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#### Advanced print-media business models for circular economy domains

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#### Short abstract

Circular Economy evolution that takes place, affects all aspects in societies and production, leading to a new view for activities in production, supply chain and consumption of goods. Within the Printing Industry and in particular the packaging printing, the current evolution includes not only the technological progress in production, but also the application of advanced concepts and systems in business models, management and workflows. The most prominent advances include the implementation of various elements ranging from continuous improvement and lean philosophies, to Industry 4.0 elements and the continuous improvement philosophy based in Lean manufacturing principles. One challenging issue for the Printing Industry, is the continuous transformation, based on the previously mentioned concepts. No matter the name used - digital transformation, digitization or digitalization, transformation is to be traced at all levels, namely at operation and business, management, technology and production. In addition to Industry 4.0, Lean philosophies and digital transformation, Circular Economy is considered as one more concept to be integrated one or the other way, in the already complex business environment of the Printing Industry. The present study investigates the current and future print-media landscape and under the scope of the integration of Circular Economy concepts in the business and operation of the printing companies. The question posed is whether and to which extend new or updated business models are required in order to facilitate this integration. As a result, the current status of the Printing Industry is to implement Circular Economy concepts, to the extent of the industry operational framework. One interesting aspect revealed, is the effort to implement these concepts, towards the "before" and the "after" in print production, which is not a part of the core printing business. Finally, the present study suggests an initial framework for the establishment of dynamic and flexible business models for the Printing Industry, where current and future innovations could be implemented.

**Keywords:** printing industry, circular economy, sustainability, business models, industry 4.0, digital transformation

#### 1. Introduction

Circular Economy is nowadays the key word summarizing environmental protection, energy efficiency and sustainability. No matter the challenges created by recent global negative issues (such as COVID-19 and the pandemic, the war in Ukraine, energy and raw materials prices and shortages), Circular Economy is here to stay.

Circular Economy evolution that takes place, affects all aspects in societies and production, leading to a more generic view of all activities in production, supply chain and consumption of goods. Further, Circular Economy creates a disrupting environment, where, new ways of doing business might be required.

The Printing Industry and in particular the packaging printing sector, is advancing rapidly and continuously. The principal evolution topics for printing and finishing include not only the technological advances but also advanced systems in management and production, quality control and workflows. The most prominent developments are (among others), the application of various Industry 4.0 elements and the continuous improvement philosophy based in Lean manufacturing principles. Such developments require a "holistic", transformation in business organization, where digitization, digitalization and the so-called "digital transformation" constitute important parts. It is necessary that all the above-mentioned separate pieces of the "puzzle" need to be brought together under "one roof" in the transformation process of the Printing Industry. Therefore, the question posed is: Which can this "roof" be?

This paper aims in investigating the printing business and the required (continuous and dynamic) transformation challenged further by the Circular Economy evolution and its application in the industry and society. The objective of the study is to investigate the how, towards which direction and to what extend the already happening transformation, is further challenged by Circular Economy characteristics.

The study focuses on business models currently operating in the Printing Industry, their evolution and characteristics and the implications caused by the various elements mentioned previously (Industry 4.0, digitalization, and Lean philosophies). Business models are explored since they are considered as the "roof" under which, every implementation of new concepts can be feasible and facilitated. Circular Economy concepts are considered as an additional parameter that needs to be implemented effectively in the print business and operation. Therefore, business models are investigated in an effort to define the effective adaptation of Circular Economy concepts in the printing industrial setting and the appropriateness of the business model structure for this purpose.

## 1.1 Methodology

The approach for writing this paper is based on the investigation and the combination of elements considered important for the current and future print-media business and industry.

It is a step-by step investigation of the theoretical framework for printing business, following a logical sequence of arguments. Among these, one could define whether there is a future in print business, and if new technologies and other concepts are applied (such as Industry 4.0 and digital transformation).

Securing with evidence that this is the case, then the study investigates further the facilitators for doing business more effectively. These facilitators are the business models that are to be applied in the Printing Industry.

Following this step-by-step approach, additional or new concepts, such as Circular Economy are investigated. Finally, the theoretical background provided by this part of the study, is summarized as a suggestion of an initial business model structure (framework) where new concepts such as the one of Circular Economy can be affectively implemented in Printing Industry and its operation, business and production.

Based on this methodological analysis, the present study begins with the Circular Economy concept and its importance for the business of today and tomorrow, in Chapter two, which is addressing the origins and the characteristics of the Circular Economy. In Chapter 3, evidence is provided revealing that, no matter the evolution of the digital world, print is here to stay, in particular in books and packaging. The third chapter

deals with the disrupting developments which are challenging the printing and packaging industries and in particular COVID-19 and the lockdowns.

