proposed pre-unit tool requires only 10 hours of fabrication and is the cheapest of the three options. For the application of our proposed solution of improved consumer feedback testing, accelerated design approvals, and early-start testing procedures, the low volume of units produced by this method is sufficient. Based on each trial run of the rapid tooling, feedback of the mold's results can be quickly incorporated into a new design and new iterations can be created within hours. This technology is quite useful in instances where lead time is the significant driver of a project.

Rapid tooling may introduce new challenges into the production of consumer packaging. The most significant challenge to rapid tooling is the volume of shots they can withstand. As plastic is injected in the blow molding or injection machine in a high temperature and high pressure environment, every shot gradually degrades the mold. Most vendors estimate that a typical rapid tooling mold is capable of withstanding 10-100 shots (RedEye, 2014). In contrast, it is difficult to justify cutting a steel mold for only 100 units when the economies of scale require hundreds of thousands of units to justify the large up-front investment. Figure 11 below demonstrates the feasible quantity of units produced by each type of tooling and its relative cost per unit. The graph indicates that from 10-100 units, rapid tooling is ideal; up to 10,000 units an aluminum cast tool is most cost-effective. Finally, any production volume greater than 10,000 units would be best served by a steel tool. The mold capital expenditure is distributed over the quantities produced, as illustrated by the negative sloping lines in the diagram. The cost per unit decreases as the number of units produced approaches the maximum capacity of each mold. Each peak represents the purchase of a new mold once the prior mold used reaches its functional lifespan.

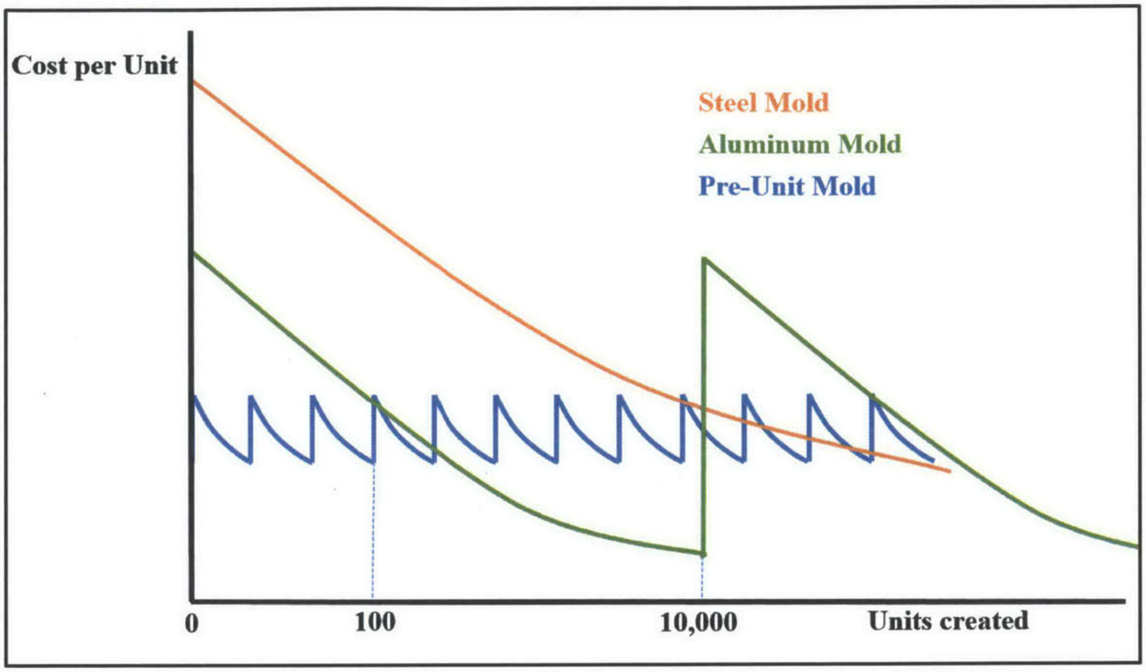

Figure 11: Illustrative example of the economies of scale for the three type of molds

In addition to the volume of shots, other challenges faced by packaging engineers include sophisticated mechanics (i.e. pump-action), non-smooth surfaces and transparent plastics. However, the technology is improving so rapidly that we expect many of these technical challenges to be partly or wholly met in the coming years.

