

# Packaging 4.0 – Questions and dilemmas

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## Abstract

Stepping into a new decade of the 21st century, we have heard and will hear much about the changes caused by Industry 4.0. The continuously appearing technical innovations revolutionize our lives, redefine the processes of production and services. Among other fields, the packaging industry has also seen new developments. Smart packaging, so-called packaging 4.0 is one type of the mentioned innovations. What does this concept mean? How unified is the interpretation of smart packaging today? What are the technological innovations driving the packaging industry? Which functions of the packaging are the most affected? What is the difference between active and intelligent packaging? What characterizes the spread of smart packaging? How can we distinguish between packaging forms providing real added functionality and solutions that sometimes seem unnecessary, almost luxurious? What can we expect in the future? Answering the raised questions is not always straightforward. There are a number of dilemmas about packaging 4.0. The questions and problems mentioned above will be discussed in this paper.

## Keywords:

Smart packaging, Industry 4.0., active packaging, intelligent packaging

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## 1. Introduction

Stepping into a new decade of the 21st century, we have heard and will hear much about the changes caused by Industry 4.0. The continuously appearing technical innovations revolutionize our lives, redefine the processes of production and services. Among other fields, the packaging industry has also seen new developments. Smart packaging, so-called packaging 4.0 is one type of the mentioned innovations. What does this concept mean? How unified is the interpretation of smart packaging today? What are the technological innovations driving the packaging industry? Which functions of the packaging are the most affected? What is the difference between active and intelligent packaging? What characterizes the spread of smart packaging? How can we distinguish between packaging forms providing real added functionality and solutions that sometimes seem unnecessary, almost luxurious? What can we expect in the future? Answering the raised questions is not always straightforward. There are a number of dilemmas about packaging 4.0. The questions and problems mentioned above will be discussed in this paper.

Industry 4.0 is transforming our lives. Smart devices, digital technologies and artificial intelligence-based solutions are gaining ground. These changes are so profound and so rapid that we could not have imagined before. There is no difference in the field of the

packaging industry either. As Thomas L. Schneider, the president of The World Packaging Organization (WPO) said „New technologies bring unexpected situations, winners can become losers, and losers can become winners - all in a very short time.” (Source: <https://docplayer.hu/18198287-Csomagolasi-innovaciok-a-biztonsagert-es-a-fenntarthatosagert-budapest-2016-majus-26-nemzetkozi-csomagolasi-konferencia.html>)

## 2. Packaging in general

Next to the basis logistics processes – loading, transport, storage – there is a need for additional processes such packaging, order picking, unit load training too. Packaging can mean the process of wrapping to be conveyed consumption goods and also the wrapping itself. This is needed because nowadays most products are not consumed at the production place. In many cases the product travels thousands of kilometres before reaching the final consumer. From the expectations for packaging it can be highlighted that: “It should ensure that the final product is delivered to the consumer in the most economical way without reducing the value of the finished product, ie. by preserving its quantity and quality... The task of packaging usually begins at the end of the manufacturing process and lasts during the total spatial distribution from production through transportation, wholesale and retail, to its delivery to the consumer,

and possibly even exists beyond. „ (Source: Tiefbrunner; Anna 2010/15)

Dörnyei (2019/13), referring to Rockstroh (1979), mentions that packaging can be interpreted as a physical product and also as an activity. „Packaging as a physical product is an element group that forms a complex but temporary cover around the product.” Dörnyei (2019/13). Packaging as an activity is „a set of operations preparing the product for shipment, distribution, storage, commerce and end use.” (Source: Dörnyei; 2019/13)

Packaging must guarantee long shelf life, food safety and quality, plus it should encourage consumers to buy the product itself. Our main expectations for packaging are the following:

- Maintaining the value of the product,
- Delivering the product in intact condition from the manufacturer through the distributor to the consumer
- Unopened, original packaging to be delivered to the consumer,
- For units with larger quantities, resealability should be solved,
- Ensure child-proof seal - for chemicals, paints and medicines
- Prevention of spillage in case of hazardous substances
- Being environmentally friendly, based on sustainable materials and technologies
- Providing information,
- Ensure traceability.

