Evaluating the Triple Bottom Line for Smart Packaging

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Abstract

The purpose of this thesis is to evaluate the benefits and challenges of smart packaging in three key areas: the people (consumers and brands), profits, and the planet. This thesis makes reference to the triple bottom line, which is used as a method of evaluating smart packaging. Results of the research and surveys conducted in this thesis conclude that smart packaging does not yet meet the triple bottom line, but it is well on its way to getting there. This is concluded based on the fact that only half of the consumers surveyed are willing to purchase smart packaging and see the benefits to paying more money for the technology. Others state that it is not worth the extra money. Smart packaging has the ability to provide brands with many benefits such as net revenue, brand loyalty, and brand awareness. However, the triple bottom line is not being met yet because there are challenges to implementing smart packaging such as high costs, and the fact that consumers must be willing to purchase smart packaging in order for brands to profit from it. Finally, smart packaging poses some challenges to the end-of-life phase such as the issue of recyclability. Smart packaging is a complex type of package, that results in higher recycling costs. If researched in-depth and appropriate materials are used, then smart packaging will pose less of an impact on recycling and sustainability.

1. Introduction

Purpose

In the retail landscape, brands are consistently trying to find new innovative ways for their products to stand out on shelves. This is where smart packaging comes into play. Smart packaging is an innovative way for brands to get their target market's attention. Brands use smart packaging as a way to stand out on the shelves, provide consumers with a more interactive and engaging experience, as well as adding

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value to their products. Brands are realizing that there are a lot of factors that must be discussed when creating a smart package. Brands need to think about whether their consumers are interested in purchasing smart packaging, how much it would cost them, and how to still produce sustainable packaging. Consumers need more than just a flashy gimmick. Smart packaging needs to do something useful for them. Consumers are also becoming increasingly aware of the environmental issues in the world today and are more focused on sustainable products and brands that help the planet.

The purpose of this thesis is to evaluate the effects smart packaging has on people, profits, and the planet. Some questions this thesis aims to answer are: Are consumers really interested in smart packaging? What do consumers seek in smart packaging and how much are they willing to pay for it? How much does it cost to implement smart packaging? Is smart packaging a sustainable type of packaging for brands to implement for a prolonged period of time? How does complex smart packaging affect the end of life phases? Lastly, how can smart packaging be disposed of or recycled in an environmentally friendly manner? By answering these questions, this thesis will be able to provide an answer to how effective smart packaging will be if it meets the triple bottom line.

What is Smart Packaging?

Definitions
Smart packaging provides an enhanced functionality. There are many other terms that can be used to refer to smart packaging: active packaging, intelligent packaging, and interactive packaging. Active and intelligent are two types of smart packaging.

Smart Packaging Applications
Smart packaging has a variety of uses that benefit brands, retailers, and consumers. Figure 1 from Capturing value from the smart packaging revolution provides an excellent summary of the various purposes of smart packaging.

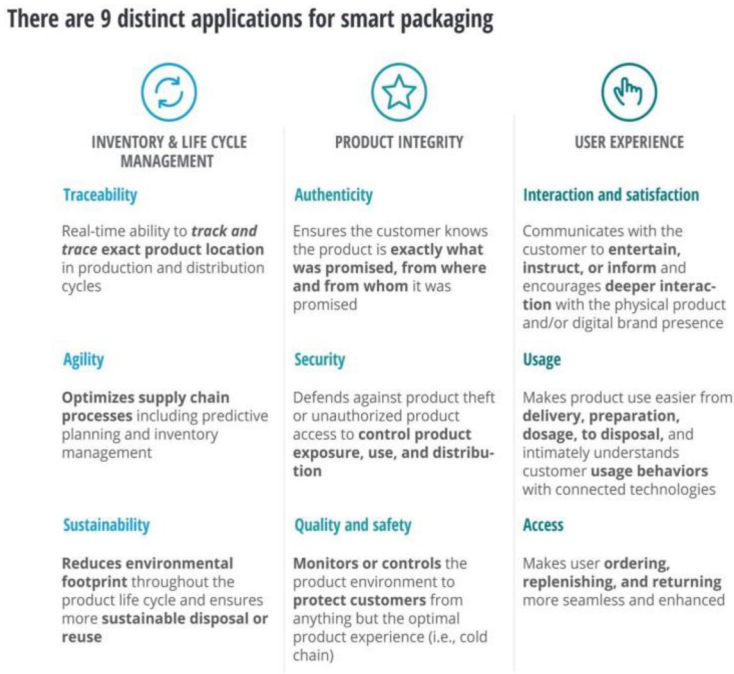

Figure 1: *Smart Packaging Applications*
Source: (Armstrong, Fazio, Herrmann, & Duckworth, 2018)

Types of Smart Packaging: Active

Active packaging is based on the idea that certain components are added to the packaging itself that release or absorb substances from the packed food or the environment to extend shelf life and maintain quality. To become familiar with active packaging concepts, this section of the thesis will introduce some common active packaging technologies.

One of the most common types of active packaging is moisture absorbers. Moisture absorbers are an efficient way to control excess water accumulation in a package (Realini & Marcos, 2014). One method of implementing moisture absorbers in packaging is by using a super absorbent polymer in between two layers of microporous or non-woven polymer (Realini & Marcos, 2014). Another method of using moisture absorbers, specifically in meat products, is building a dual-compartment system into the packaging where the second compartment has porous seam in which moisture and drip loss from the meat is diverted (Realini & Marcos, 2014). This ensures an attractive presentation as well as hygienic storage. Lastly, a common type of moisture absorber, often found in products that need climate or humidity control, are little silica sachets placed in products. These sachets have often been found in purses, pharmaceutical bottles, dried food packages and ground coffee jars (Gaikwad & Ajji, 2018). Silica sachets are also commercially available via companies such as Sorb-It, Ageless, MiniPax, and FreshPax (Gaikwad & Ajji, 2018).

Antimicrobial packaging is a type of active packaging which controls the growth of microorganisms. This technology aims to extend the "lag" phase and reduce the "growth phase" of microorganisms, which helps to extend shelf life, maintain quality and keep food safe (Realini & Marcos, 2014). For microorganisms that are non-volatile or can possibly migrate into the food, the packaging must be in direct contact with the food for maximum effectiveness (Realini & Marcos, 2014). Some examples of innovative ways to implement antimicrobial packaging are using natural extracts and essential oils from grapeseed, garlic, oregano, and thyme. These essential oils have components that delay the growth of microorganisms in meat products (Realini & Marcos, 2014). Other forms of antimicrobials include salts, oxides, and colloids.