5.4.Case study of a new to the world mascara launch

In order to better understand how the proposed solution fits in with InnerBeauty's process, it is helpful to follow an actual case study of the pseudonym-named EyeDust mascara at InnerBeauty

The company provided us with data on new product launches that required sales samples for retail customers by March of Year 3, for retail availability by January of Year 4. Table 6 below describes the quantity requirements of sales samples for each type of product and each type of customer. The term stock keeping unit (SKU) may identify a unique color shade, decoration or enhancement within the same product line. The number of sets indicates how many assortments of SKU's will be provided for each segment of customer. The number of sets times the number of SKU's calculates the total unit quantity requirement. Full sets are provided only to large key customers such as Wal-Mart, Target, CVS, etc. and are typically presented in sales meetings to the buyers of each retailer. Field sets are a smaller selection of SKU's, typically shipped to small and medium sized customers. The miscellaneous units are used for marketing materials such as photo shoots and advertisements.

Table 6: New Products Introduction for Spring of Year 4

		Complete sets		Field (partial) sets		Miscellaneous		
Category	**Product ID**	**# of SKU's**	**# of Sets**	**# of SKU's**	**# of Sets**	**# of SKUs**	**# of Sets**	**Total Quantity**
Face	1	12	45	2	555	3 2	21 41	1795
	2	9	63	1	555	4	21	1206
	3	7	25	1	110	0	0	285
Eye	4	4	73	1	555	1 1	21 41	909
	5	4	53	1	565	2 1	21 41	860
	6	6	53	1 6	445 160	4	21	1807
	7	2	53	2	110	2	21	368
Lips	8	36	53	4	555	5	21	4233
	9	9	53	9 1	110 445	5	21	2017
	10	13	53	1	110	0	0	799
	11	3	40	3	75	0	0	345
Nails	12	9	53	9	110	5	21	1572

In a typical season, 25% of new products will be new to the world, that is, they will have completely new packing and/or formula. The remaining 75% will be modifications to existing pack or formula. The EyeDust mascara case study provides the most practical understanding of our proposed solution as it is a new to the world product. The start date for this project is omitted for confidentiality purposes and the baseline will be taken as February of Year 1.

5.4.1. Planned project timeline for EyeDust mascara

Initial design began in February of Year 1 when the project establishment phase kicked off. After four months of market research and design, three different design iterations were created over the following six months. These designs were created via 2D concept drawings and 3D SLA prototype models and then presented to consumer feedback panels. After10 months of design and consumer feedback, executives felt confident enough to freeze the design and approve the business plan, achieving the project confirmation milestone in February of Year 2. In so doing, they approved a budget including $100,000 for the unit tooling and $200,000 for manufacturing line modification. The sales samples target ship date was set to September of Year 2, setting up full retail launch for November of the same year, allowing them eight months to bring the product to life and into the hands of retail customers' buyers. In this time, eight total mold tools would have to be developed for bottles, cap, wiper and brushes. Two additional tools are needed for waterproof versions of the bottle and brush, as the resin of a waterproof pack cures differently. The bottles are blow molded while the other parts are injection molded.

5.4.2. Actual project timeline

Over the course of the project, numerous unforeseen issues arose causing untimely delays. For example, the tank that made the formula experienced a startup failure. Additionally, the changes on the production lines had to be modified more than expected, exceeding the $200,000 budget by two and a half times, to $500,000. Eventually the sales samples were delayed by eight months and were completed on April of Year 3 with full retail launch set for January of Year 4 as shown in figure 12 below.

This case is not exceptional but rather a typical example of the challenges faced by InnerBeauty. In an industry where product innovation is the key driver of revenue and margin, it takes InnerBeauty two years and 11 months to bring a product from concept to shelf. This amount of time is entirely too long when compared with the ever-changing cosmetic fashion trends themselves.