Ideal packaging ensures maximal product protection, marketability, customer friendliness and complies with packaging rules, regulations, and asset protection requirements at minimal cost.

Packaging can also provide added value, for example in the case of aroma sealing, or we can mention the value-adding effect of the optionality to consume/use the product directly from the packaging. The value-adding feature of packaging is particularly true for some smart packaging solutions, which we will return to later.

Most frequently four functions of packaging<sup>1</sup> are highlighted in the literature related to the aforementioned requirements.<sup>2</sup> One is the protection function, where packaging protects the product from environmental influences and vice versa, it protects the environment from the goods. In this function, packaging helps to prevent quantitative and qualitative losses during loading, transportation, storage, and protects the product from mechanical, chemical, biological or even weather conditions, effects and pollution. Secondly, the

rationa- lization function can be stated, packaging facilitates the handling of goods - for example through proper sealing, often resealability. This supports the easy loading of goods, stacking optionality and secure fixing for load-ing and transport. It is important that packaging should be easily removable and it should be ensured that its' materials can be collected and recycled for environmen- tal and sustainability reasons. We can also highlight the marketing function of packaging, playing a big role in the sale of goods primarily in the field of awareness raising and advertising. Aesthetic packaging is impor- tant for attracting customers, as this also encourages potential buyers to realize the purchase. Communication function of the packaging can be mentioned as the fourth function, closely linked to the marketing functi- on. In this context, the packaging is a „mediation tool „, between the product and the environment, provides information, identifies the product and supports easier choice. It also describes the product, provides directions for use and informs customers of the product's usability and warranty.

There are three basic forms of packaging<sup>3</sup>, which are the followings:

1. Consumer packaging: is in direct contact with the final consumer, contains goods in smaller volume and quantity.
2. Multipack: consists of a defined number of consumer packages. It always contains the same type and number of consumer packages.
3. Shipping packaging: is used to make shipping easier and more efficient. There are two forms existing:
  - a. individual transport packaging, which is usually used for the transportation of high value, higher volume goods eg. household appliances.
  - b. unit cargo, which optimizes space utilization in warehouses, transport vehicles and facilitates the automation of material handling and storage.

We note here that most of the aforementioned packaging functions are provided by consumer packaging (based on Tiefbrunner 2010/17. page)The literature mentions the model of optimal packag- ing (OP) (based on Medvéne 2006/17. page). The opti- mal packaging model is directly linked to the previously mentioned requirements and functions of packaging. According to the model, the packaging must also meet the requirements of product protection, suitability for distribution, transport, storage, consumer information, and customer-friendliness.

Based on the above, it can be stated that there are many requirements for packaging, causing challenges for the

manufacturers, designers and also for the whole packaging industry.

Packaging requires:

- Packaging materials (paper, plastic, textiles, ...)
- Packaging equipments (box, canned glass,...)
- Packaging accessories (label, adhesive,...).

Packaging materials are primarily related to the subject of this study, the history of packaging is not detailed within this paper. We only mention that our ancestors worked with different types of packaging materials, equipments and accessories in each historical period in accordance with the technical, technological, economic and social conditions of that time.<sup>456</sup> Nowadays, we have come to a point, where we can realize that packaging materials used in the past are still present in the packaging industry in modern versions (glass, wood, paper, plastics, metal, textiles,...) and next to them new packaging materials and solutions are constantly appearing. These can be connected to the category of Packaging 4.0.

### 3. The types of smart packaging and the technical solutions behind it

Various definitions of smart packaging can be found in the literature. Two of them are quoted below: “Smart packaging is more than just using traditional packaging with fine print, possibly with bar code. Smart packaging is a system that can carry intelligent functions (signalling, sensing tasks), helps to increase shelf life, improves safety, quality, and warns consumers about potential problems and dangers.” (Source: Chakravarthi AVPS <https://anzdoc.com/csomagolasi-innovaciok-a-biztonsagert-es-a-fenntarthatosager.html> ) Based on a different description: “They not only preserve the value of the packaged goods, but they also contribute to quality preservation, usage and product safety by improving a functional feature.” (Source: Anna Tiefbrunner, 2010/133)