An important type of active packaging technology is carbon dioxide emitters/ generators. The purpose of carbon dioxide emitters is to increase the CO2 levels in the package (Realini & Marcos, 2014). The increase in CO2 helps reduce the surface growth of microbes as well. Carbon dioxide emitters are commonly used and associated with modified atmosphere systems (MAP) (Realini & Marcos, 2014). Oxygen scavenging is a similar technology in active packaging which has an inverse function. Scavengers are used to remove oxygen from the packaging once it is sealed as oxygen is often responsible for the oxidation of food, resulting in a growth of bacteria, reducing the quality and shelf life of food. Oxygen scavengers are also used in combination with MAP systems and vacuum packaging to ensure almost all of the oxygen has been removed from the package. These scavengers come in the form of iron powder oxidation, ascorbic acid oxidation, photosensitive dye oxidation, enzymatic oxidation, unsaturated fatty acids, or immobilized yeast (Realini & Marcos, 2014).

The last major type of active packaging this thesis will be discussing is antioxidant packaging. Antioxidant packaging is an alternative to oxygen scavenging when preventing food oxidation (Realini & Marcos, 2014). Antioxidants can be included into the packaging material itself such as polymers. Other ways to implement antioxidants is via sachets, labels, coatings on packaging surfaces, and multilayer films (Realini & Marcos, 2014).

Types of Smart Packaging: Intelligent

The main purpose of intelligent packaging is to monitor the condition of packed food and its surrounding environment. Its primary task is to communicate information about the product such as its status, spoilage, and traceability in order to ensure the food is safe and maintaining quality. Other reasons intelligent packaging is used is to increase brand loyalty, raise brand awareness, increase consumer engagement, and provide added value and convenience for the consumer. Some functions that fall under intelligent packaging are: detecting, sensing, recording, tracing, and communicating. Indicators provide information about a change, such as temperature, oxygen, integrity, and freshness (Realini & Marcos, 2014). Biosensors

are used to detect, record and transmit information about biological changes to the food and the package.

The first type of intelligent packaging this thesis will discuss are time temperature indicators (TTIs). The purpose of TTIs is to continuously monitor the temperature and time history of chilled and frozen products throughout the food supply chain (Realini & Marcos, 2014). These indicators work by providing a visual indicator that can inform about a cold chain break and when the food is no longer cold. TTIs on the market today are based on physical, chemical, enzymatic and biological processes (Realini & Marcos, 2014). An indicator developed by 3M, Monitor Mark®, is a fatty acid that has a selected melting point that is mixed in with a blue dye (Realini & Marcos, 2014). When that melting point has been reached, the substance melts, diffusing through the indicator and allowing the blue dye to show. Another type of TTI available is one that uses a photochemical reaction where the indicator contains a pigment that changes colour over time at temperature-dependent rates (Realini & Marcos, 2014). The indicator is activated when it is exposed to UV light, becoming dark blue and then fading over time. One of the most unique and innovative types of TTIs available is one that is a label for barcodes printed with fading inks. When the product is exposed to critical temperatures, the barcode starts to disappear, hindering consumers and cashiers from scanning that product at checkout (Realini & Marcos, 2014).

Another technology used for intelligent packaging is integrity indicators. Integrity indicators can be something as simple as a time indicator, which informs consumers how long a package has been open for (Realini & Marcos, 2014). Time indicator labels are activated when a product has been opened for consumption, the breaking of a seal acting as a trigger. Over time the indicator will start to change colour. In meat products, the most common type of integrity indicator are gas indicators, which provide information on the package throughout the supply chain (Realini & Marcos, 2014). A more specific example would be oxygen indicators, which are the most common type of gas indicators used in MAP systems.

Biosensors are used in a variety of ways. A biosensor is a “compact analytical device that detects, records, and transmits information pertaining to biochemical reactions. It consists of two primary components: a bioreceptor that recognizes a target analyte, and a transducer that converts biochemical signals into a quantifiable electrical response” (Realini & Marcos, 2014). Biosensors are usually used as freshness sensors/indicators. Freshness indicators have not yet become popular in the market because food processors are unwilling to risk their brand image by implementing a system that could show their products are not fresh.

A major technology used in intelligent packaging is radio-frequency identification tags (RFID). RFID tags “use RF electromagnetic fields to store and communicate real-time information” (Realini & Marcos, 2014). The tag is composed of an

integrated circuit that is attached to an antenna transmitting information stored on the chip to a reader (Realini & Marcos, 2014). A key advantage of RFID tags is that they can be remotely accessed and controlled, allowing multiple products to be monitored simultaneously (Realini & Marcos, 2014). Advanced RFID tags can also be used in combination with other forms of intelligent packaging such as TTIs and biosensors. The use of RFID tags allow for a more efficient supply chain, reduced waste production, and increased savings.

The Triple Bottom Line

The triple bottom line is a concept used to broaden a business's focus from only looking at profits to considering environmental and social factors as well. The three bottom lines are: people, profit, and planet. A more formal definition of the triple bottom line is it "captures the essence of sustainability by measuring the impact of an organization's activities on the world" (Slaper & Hall, n.d.). Companies use the triple bottom line as a method of running a business that generates profits, but also improves people's lives and helps the planet at the same time. Nowadays, an increasing number of consumers are willing to pay more for items produced by brands that are socially and environmentally responsible.

It should be noted that implementing a planet and people bottom line can help a company increase their profits as well (Kenton, 2019). In 2015, millennials were the largest consumer demographic, and 73% of them said that they were willing to pay more for goods that met the people and planet bottom lines, which was an increase from 43% of millennials in 2014 (Kenton, 2019). Implementing a triple bottom line can help build corporate brands and goodwill, which represents 30% of the brand's value in public companies (Kenton, 2019).

Measuring the triple bottom line can be a difficult task. How does a company measure the value of an oil spill – or the prevention of one? Since there is no standardized method of evaluating a company's triple bottom line, each company has the ability to use their own metrics that work for them (Kenton, 2019). One method to measure the triple bottom line is by monetizing the social and environmental impacts (Slaper & Hall, n.d.). An example would be calculating environmental damage by how much waste or greenhouse gas emissions are produced. However, a drawback to this method is that not all social and environmental impacts can be monetized. Another method would be to create an index (Slaper & Hall, n.d.). This eliminates the incompatible units issue as long as a universally accepted method of accounting is used (Slaper & Hall, n.d.). An issue with this type of method includes determining how each bottom line should be weighted. A third method of measuring the triple bottom line would be to simply measure each factor/category on a standalone basis, removing the need for common units (Slaper & Hall, n.d.).

Applying the Triple Bottom Line to Smart Packaging

Based on the definition of "Triple Bottom Line" provided, the triple bottom line will be applied to smart packaging in a similar fashion. Since smart packaging is not a brand or corporation in itself, certain variables of the triple bottom line may not directly apply. Therefore, the triple bottom line will be applied to smart packaging as an evaluation of its functions and ability to benefit consumers and brands while maintaining a sustainable packaging life cycle.

For the social aspect, this thesis will focus on how useful and beneficial smart packaging is to end users (consumers) and brands (business-to-business consumers) that wish to use smart packaging for their product. This thesis will determine the end users' willingness to purchase smart packaging, how much more they are willing to pay for it, and what their overall level of interest in this technology is. This information will then be used as part of discussing what the benefits and challenges of implementing smart packaging are for brands.