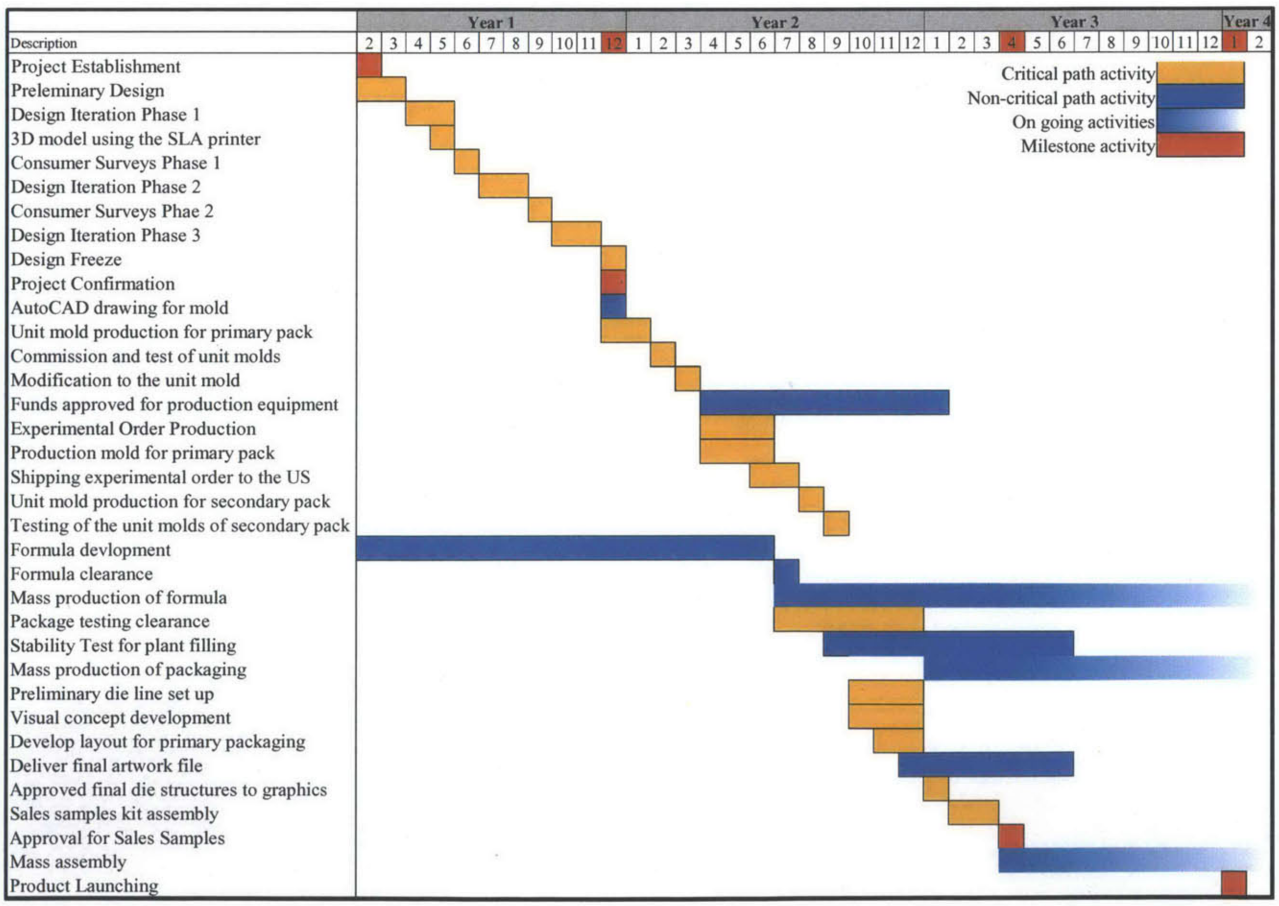

Figure 12: Actual project schedule of EyeDust mascara

5.4.3. Benefits of using a pre-unit tool mold

By implementing the pre-unit tooling process into the EyeDust product development process, a 35-month "new to the world" process can be reduced by anywhere from five to nine months, or a 14%-26% reduction as shown in figure 13 below. Each time savings is detailed as follows:

- Three to six months by eliminating the number of design iterations: Every design iteration takes around four to six weeks followed by a four week consumer input session. The pre-unit tooling may reduce the number of design iterations since a semi-final product will be provided to the consumers that give valuable feedback.
- One to two months by eliminating the possibility of unit tool redesign: In some cases, InnerBeauty has to redesign the unit tool after a test failure.
- One month by shifting the manufacturing test earlier in the process, rearranging previously sequential steps to in-parallel. The pre-unit tooling will provide enough units to allow manufacturing engineers to identify changes needed to the production line such as re-balancing, new machinery parts, and updated quality controls.

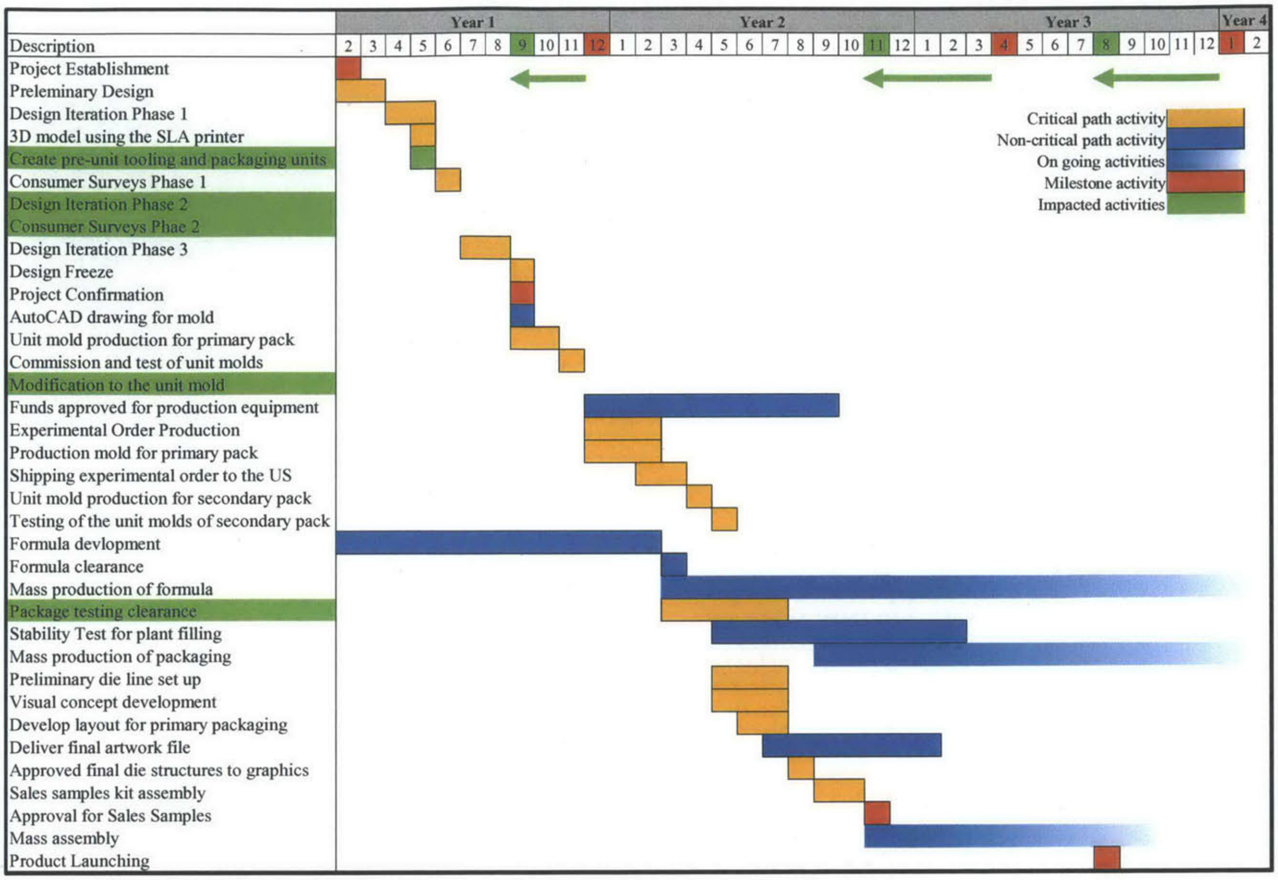

Figure 13: Project schedule reduction after integrating the pre-unit tool solution