Smart packaging can be split basically into two major groups. One is active packaging, which protects the product from environmental impacts and prolongs the quality of the product. Thus, for example, the active packaging ensures the „breathing” of vegetables and fruits. This type of packaging gives greater functionality to the product. Its’ special type is the indicator packaging, which shows, for example with a colour change the various transformations (temperature, pH, carbon dioxide, etc.) within the package. It is mainly used for frozen products. The advantage of this solution is that consumers will not dispose the product simply

because its estimated warranty period has expired by 1-2 days. This is particularly important in an age where nearly 80 million tonnes of food are getting wasted in Europe within 1 year.<sup>7</sup> Another type of smart packaging is intelligent packaging, which is able to communicate with the buyer about the status of the content, product, and give feedback to the seller after purchase. When we examine these intelligent features, we see that they are related to the marketing function of the packaging, and are therefore essential. Here we demonstrate the smart solutions by some examples. Firstly, we bring examples of the additional functions, these became common practices. These include modern medicine packaging solutions making counterfeiting impossible, providing the elderly with easier box opening, protecting against environmental damage (moisture, chemicals, light, etc.) with a built-in barrier layer, allowing child-proof sealing or providing information for visually impaired consumers by Braille writing. Special packaging materials for cosmetics may also be mentioned, where the packaging protects the product for example from ultraviolet radiation.

There are types of packaging that provide experiences based on today’s consumer trends. Such a solution can be a video embedded in the package, which briefly describes the product. We can find examples of perfumes illuminated by LED lights (more on Bedő, 2017/31), vodka-glass lighting dependent on the volume level of the music giving special experience to partying young people, lipstick cases with mirrors and lights easing the application in a dark bathroom. The above examples are based on the idea that light, sound and motion picture, together with packaging, evoke emotions in consumers.

Today we come across packaging solutions that provide additional information about the product, its potential uses, or about the consumer. An example of the latter is the use of the Near Field Communication (NFC) code, which „tests” on the phone whether the right person is opening the (drink) bottle by confirming the age. We can face with solutions where we get consumption suggestions and recipes for the product after scanning the QR code. For example in the case of vodka: “The label contains visual recognition technology that is matched with the application during use. Scanning the tag through Shazam app allows users to access free-brand content, including cocktail trends, recipes and social media, to create more interactions with the product.” (Source: <https://www.trendhunter.com/trends/warhol-absolut-vodka>)

Let’s take a look at the technology behind smart packaging! Many technical solutions support smart packaging. Below we mention the most important ones. One of them is the use of the RFID (Radio

Frequency Identification) tags, which can continuously track the path of a product, which not only causes difficulties for thieves, but can also automate inventory management. The application of the previously mentioned NFC technology offers many possibilities ranging from extending security solutions to multimedia communication of product information. Major beverage manufacturers already provide their premium category products with an encoded NFC chip that contains all the important details of the product and, above all, verifies that the drink was actually made by them, stating it is not a counterfeit. Customers with an "NFC phone" can scan this information in a snap while holding their cell phone over the bottle in the shop. The TTI (time-temperature-indicator) labelling solution is useful for foods, for example through continuous temperature measure of refrigerated products. If it notices that the product has been in a warmer environment for a long time than the set temperature, the label will become discoloured, turn red, and it can be read clearly that the food is not recommended for consumption. Using LED light on the packaging can help you to sell your products in the perspectives of marketing (such as the LED-lighted perfume mentioned earlier.) Augmented Reality (AR) allows us to get extra information about the product with the help of the smartphone. In the case of printed electronics and microsensors, the circuitry is being printed by innovative printing machines, which then starts to operate using either body, product heat or human energy and provide information to the consumer. The use of QR code is useful for product identification and protection against counterfeiting. Special cases of smart packaging solutions include special materials (such as bioplastics) that eliminate the use of environmentally harmful plastic, extend the shelf life of the product, and may include a sensor that informs the customer if the product is unsuitable for consumption. Smart solutions include blockchain technology<sup>8</sup>, which can be used in tracking as well.

## 4. Questions and dilemmas

What questions do smart packaging solutions raise? There are many benefits of smart packaging. As we have already shown above, the product's warranty can be indicated showing the real condition, it retains the aroma, provides additional product information, can be eye-catching, and so on. But the question is: Do the smart packaging solutions above only have positive effects? Let's start by examining the question below.