The profits pillar will be evaluated based on how profitable and beneficial smart packaging can be to the brand. This will include monetary profits, increases in brand loyalty, and increases in brand awareness. First, the costs of implementing smart packaging will be looked at, focusing on the prices of various technologies itself. Next, the benefits that smart packaging provides brands with will be discussed. Finally, both of these costs and benefits will be compared against the results of the people bottom line to see if investing in this technology is worthwhile for brands.

When discussing the planet bottom line there will be a key focus on the recyclability of intelligent packaging because electronic components can complicate the recycling process. One main hardware this thesis will look at are RFID tags and the impact it has on end-of-life phases. It is also suggested that RFID tags can be used to solve other sustainability issues such as food waste and increasing efficiency.

2. Methodology

Since smart packaging is a new and emerging technology, not many consumers are aware of what smart packaging is. In order to introduce the concept of smart packaging to readers, the primary method of research for this section was reviewing and researching the functions of smart packaging as well as technologies used in it.

When evaluating the triple bottom line, multiple case studies are used as further evidence of the facts and conclusions made. The goal of conducting case studies is to provide readers with real life examples of brands that are creative with how they use smart packaging technology. In most instances, the case studies allow for a thorough analysis of all three bottom lines including consumer interest, cost of the technology used, and sustainability goals for the packaging.

For the people bottom line, a survey was conducted to receive consumer feedback about smart packaging. The survey was used to determine how willing consumers are to purchase smart packaging, how much more they would pay for it as well as how smart packaging would affect their perception and opinion of a brand, including brand loyalty.

Some limitations imposed on this thesis are time and level of difficulty in determining costs of smart packaging. Due to a time constraint, a longer and more thorough survey with a larger group of respondents was not possible. Within a short period of time, only a handful of consumers were surveyed, acting more as a focus group. Due to the smaller number of consumers surveyed, the numbers cannot be deemed as accurate as those collected from a much larger demographic. The limitations on obtaining accurate costs for smart packaging technologies is that cost is usually determined by the type of product being packaged. Costs are provided in the form of quotes where type of product, volume, size, and type of materials are first taken into consideration. As a student conducting research for the sole purpose of knowledge and information, quotes were difficult to obtain. Therefore, costs listed in this thesis are based on smart packaging technologies that are commercially available. For the purpose of this thesis all costs must be considered as approximations.

3. Results and Discussion

Triple Bottom Line: People

A smart package needs to be useful and entice a consumer. Consumers need to be willing and interested in purchasing products with smart packaging in order for the technology to truly take off and be successful. They must accept smart packaging and in order to do that, they need to see the benefits of it. To gain insight into how consumers feel about smart packaging, a small survey was conducted. Due to the limitations discussed earlier, this survey is not based on a large group of people, but a rather small group. A total of 25 people were surveyed with the majority of respondents being in the 18-25 (56%) or 26-45 (36%) age range. In terms of gender, the respondents were almost evenly represented.

A general question that respondents were first asked was how often they go grocery shopping, to which the results stated that 68% shopped once a week, 20% shopped less than once a week, and 12% shopped 2-3 times a week. Another question they were asked was if they shopped for groceries online. 24 out of 25 respondents said no they do not while 1 person said that they do buy groceries online. The purpose of these questions was to find patterns on their grocery shopping habits. This information can lead to the creation of smart packaging that targets user experience applications such as access and usage by providing convenience to the consumer. It can also create new purposes and uses for smart packaging.

For brand loyalty, consumers were asked a variety of questions to see what factors and uses of smart packaging would entice them to increase their brand loyalty and purchase a specific brand over others. Based on the results of the survey, respondents would be more loyal to brands that allowed consumers to obtain information such as where their product is coming from, how it was made, and overall transparency and traceability of the product.

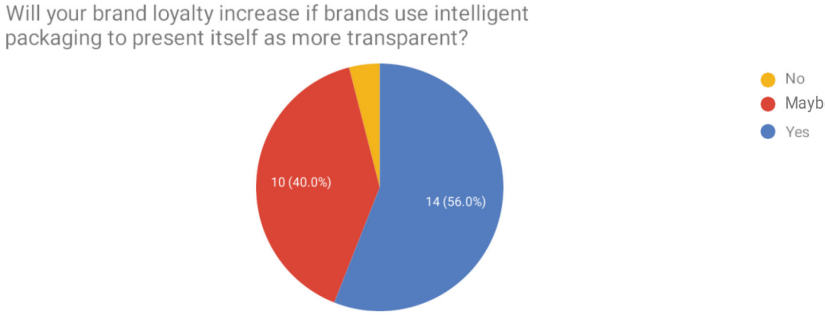

Figure 2: *Brand Loyalty*

Consumers were then asked how much they were willing to pay for these benefits. Willingness to pay was broken down into three sections: added safety, added convenience, and uniqueness and consumer engagement. Figures 3 to 5 show the results.

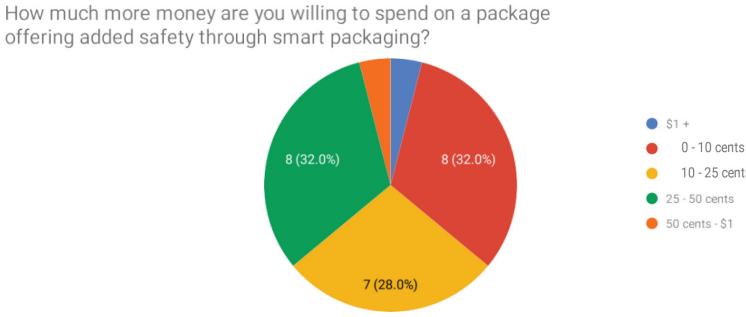

Figure 3: *Added Safety*

Figure 4: *Added Convenience*

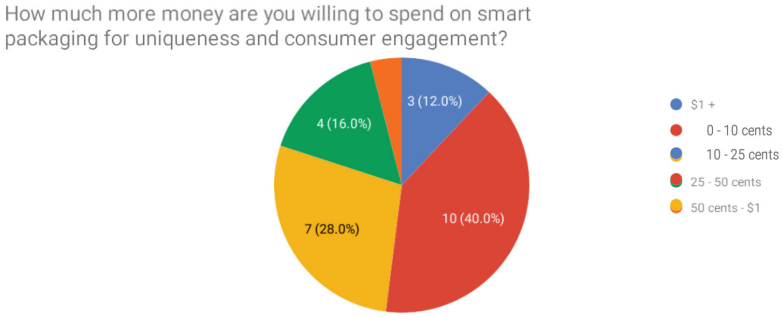

Figure 5: *Uniqueness & Consumer Engagement*

Comparing Figures 3, 4 and 5, one key section that stands out is the varying percentage of how many respondents are willing to pay over $1.00 for smart packaging for the different purposes. In Figure 3, only 4% are willing to pay over $1.00 on smart packaging for safety purposes, while in Figure 4, 16% are willing to pay $1.00 for convenience, and 12% are willing to pay $1.00 or more for the uniqueness and engagement smart packaging provides in Figure 5. This might show that consumers may already think that products are safe enough, and they trust the brands that produce the products they buy. Consumers would rather pay more for smart packaging that provides them with more convenience or engages with them in some way. For safety and consumer convenience, the more expensive sections of the pie graphs have higher percentages of people willing to pay for that feature.