We suspect that such long development times are common in many large CPG firms. Implementing this pre-unit tool framework into product development trims out some of the longest lead times in the critical path and thus reduces the overall time to launch a new product.

This case study exemplifies how unforeseen issues arise during the process that may extend planned schedules. The pre-unit tool enables more flexibility by allowing InnerBeauty to discover and re-engineer design issues earlier in the process. Though the reduction in timelines is incremental, the five to nine months allows a CPG firm to launch a new to the world product a full sales season earlier than planned.

6. CONCLUSION AND RECOMMENDATIONS

Over the course of ongoing discussions with InnerBeauty and an analysis on the state of additive manufacturing, our proposed solution had evolved. What began as an open ended approach exclusively focused on 3D printing sales samples, gradually pivoted toward the design phase of the product development process, with consideration for the critical path. We were also able to provide realistic assessments of additive manufacturing technology's capabilities. Thus the "pre-unit tooling" solution was born: a technology-driven process step integrated between preliminary product design and unit tool development. Using the pre-unit tooling would allow for some of the testing to be done in parallel or earlier in the process, shaving approximately 20% from the product's development timeline. More importantly, putting a shelf-ready finished product into the hands of consumers for testing would improve the feedback's credibility, providing more confidence to the executives who approve its launch. Furthermore, having the capability to provide the design team with a shelf-quality product within two weeks of concept inception would give them ample freedom to experiment with more innovative concepts. In the words of a project manager at InnerBeauty, "if the designers were in the room right now they'd be applauding."

The steel cast unit tooling is an expensive investment and senior executives have been traditionally hesitant about freezing the design and approving the budget. Additionally, the large size of the organization combined with the vast diversity of stakeholders creates communication gaps and conflicting incentives that curbs the firm's ability to quickly bring new innovations to market. Developing new to the world primary packs may take 35 months and comprises around

25% of each season's product release, so there is a significant opportunity for InnerBeauty, as well as any other CPG firm to implement these recommendations.

The sophistication of 3D printing technology is quickly advancing. Limitations in its capability today may not exist in the future, opening the door to new opportunities. For example, instead of only being able to shoot in limited quantities, 3D printed molds of the future may be able to shoot in the quantities of thousands. To implement our proposed solution, we recommend that InnerBeauty run a pilot on a non-strategic product to ensure integration with existing people and processes while testing the capabilities of rapid tooling.

From the standpoint of product innovation, companies that seek innovation faster may locate some suppliers in close proximity to their R&D innovation centers. InnerBeauty's adoption of mass-production procedures for the purpose of creating sales samples illustrates the pitfalls of a typical CPG firm using an efficient supply chain rather than an appropriately responsive one. Though we did not explore on-shoring their supply base, developing an adaptive supply chain via dual sourcing is an area for InnerBeauty to explore going forward. Additionally, as their sales samples' supply chain is so intertwined with that of its mass production, InnerBeauty can look to dual sourcing as an appropriate intermediate step.

There are also others initiatives InnerBeauty can consider to improve their time to market. The current organizational structure of sales samples lacks a single point of contact that can be solved by appointing a project manager. Furthermore, the large size of InnerBeauty and the various functions involved inhibits effective communications. A systematic way to track the status of sales samples would provide all stockholders transparency to be readily informed of the latest status and risks.

The pressure on CPG companies to launch innovative products faster will only continue to intensify. Firms such as InnerBeauty will have no choice but to streamline their product development value chain by implementing process and technology innovations. Leveraging cutting edge additive manufacturing technology into critical path activities will reduce InnerBeauty's overall time to market, ensuring their competitive advantage.

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