„Packaging must excel in three dimensions: sustainability, profitability and environmental protection.” (CSA-OSZ Yearbook 2016/53)<sup>9</sup> Among smart solutions, there are many cases where we may

feel that the packaging is redundant, exaggerated or luxurious, thus harming the sustainability dimension. For example, perfumes illuminated by LEDs. We can find packages with significant costs. In all cases, it is necessary to weigh the marketing benefits and costs of smart solutions in order to determine the economy of packaging. Comparing the two pages can provide valuable information. Analysing environmental considerations, we can start from the often-heard statement that „The most environmentally friendly packaging is if there is no packaging at all.” It is not easy to comply with this principle, but minimizing the use of packaging materials is already a good solution, or to use simple, reusable materials, avoid materials that are harmful to the health and the environment, or avoid over-packaging. If we look at the above, we can see that there are some elements that are definitely damaged in smart packaging. For example, some smart packaging solutions can be exaggerated. Because of marketing, there are often items on the package which is considered luxurious (such as video on the box). At the same time, it is visible that companies can win consumers with unique, innovative packaging. These packages are attractive especially for younger generations.

The future consumer - the future of smart packaging  
With regard to smart packaging, in the future the emphasis should be placed on packaging that offers truly added functionality, rather than on the redundant, sometimes seemingly luxury solutions. Corporate responsibility plays a major role in this. It can be mentioned that the decision on the individual smart packaging forms can be controversial within a given manufacturing company as marketing, logistics, finance as functional areas may even take opposite view on smart packaging. Particular attention should be paid in the future to recycled materials, biodegradable plastics or even edible packaging (such as seaweed edible plastic). When it comes to smart packaging, we cannot continue without looking at the future consumer. „The consumer of the future is today's Digital Native,” said Dave Rodgers, Microsoft's retail manager. Source: <https://www.packworld.com/home/article/13371893/pac-to-the-future-customization-connection-community> It is becoming increasingly common that, due to the young generations, we have to deal with 5 "I" instead of 4P's of products. These are:

- Instrumental – everybody owns a smartphone
- Interconnected – connection with technology, community
- Informed – they know more than anyone else about the product they want to buy
- In place – they actually make purchases with their

- phones while in the store
- Immediate – they want to buy now, they want to get the product now

Young people are receptive to smart technologies and value their use also in the field of packaging.

In the early 2010s, “Ipsos conducted a survey in connection to consumer expectations towards packaging in 26 countries. In particular, they were interested in the additional services of food packaging for what the public is willing to pay higher prices. According to the general opinions of the countries “keeping the food fresh” and “environmentally-friendly” functions are the ones, for which people are ready to pay more (the distribution of responses was the same for these two functions). The „reusable” and the „easier to use” aroused significantly less interest. The least important aspects were the „avoid spillage of food”, „keep food at the right temperature” and „easy-to-eat”. ., (Source: Nagy (2013/17)) By 2020, in my opinion, we have come to realise even greater expectations for packaging. In the future, it will be even more important to increase consumer safety and the opportunity for greater consumer interaction through packaging. The former can lead to an increase in the role of active packaging and the latter to the role of smart packaging. The green approach, the increased focus on sustainability aspects, and the „limited” nature of the Earth’s carrying capacity implies the need to minimize food waste, which not only directly affects consumption, but also the quality of packaging and the amount of packaging material. The importance of using recyclable materials and environmentally friendly packaging technology will increase in the future. With the spread of sustainability, there is a growing need to getting rid of the disposable packaging and minimize the burden on the environment created by the use of disposable packaging materials. Return and multi-path packaging may come to the forefront.