Another factor that respondents were asked about was the sustainability of smart packaging and how that would impact their decision. First, respondents were asked how much they pay attention to sustainable packaging while grocery shopping in general. The responses were that 4% always buy products that have sustainable packaging, 56% try to buy products with sustainable packaging, while 40% have never thought about sustainable packaging while grocery shopping before. Respondents were then asked if they would purchase smart packaging regardless or whether or not it was sustainable and the results were 8% for yes, 68% for maybe, and 24% for no they would not buy unsustainable smart packaging.

Case Study: Fresh-Check Indicator

TimeTemp Corporation is a leading international manufacturer of time-temperature indicators for food products (Fortin & Goodwin, n.d.). Fresh-Check is one of their products which is a TTI the size of a postage stamp that can be applied to the outside of a package (Fortin & Goodwin, n.d.). In a previous study discussed in this article, consumers in Finland were surveyed about whether or not they were willing to pay more for packaging that included TTIs. 59% said that they were willing to while 41% said no because they believed the food was already safe enough, labels guaranteed food safety and quality, and they could not afford higher prices (Fortin & Goodwin, n.d.). In another study in the Belgian food system, findings revealed that consumers care most about the expiration date, meat type, weight and price on

a label and only 10% of the people surveyed were willing to pay more for a label that had more information on it (Fortin & Goodwin, n.d.). However, the labelling with the most traceability and origin information was most preferred (Fortin & Goodwin, n.d.).

In interviews with grocery store managers and food technologists talking about Fresh- Check, some issues that were discovered were that people did not have much knowledge or awareness about these indicators and had a general distrust towards them (Fortin & Goodwin, n.d.). Some retailers also wondered if these indicators would force them to throw out produce that is still sale-able. Retailers questioned about consumer abuse and mishandling after purchase as well.

	Yes	No	Maybe
Brand Recognition for Fresh Meat Products	37%	63%	
Been or Known Someone who has gotten sick from Fresh Meat Products	26.3%	73.2%	
See a Benefit for Fresh-Check® Indicators	74.4%	4.4%	21.2%
More Likely to Buy Product with Fresh Check® Indicator	58.0%	16.8%	25.2%
See Fresh Check® Indicator as Significant Food Safety Advantage	71.7%	7.6%	20.5%
Preference for Buying Product with Fresh Check® Indicator	57.3%	8.5%	34.3%
Prefer Shopping at Stores that offer Fresh Check® Indicators	34.5%	24.1%	41.4%

Table 1: *Fresh-Check® Survey*
Source: (Fortin & Goodwin, n.d.)

	0 Cents	10 Cents	20 Cents	30 Cents	40 Cents	50 Cents	> 50 Cents
Willingness to Pay	16	104	35	34	11	35	7

Table 2: *Fresh-Check® Survey*
Source: (Fortin & Goodwin, n.d.)

Peter Ragaert, a technological advisor for Pack4Food at the University of Ghent in Belgium also mentioned that time-temperature indicators may not be 100% accurate (Fortin & Goodwin, n.d.). Modified atmosphere packaging for example, creates a different environment inside the package than the outside, so a time-temperature indicator on the outside of the package may not accurately predict the actual state of the product (Fortin & Goodwin, n.d.).

For the Fresh-Check product, a survey outside seven major grocery stores was conducted that included about 250 people surveyed (Fortin & Goodwin, n.d.). In this survey, almost 75% saw a benefit to using Fresh-Check as a food safety advantage, while 21% said maybe to seeing a benefit to using Fresh-Check (Fortin & Goodwin, n.d.). 57% said they would rather buy a product with a Fresh-Check indicator on it and the people that said yes to purchasing a package with a Fresh-Check indicator said that the main reason was for safety and health (Fortin & Goodwin, n.d.).

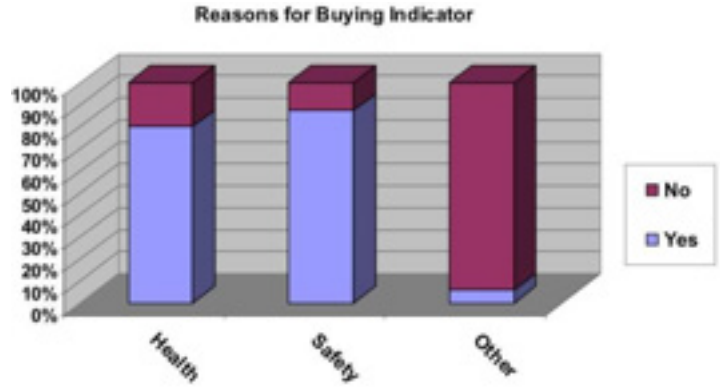

Figure 6: *Fresh-Check® Survey*
Source: (Fortin & Goodwin, n.d.)

Conclusion

Based on the survey data and Fresh-Check case study, there is a real market and opportunity for growth for the smart packaging industry. The applications that consumers would find most beneficial are product integrity (authenticity, traceability, safety) and user experience (convenience and information). Consumers are willing to pay anywhere from 10 cents to over $1.00 depending on how useful smart packaging is for them. Further research should include a bigger survey conducted as well as educating consumers on what smart packaging can do for them. Other methods of research can include tests where consumers are given the opportunity to evaluate some smart packaging examples themselves, try it out, and based on their experience decide how valuable smart packaging can be in their daily lives. As far as sustainability goes, consumers are becoming more aware of the environmental issues prevalent in our world today. The packaging industry's goal as a whole should be to strive for sustainability and that includes smart packaging. However, that being said, there will always be consumers that will buy a smart package, sustainable or not, if it presents them with sufficient value.

Triple Bottom Line: Profits

For brands, the cost of smart packaging is one of the main barriers to adopting and implementing this new technology. Active packaging is a more developed and thoroughly researched technology, and is much older. Due to this, there are not as many high costs for active packaging. Active packaging technologies have also become commercially available such as moisture absorbent sachets. The more costly type of packaging is intelligent packaging, since it is a newer form of smart packaging and includes hardware components. The hardware itself is also a newer technology such as RFID and NFC chips. Implementing RFID and other tags have not yet become a commercial success due to the costs. To embed this technology in packaging, it also requires advanced equipment that has the manufacturing capabilities to support smart packaging.

To evaluate the profits and benefits of smart packaging for brands, the results from the people bottom line will be used to weigh the benefits against the costs for brands interested in implementing smart packaging. Profit may not always be in terms of net revenue. Brands can benefit from smart packaging in other ways such as increased brand awareness and brand loyalty.

Active Packaging Costs

Moisture Absorbers are a common type of active packaging that have become commercially available. For food applications, the most common forms of moisture absorbers are sachets, pads, humidity regulating trays, and polymeric films. Generally, the commercially available moisture absorbers are little

sachets and moisture absorbent pads. These can be bought by consumers for a variety of purposes. The humidity regulating trays and polymeric films are harder to find for consumers since they are used for food and need to be implemented during manufacturing. Listed in Table 3 are the costs of some commercially available moisture absorbing technologies. It is evident that the cost of moisture absorbers can vary greatly. Generally speaking, the smaller the size of the moisture absorber sachet, the cheaper it is.

Source	Product	Product Size	# of units/ bundle	Bundle Price	Price/unit
Amazon.ca	Sorb-It Silica Packets	0.625" x 0.281"	Pack of 6,000	$695.99	$0.12
Amazon.ca	Sorb-It Silica Packets	0.875" x 1.5"	Pack of 5,000	$1,236.06	$0.25
Amazon.ca	Sorb-It Silica Packets	0.875" x 2.125"	Pack of 3,000	$567.99	$0.19
Amazon.ca	Sorb-It Silica Packets	1.5" x 3.25"	Pack of 600	$784.99	$1.30
Amazon.ca	Dri-Lock SafePro Moisture Absorbent Pads	4" x 7"	Pack of 500	$75.17	$0.15
Amazon.ca	Dri-Lock Saveazon Moisture Absorbent pads	4" x 7"	Pack of 2,000	$264.22	$0.13

Table 3: *Cost of Moisture Absorbers*

This table takes a look at some commercially available moisture absorbers. Source: (Amazon.ca, n.d.a)

Source	Product Strength (in cubic centimetre)	# of units/ bundle	Bundle Price	Price/packet
ULINE Canada	30	Pack fo 6,000	$244.00	$0.04
Amazon.ca	50	Pack of 100	$33.40	$0.33
ULINE Canada	50	Pack of 5,000	$239.00	$0.05
Amazon.ca	100	Pack of 100	$15.74	$0.16
ULINE Canada	100	Pack of 2,500	$166.00	$0.07
Walmart	300	Pack of 100	$29.98	$0.30
Amazon.ca	500	Pack of 100	$34.47	$0.34

Table 4: *Cost of Oxygen Absorbers*
This table takes a look at some commercially available oxygen absorbers.

Oxygen scavengers or absorbers are commercially available in the form of sachets, similar to the moisture absorbers. Table 4 provides a list of various oxygen absorbers that are available to consumers today. The cost of oxygen absorbers depends on the strength of the absorber. The strength of these absorbers are measured in cubic centimetre, which indicates how much oxygen it can absorb. A weak oxygen absorber can have a 30cc strength versus a stronger absorber with a 100cc strength.

Intelligent Packaging Costs

As noted before, intelligent packaging is more costly than active because this type of packaging requires a hardware component or a device to act as a reader. The main types of hardware used in intelligent packaging are RFID tags, NFC chips, and TTIs.

RFID tags can cost as little as 10 cents or up to $50 depending on the type of tag used, type of application, and volume of the order (RFID FAQs, n.d.). For smart labels that are applied to pallets and cases, RFID tags usually cost around 15 cents or more (RFID FAQs, n.d.). RFID tags are considered “active” when there is a battery included in the tag. These active tags are the most expensive type of RFID tags because they are completely automated and require no human intervention (Advanced Mobile Group, 2016). On their own, active tags can cost $15 - $20, but when combined with a sensor, the costs can increase to $50 per tag (Advanced Mobile Group, 2016; RFID FAQs, n.d.). Although active tags are battery powered, readers are available for these tags and are the least expensive, costing $1,250 to 1,500 each (Advanced Mobile Group, 2016).

Less expensive RFID tags are ones that are smaller and do not include a battery. These are called “passive” tags. Passive tags require a reader to provide it with the power necessary to respond and transmit data (RFID FAQs, n.d.). Basic passive

tags used for paper, non-metal, and liquid materials cost about 10 cents each (Advanced Mobile Group, 2016). Metal passive tags are larger and can be used on metal materials which are a little more expensive at US$1.00 per tag (Advanced Mobile Group, 2016). Readers for passive tags are the most expensive, ranging in price from $3,000 to $20,000 a piece (Advanced Mobile Group, 2016).

Source	Product	Product Size	Min. Order Quantity	Price/tag
Alibaba.com	UHF RFID Inlay	Customizable	1	$0.05 - $0.06
Alibaba.com	RFID Anti-theft Passive Tag	Customizable	1,000	$0.10 - $0.30
Alibaba.com	Plastic Anti-Metal RFID Tag	Customizable	1,000	$0.15 - $0.25
OnlineLabels.com	High Performance Thermal RFID Labels	4" x 1"	2,500	$0.14
OnlineLabels.com	General Purpose RFID Inlay Thermal Labels	4" x 2"	2,500	$0.14

Table 5: *Cost of RFID Tags*
This table takes a look at some commercially available RFID tags.

Source	Product	Product Size	# of stickers/roll	Price of Roll	Price/Sticker
Amazon.ca	NFC Stickers	1"	20	$47.75	$2.39
Amazon.ca	NFC Inlay White, Wet	22mm	1,000	$325.22	$0.33
Go to Tags Store	NFC Stickers	38mm	1,000	$384.70	$0.38
Amazon.ca	NFC Inlays Clear, Wet	38mm	1,000	$482.77	$0.48
Go to Tags Store	NFC Stickers	25mm x 25mm	3,000	$929.23	$0.30
Alibaba.com	Paper NFC Inlay Clear, Wet	50mm	500 min./order	N/A	$0.10 - $0.45
Alibaba.com	Contactless NFC Stickers	custom	10000 min./order	N/A	$0.12 - $0.15

Table 6: *Cost of NFC Chips*
This table takes a look at some commercially available NFC chips.

A newer form of RFID tags are near field communication (NFC) chips, which are a short range version of RFID tags (RFID FAQs, n.d.). NFC chips also use a reader device such as a smartphone to read data from the chip. The benefit of NFC chips is that they can be formatted to fit and reflect the use case. Tables 5 and 6 depict a list of various types of RFID and NFC tags and their associated costs. Based on the tables, some NFC chips seem to be more expensive than passive RFID tags as well. When comparing the cost of these tags to active packaging technologies from Table 3 and 4, the cost per unit is in the same range.

It should be noted that since intelligent packaging using RFID tags and other electronics is a newer industry, these technologies have not taken off yet. Because smart packaging is in its early stages of the product life cycle, start up costs are still high with early adopters (retailers and brands) trying to pioneer the use of intelligent packaging. However, it is predicted that once intelligent packaging takes off and becomes a mainstream technology, the costs of sensors, RFID tags and NFC chips will decrease. Figure 7, from *Capturing value from the smart packaging revolution*, predicts the falling costs of sensors for intelligent packaging.