The demand for safe food products with minimal processing and reduced additives is emerging as a trend. (Source: Singh et. al; 2011/258) This may also boost future demand for active packaging. As time goes on, the customer-friendly nature of packaging continues to be present and becomes even more significant. Consumers want to buy packages that provide more detailed information about the „history” of the product, about the food quality (Robertson, 2006). Customer-friendliness in packaging means hygienic, easy to open and close, and low weight solutions. For the 21st century’s consumer design is an important aspect besides being provided with real information on the product.<sup>10</sup> When applying smart solutions, you need to consider carefully-ly how much more expensive this product type is and how these costs can be “passed”

on to the consumer. Aday et. al. (2015) conducted a questionnaire survey that mapped consumer perceptions of smart packaging. Most customers would accept a 10 percent price increase for smart packaging solutions after seeing the positive effects of innovative packaging.

## 5. Summary

Increasing consumer income through age and socio-economic changes contribute to new food demands (based on Jensen, 2006). In addition, changes in retail operations (market globalization) and lifestyle (spending less time shopping and cooking) have also created new requirements for food packaging (based on Restuccia et al., 2010). Therefore, consumers express increasing preferences for fresh, comfortable and natural products (without preservatives) and healthy foods with longer shelf life (Zink, 1997). We can expect that the use of new technologies and new materials in packaging will continue and even accelerate in the future. We can count on the diffusion of smart packaging not only for food, but also for other products. At the same time, we see that the adoption of smart solutions is particularly high by the food sector.

Today we know, that Packaging 4.0 is an added value option. According to the research by Smithers Pira: “The combined market<sup>11</sup> is expected to grow at an annual average of 5.9%, reaching \$7.56 billion by 2023.”<sup>12</sup> What can be expected in the future? On one hand, there is a continuing trend to fit the packaging exactly to the size of the product, thereby reducing both waste and costs. It is important to eliminate large, heavy, unnecessary packaging in the field of packaging design. On the other hand, smart packaging seems to be spreading in the future. It is particularly important that smart solutions should meet with the requirements of sustainability and environmental friendliness. It should also be noted that not all „smart appearing” solutions meet with all the conditions. That is why it is important to carefully estimate and calculate every level, before introducing new packaging solutions

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[11.] Combined market: active and intelligent packaging together.

[12.] Source: <https://www.smitherspira.com/industry-market-reports/packaging/active-intelligent-packaging-to-2023>

## Jegyzetek

[1.] Based on Tiefbrunner 2010/17-18. page

[2.] It is mentioned here that we even meet the economic function that clarifies „packing is a profitable cost factor”. (Dörnyei (2019/13)

[3.] Based on Tiefbrunner 2010/17-18. page

[4.] Information on this area can be found at the following pages: <http://hamzhang.blogspot.com/2009/03/packaging-history.html>  
[https://www.google.hu/search?q=csomagol%C3%A1s+t%C3%B6rt%C3%A9net&client=firefox-b&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj\\_g9Kczf3SAhUEM5oKHZX-8BWUQ\\_AUICcB&biw=1280&bih=643#imgrc=BwiUn8c83b6IFM](https://www.google.hu/search?q=csomagol%C3%A1s+t%C3%B6rt%C3%A9net&client=firefox-b&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj_g9Kczf3SAhUEM5oKHZX-8BWUQ_AUICcB&biw=1280&bih=643#imgrc=BwiUn8c83b6IFM)

[5.] <https://hu.lush.com/article/csomagolas-tortenete>

[6.] <https://www.cimkeplaza.hu/blog/csomagoloanyagok-tortenete-ahogy-kezdozott/>

[7.] Source: based on [https://ec.europa.eu/commission/presscorner/detail/hu/MEMO\\_16\\_3989](https://ec.europa.eu/commission/presscorner/detail/hu/MEMO_16_3989)

[8.] The implementation of blockchain technology has a big future ahead, for example, „it allows a more reliable blockchain-based forwarding, foreign trade transactions and lower transaction costs.” <http://bertazsolt.com/mire-jo-blockchain-technologia/>

[9.] Dudás (2012/ 180-194) also investigates this issue.

[10.] It is noted that the role of „on the go” packaging is increasing. „A busy lifestyle reduces the size of packaging in the FMCG market, but the growth in single-person households, aging populations (lighter packaging, pharmaceuticals and dietary supplements) and even growing populations in developing societies also contribute to single-dose packaging ...” Source: [https://issuu.com/termekmixmag/docs/termekmix\\_2017\\_junius](https://issuu.com/termekmixmag/docs/termekmix_2017_junius)