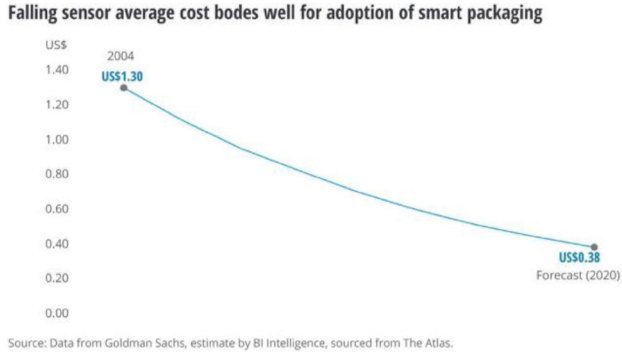

Figure 7: *Prediction of Falling Sensor Costs*
Source: (Armstrong et al, 2018)

Another form of intelligent packaging with higher costs are time-temperature indicators (TTIs). Table 7 lists the costs of various TTIs and based on the results TTIs are much more expensive when bought in smaller quantities. In general TTIs are more expensive because they are made of complex technology – TTIs must be able to sense the temperature changes and indicate that to retailers and consumers.

Product	Product Description	Minimum Order Quantity	Per unit cost @ min. quantity	Higher volume per unit price
Cold Chain TTI Labels	Non-reversible Temp. Indicators	20	$6.32	$5.06 @ 1,000+
Cold Chain TTI Labels	Falling & Rising Indicators	25	$3.95	$3.16 @ 10,000 +
Cold Chain TTI Labels	Trigger Temp. 5˚, 48 hour run out	100	$3.99	$2.95 @ 5,000 +
Cold Chain TTI Labels	Falling & Rising Indicators	100	$9.00	N/A
Cold Chain TTI Labels	Rising Temp. Monitor, permanent	100	$1.45	$0.93 @ 10,000 +

Table 7: *Cost of Time-Temperature Indicators*
This table takes a look at some commercially available TTIs.

Benefits of Smart Packaging for Brands

Smart packaging, especially intelligent packaging, can provide a lot of benefits to brands and retailers. RFID tags, for example are a great tool to use throughout the supply chain because it allows for better supply chain management (Pierce, 2014). The supply chain can be made more efficient when the data RFID tags collect is analyzed and weaker points or problem spots in the supply chain can be identified and fixed. In addition, intelligent packaging can enable better stock and inventory management as well. If all products or pallets are equipped with RFID tags or NFC chips, inventory can be accurately calculated through those tags, rather than manually calculating inventory levels.

Smart packaging also provides security of the product and condition monitoring (Pierce, 2014). This would include factors such as any spoilage and shrinkage of product that may occur throughout the supply chain and distribution. It would reduce shrinkage because a brand's products would be connected to a surveillance system via the packaging (Pierce, 2014). This way products can be tracked every step of the way and always be accounted for. Another benefit similar to condition monitoring is extending shelf life. Extending the shelf life of products can provide huge savings to brands if products do not spoil very fast and consumers are still able to consume it. Extending the shelf life would also prevent food from going to waste. Food retailers estimate that about 31% of all food products are discarded due to spoilage, resulting in a loss of US$146 billion (Armstrong, Fazio, Herrmann, & Duckworth, 2018).

A global packaging survey conducted in 2012 on new consumer technology solutions states that some of the key drivers behind the increase in demand for smart packaging are consumer convenience, lower costs, safety, and traceability ("Global Packaging Survey", 2012). Safety is an important benefit in the food and pharmaceutical industries because it pertains to both consumers and the brand (LaManna, n.d.). This means ensuring that consumers are not prone to any hazards from food or drugs because incidents like that are dangerous, expensive, and can "kill" a brand (LaManna, n.d.). The food and pharmaceutical industries are also becoming tighter on regulations or introducing new ones, requiring brands to find new and innovative ways to ensure their products stay in compliance (LaManna, n.d.).

A key reason smart packaging is beneficial is access to information. Using smart packaging can help brands learn more about their consumers and target them in a more specific way using loyalty offers or special promotions (Pierce, 2014). As mentioned earlier, data collected on consumer behaviour can allow the brand to identify niche markets that they may not have known about or could not target before. With this additional information brands can target niche markets based on how their product is used and consumed.

Along with collecting information, intelligent packaging is used to reach shoppers at the point of sale (Wood, 2016). At the point of sale, intelligent packaging can assist with creating enhanced in-store visibility (Wood, 2016). Specifically, technologies such as printed electronics can be applied to create OLED lighting, allowing the brand to stand out (Wood, 2016). Intelligent packaging also engages consumers while they shop. Consumers can use the smart packaging to access content via their smartphone, download apps, look at additional information, and share an experience online (Wood, 2016). By using intelligent packaging, it also allows the brand to receive feedback from the packaging, to assess and analyze how well their product is capturing consumers' attention.

Case Study: Amazon Dash Replenishment Service

A consumer convenience focused smart packaging technology is being offered by Amazon called the Dash Replenishment Service (DRS), which is beneficial to consumers, and to retailers using this service, as well as Amazon for hosting this service. This originally started out as the Dash Button, which was a piece of hardware (a button device), that allowed consumers to re-order one specific product; the button was linked to a product and consumers would use the button when they wanted a refill on that item. The purpose of the Dash Button was to make purchasing typical low-cost household items easy and convenient. This was a very successful service provided by Amazon. Along with this benefit to consumers, using the Dash Button had benefits for the brand. Dash initiated purchases had increased to 4 purchases per minute by 2017 (Pierce, 2018). Ziploc has more than 50% of their Amazon sales via the Dash Button and Cottonelle's share of the wallet in the bath tissue category doubled from 43% to 86% among Dash users in 2016 (Pierce, 2018). Since then, Amazon has decided to take this technology one step further by using DRS which allows brands to embed the technology directly into their packaging so when it senses that supplies are low, it can automatically reorder that item, even without the push of a button (Pierce, 2018). The smart packaging would include either RFID, NFC or Bluetooth Low Energy (BLE) technology.

From a cost perspective, they are focusing on embedding their service in device-plus consumables, claiming that is the most useful way of using this service right now (Pierce, 2018). In an interview with Packaging Digest, Williams and Jabil Packaging Solutions, the company that creates the technology for DRS, stated that depending on the way NFC chips are implemented in the package, it can increase the cost of the package by 15 cents. An increase of 15 cents in cost makes sense for high- end beauty products and spirits, but not for low cost consumables that are sold for $2.00 (Pierce, 2018). For those low cost consumables, the DRS technology would be applied in the form of a label using conductive inks for the sensory solution and to augment the label (Pierce, 2018). Then it would only be a matter of going from a low-end label to a high-end label with minimal to negligent costs for durables and consumables. Printed electronics are depended on to bring down the cost of connecting packaging to the DRS system (Pierce, 2018). This is

because printed electronics can be printed roll-to-roll, allowing them to print faster and cheaper than the current method of printing flexible electronics (Pierce, 2018). For this DRS service, consumers can use the Amazon app to set their own auto-replenishing level to trigger a reorder, as well as have the option of changing the order in the app if need be (Pierce, 2018). Consumers receive convenience through the smart packaging and control of it through the Amazon app. Other benefits for consumers include keeping an inventory of items in your household and freeing consumers of the mental labour it takes to determine what they need. In a business environment this service can also help ease the process of calculating inventory and increase efficiency in the supply chain (Pierce, 2018). It is also beneficial to brands that embed this technology in their packaging because it provides valuable consumer insight about how their consumers are using their product. It can provide basic yet valuable information such as the frequency of usage and how often it needs to be ordered (Pierce, 2018). This in turn will help brands market their product to specific kinds of households based on use.

Conclusion

Based on the data and analysis from the people bottom line and the costs and benefits showcased in the profits bottom line, it can be concluded that investing in smart packaging is worthwhile for brands and retailers. From the data interpreted in the people bottom line, the majority of consumers are willing to pay at least 10 cents for smart packaging. Looking at the costs of actually implementing intelligent packaging hardware the costs of items such as RFID tags and NFC chips are similar, starting at 10 cents or even less. The amount of money consumers are willing to spend will also depend on the type of smart packaging offered. Generally, smart packaging that provides a type of convenience and safety will result in consumers willing to pay more for the packaging.

From the survey conducted in the people bottom line, consumers understand that brands that go above and beyond to ensure customer satisfaction and increase safety of products, are brands that put the consumers first. When consumers see that smart packaging applications are beneficial to them, it will increase their brand loyalty. If the right application of smart packaging is identified, brands and retailers will earn their much deserved profits through revenue, brand awareness, and loyalty.

Triple Bottom Line: Planet

It should come as no surprise that consumers, brands, and companies globally are paying more attention to the ever growing environmental issues prevalent today. Consumers are demanding that retailers and brands be more aware of the impacts they have on the environment and come up with innovative solutions to battle issues like global warming. When shopping, consumers are also becoming more

conscious of the products they buy, ensuring that the brand whose products they would like to purchase, invest in sustainable practices.

Alas, a global movement is finally happening, with countries and governing bodies banning harmful materials and products such as plastic shopping bags and plastic straws. Brands are coming up with innovative solutions such as biodegradable plastics and packaging as well as implementing zero waste solutions in grocery stores. A major issue that needs tackling is the end-of-life stage in the product life cycle. End-of-life includes activities such as reuse, recycle, recovery, or landfill.

Currently 95% of plastic packaging material value is lost after a short first use cycle, roughly $80 - $120 billion (Ellen MacArthur Foundation, 2016). Plastic packaging material is mostly linear with 78 million tonnes being produced annually (Ellen MacArthur Foundation, 2016). Of the 78 million tonnes, 98% is virgin stock – pure, non-recycled material – with 14% being diverted for incineration/ energy recovery – which is the lowest form of value that should be obtained from packaging materials (Ellen MacArthur Foundation, 2016). 40% ends up in landfills, while 32% is leaked into the environment – land and ocean environments (Ellen MacArthur Foundation, 2016). 14% is collected for recycling and from that 4% becomes lost in the process due to those packages being non-recyclable. 8% of the 14% is diverted for cascading recycling and only 2% is used in closed loop recycling (Ellen MacArthur Foundation, 2016). That is a shockingly low number compared to the majority of the waste that is being leaked out into the environment or ending up in the landfill.

It is clear that smart packaging may pose a problem to the end-of-life stage. Smart packaging can become a complicated package to recycle due to the increasing number of materials used in the packaging. Additives that are used in active packaging could alter the composition of material and decrease the value of a pure material such as corrugate or plastic. Many electrical components are used in intelligent packaging such as RFID tags, NFC chips, and sensors that could contain metal components, adhesives, plastics and other tiny components. This would be considered a multi-material package, which are primarily more complex to recycle and reprocess. In this section, the recyclability of RFID tags primarily will be researched because it is an electronic component that is becoming more popular in smart packaging. Other aspects that will be looked at is how smart packaging can be used to reduce other environmental impacts.

Recycling RFID Tags

RFID tags can be tricky to recycle because it is an electronic component with many materials inside it. RFID tags when embedded into a package, causes that packaging system to be more complex to recycle. One of the main reasons that packaging is not recycled is that packages are made up of multi- materials that are difficult to separate in end-of-life stages. It is evident that the use of RFID tags or

any other electronic hardware in smart packaging will prove to be an obstacle when creating smart packaging.

RFID tags are composed of many metals and plastics that are not easy to recycle and reprocess together. The metal and semi-metal components of the RFID tag have higher carbon footprints as well as higher material value (Schindler et al., 2012). According to the book *SMART TRASH: Study on RFID tags and the recycling industry*, recovery of the metals from RFID tags is the most feasible way to reprocess the tags because of the high metal value (Schindler et al., 2012).

One method of recovering metals from RFID tags is "copper metallurgy", in which copper, gold, and silver can be recovered through copper refining. Gold and silver can also be recovered because this process has the collector capacity to capture other metals as well (Schindler et al., 2012). The downside to this process is that aluminum is lost as a secondary metal (Schindler et al., 2012). In another method of recovering metals called "aluminum metallurgy", copper, silver, and gold are lost because they dissolve in the melt and become alloying elements (Schindler et al., 2012). Recovering copper, silver, and gold then becomes a more difficult task later on in the process. To send RFID tags down the metallurgical route, the tags need to be extracted from diverse waste streams, which is not a feasible process (Schindler et al., 2012).

First, it is important to evaluate which waste streams RFID tags will end up in based on where RFID tags are used. Generally, RFID tags fall under the electronic devices category because they contain batteries or other power supplies. The impact of the RFID tag in a waste stream will depend on whether the waste stream is complex or a single material waste stream (Schindler et al., 2012). Another factor to consider would be the recycling process. For example, material recycling usually means that a high purity of the material is needed in recycled objects, but this can become a difficult process if there are too many different materials in that waste stream or the objects are composed of multi-materials (Schindler et al., 2012).

RFID tags attached to packaging that is a single material will now make that package complex to recycle, resulting in increased costs of recycling and reprocessing. RFID tags that are attached to an already complex package will have less of an impact on the recycling process because that waste stream would already be equipped for handling complex items (Schindler et al., 2012). In the reprocessing of complex objects, the first step required usually is dismantling or deconstruction of the package to separate the various materials in the package (Schindler et al., 2012). This generally goes for all multi-material packages that are recyclable and can be applied to packaging that has RFID or other electronics embedded in it as well. Another option to recycle intelligent packaging would be to remove the RFID tags manually first, to allow it to be reprocessed for metals, or let it remain attached

to a dismantled part of a package and go through subsequent recycling (Schindler et al., 2012).

RFID tags that are used in a closed loop application are reused and do not generally enter the waste stream. Closed loop applications can include RFID tags being reapplied or staying with a container that is being emptied and refilled. These types of applications would normally be seen in a supply chain or distribution systems.

Sustainability Benefits of Smart Packaging

Although smart packaging may be a complex package to dispose of or recycle in a sustainable manner, it has been argued that smart packaging technologies can actually have a positive impact on other sustainability aspects. For example, as mentioned in the "Benefits of Smart Packaging for Brands" section, about 31% of all food products are discarded due to spoilage, resulting in a loss of US$146 billion (Armstrong, Fazio, Herrmann, & Duckworth, 2018). When discussing smart packaging, it requires looking at the sustainability problem from another point of view. Minimizing packaging can result in a counter-productive solution, where too little packaging may cause the product to be damaged. In the fight against food waste, active packaging plays the role of extending shelf life, not by adding preservatives into the food, but by adding it to the packaging.

Another suggestion to using smart packaging technology is implementing RFID tags in recycling bins to allow authorities to keep tabs on bins (Murphy, 2017). Using RFID tags would also save sanitation workers from spending lots of time determining which bins should go where and what should be in each bin (Murphy, 2017). Since municipal governments earn money from recyclables, implementing RFID tracking

chips in bins could help them enforce recycling rules and save money on trash disposal (Murphy, 2017). That being said, if RFID tags were to be implemented, existing recycling bins would have to be replaced, the tags would have to be purchased, and scanning devices in garbage trucks would need to be installed (Murphy, 2017). RFID tags can also be used to determine the contents of a recycling bin to provide information such as if consumers are recycling and if the waste has been sorted appropriately (Murphy, 2017). Based on this information, necessary action can be taken against consumers who do not recycle or for community outreach purposes to educate communities to participate in recycling (Murphy, 2017).

The benefits of using RFID tags in recycling bins to improve sustainability must be weighed against the possible drawbacks. Some drawbacks include the cost of RFID tags themselves as well as privacy concerns for consumers (Murphy, 2017). Consumers have been known to state that tracking what they recycle by "rummaging through their trash" is equivalent to "peering into their private lives" (Murphy,

2017). Nonetheless, RFID tags can help the end- of-life stages for products by ensuring that they are disposed of correctly and improve overall recycling systems.

Smart Packaging Challenges

Although there are many benefits to smart packaging and market size is expected to increase, there are some challenges that brands face when wanting to adopt this new technology. First of all, a factor that brands find challenging is the high cost of raw materials. Companies wonder how they would make money, especially packagers since they provide critical substrates but are not seen as value-added participants to smart packaging (Armstrong et al., 2018). Another challenge brands face is the complexity in recognizing the right technology for their purpose ("Global Packaging Survey", 2012). If smart packaging is implemented incorrectly, without thorough research and use of materials, another problem it can face is recyclability (LaManna, n.d).

It is also speculated that since smart packaging, especially intelligent packaging is still in its early stages of the business life cycle, there is not enough solid evidence suggesting that smart packaging will be a commercial success that will be accepted globally (LaManna, n.d). At the moment, only early adopters and risk takers are investing in smart packaging. As another result of being a new technology, legislation can be a problem because smart packaging has not been standardized. To implement it without creating issues such as privacy concerns, heavy legislation needs to be put in place. Since smart packaging could collect information, it would need to be ensured that the data is sanitized, blinded, and/or aggregated in order for brands to be able to use it without breaking privacy laws (Armstrong et al., 2018). The other issue is who owns the information that is collected since there are multiple stakeholders involved in the process of creating smart packaging (Armstrong et al., 2018).

As with any new technology and innovation, scalability is a concern for brands (Wood, 2016). Technology must be robust, scalable, and reliable for a high volume of products (Wood, 2016). If smart packaging does become a commercial success, support would need to be put in place for consumers to access for technical support purposes (Wood, 2016). Consumers must also be educated on the various smart packaging technologies so they can recognize and use them correctly. To make it as easy as possible for consumers to use, the interface for smart packaging must be seamless to drive consumer interest and engagement further (Wood, 2016). Other technological obstacles include standardization of the technology itself (Armstrong et al., 2018). Standards for the Internet of Things (IoT) have not yet been established, and because the industry lacks one single standard to which all participants can build solutions to, it is delaying the growth of the industry (Armstrong et al., 2018).

From a management and organizational perspective, one challenge the smart packaging industry faces is that very few brands/companies have all the necessary

equipment in-house to create a smart package. Securing and managing all the different pieces required that you do not own for a smart package proves to be a challenge in itself (Armstrong et al., 2018). It would require efficient planning and logistics to be put in place to bring all the pieces together. Despite these challenges and obstacles, the smart packaging industry looks promising, with enough consumers and brands interested in this innovation for the industry to really take off. The credit for making smart packaging a success will go to the early adopters, risk takers, and innovators who believe in the benefits of this technology and work to find new ways to drive costs down and new purposes for it.

4. Conclusion

In conclusion, based on all the evidence provided in this thesis, the assumption can be made that smart packaging at the moment does not meet the triple bottom line, but is very well on its way to getting there. It was originally hypothesized that perhaps smart packaging did meet the triple bottom line – that there are many important benefits for consumers and they recognize that; even though costs were higher than what would be considered ideal, smart packaging provides many wonderful opportunities for brands to connect with those consumers. Even when looking at sustainability, smart packaging can result in complex packaging, but with the right use of materials and avoiding others such as silicon, RFID tags and smart packaging can be recyclable. Smart packaging can be used to assist in other sustainability issues as well such as reducing food waste. Based on predicted future trends of smart packaging, this technology will meet the triple bottom line in the future. Consumers can only be exposed to the benefits of smart packaging if they are able to use it themselves, and that can only happen when brands and retailers are willing to invest in the technology. Brands will invest in smart packaging technology when costs and other barriers are overcome by the industry. Cost, standardization, and legislation are barriers that will be resolved in the near future as the technology continues to evolve, driving costs down and creating a single standard.

When the people bottom line was evaluated, there is an overall mixed signal from consumers. Many consumers say that smart packaging would be beneficial for them and can help make small tasks convenient for them, but there are many others who also say that smart packaging is not an essential technology and therefore are only willing to pay the minimal amount for it. Of course, not all consumers will be interested in the idea of smart packaging. Smart packaging may only target a niche market of consumers who are looking for more ways that technology can make their lives easier. Because this is also a relatively new technology, it has not yet become a commercial success and many consumers are still unaware of what smart packaging is. If more consumers were exposed to smart packaging and educated on the various ways this technology can be used, they may be more open to the idea of using it.

In the profits bottom line, it is no surprise that the costs of intelligent packaging are currently higher than what brands wish they were. This is due to the fact that it is a new technology, in the early stages of the business life cycle. Costs are always higher during the introduction of new products and technology, which is expected. However, as the technology continues to evolve and become mainstream, costs of hardware such as RFID tags and NFC chips will decrease. Other emerging technology that will help reduce costs include printed electronics as well.

For the planet bottom line, smart packaging can be recycled if it is created appropriately. In order to create sustainable smart packaging, it is important to first research which materials are ideal for recycling and in what combination. If materials are chosen carefully, then smart packaging can be recycled. In other sustainability aspects, smart packaging can help reduce food and product waste by extending shelf life and providing accurate information on the status and state of the food.

Smart packaging is a very new technology, especially intelligent packaging, and the industry does not have all the resources and capabilities yet to meet the triple bottom line. It is too soon with not enough research and testing being done yet to come to a firm conclusion on the success of smart packaging. Smart packaging is on the cusp of meeting the triple bottom line and as soon as a few wrinkles are ironed out, this technology will change the food and packaging industry for the better.

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