The fourth chapter refers to the latest trends regarding the technological developments and mainly those originating from the Industry 4.0 and digital transformation topics, whereas chapter five is addressing the latest trends in business models and their application in the Printing Industry.

Finally, in chapter six, the key findings are summarized, suggesting some structures of business models for the Printing Industry, and their evolution towards the implementation of Circular Economy concepts.

# 2. Circular economy

A lot of discussion takes place nowadays, on Circular Economy, therefore it is rather difficult to find out evidence which will be both credible and suitable for a specific industry domain, such as the one of printing and packaging production. In this part of the study effort will be given to clarify some principal issues concerning Circular Economy, towards its implementation in the Printing Industry.

## 2.1 Circular Economy context and definitions

At a document published by the European Parliament (2015) it is argued that unlike the traditional linear economic model based on a "take-make-consume-throw away" pattern, a Circular Economy is based on sharing, leasing, reuse, repair, refurbishment and recycling, in an (almost) closed loop, where products and the materials they contain are highly valued. In practice, it implies reducing waste to minimum. (Bourguignon, 2016)

Further, regarding the role of design science in Circular Economy, it is stated that Circular Economy is increasingly seen as a key approach to operationalising goals and supporting the transition to a sustainable society by enhancing competitiveness and economic growth. Creating a Circular Economy requires fundamental changes throughout the value chain, from innovation, product design and production processes all the way to end of life, new business models and consumption patterns. (Pigosso and McAloone, 2017)

Circular Economy is opposed to the so-called Linear Economy model. The main difference between Linear and Circular Economy is presented in Figures 1 and 2 as follows (Kholod, 2019).



Figure 1: Linear Economy (Kholod, 2019)

The Circular Economy, in contrast, has the opposite aim: to radically limit the extraction of raw materials and the production of waste. It does this by recovering and reusing as many of the products and materials as possible. The Circular Economy is a "make/remake – use/reuse" economy.



Figure 2: Circular Economy (Kholod, 2019)

Another way to describe Circular Economy is the term "Closed Loop Economy". Whether the term is Closed-loop economy, Circular Economy, Closed-loop supply chain, or Closed-loop system – it's all essentially describing the same thing. A Closed-loop economy is an economic model in which no waste is generated; everything is shared, repaired, reused, or recycled. What would traditionally be considered "waste" is instead turned into a valuable resource for the creation of something new.

As such, a Closed-loop economy is essentially the result of multiple companies operating on a closed-loop supply chain. This requires an intelligent reimagining of how products (and packaging) are designed, manufactured, sold, refurbished, and recycled. (Quincy Recycle, 2020). The elements of the Closed-loop economy are illustrated in Figure 3.



Figure 3: Elements of a Closed-loop economy (Closed loop, 2022)

Finally, in the study "On biodegradable Plastics" (Selke, 2015), it is mentioned that each possible waste management namely improper disposal (litter), landfill, incineration, composting, recycling and reuse is not in any way compatible with the use of biodegradable plastics. Packaging systems based on biodegradable plastics are not automatically more sustainable than those based on non-biodegradable plastics. This conclusion is supported strongly by the general agreement that the whole package-product system must also be considered sustainable. If this package system fails to provide adequate protection for the goods it contains it is not really sustainable at all, as in this case both package and product will be wasted. (Selke, 2015) This argument is further enhanced if a clear distinction between Linear economy, Re-use economy and Circular Economy is made. As it is stated in a Fujifilm white paper, "the EU's Circular Economy Action Plan3 outlines a strategy to transform Europe's economy into a sustainably driven, fully Circular Economy by 2050. To achieve this goal, we must take action at all levels of society and set clear milestones. The first goal is ambitious but not unattainable: a 50 % reduction in the consumption of primary raw materials (mineral, fossil and metals) by 2030" (Fujifilm, 2022). In Figure 4, the distinction among Linear, Re-use and Circular Economy is illustrated.



Figure 4: Linear economy, Re-use economy and Circular Economy (Fujifilm, 2022)

## 2.2 Sustainability and circular economy

According to Morales, et al. (2021), Circular Economy and sustainability are interrelated, without being exchangeable. While sustainability tries to reconcile the management of productive resources with their increasing consumption, Circular Economy aims to make the productive process more efficient, reducing, reusing and recycling the results of the productive process as much as possible.

A similar mindset is placed by Kuehn (2022). She defines sustainability as a principle of action according to which the conservation of resources is aimed at by means of natural regeneration to further satisfy needs. Comparing sustainability with Circular Economy she argues that "Circular Economy describes the process of optimal use of resources, optimal use of energy and, above all, the processing and reusability of used resources".

In addition, as it is pointed out by Morales, et al. (2021) sustainability is understood as the "dynamic equilibrium between the allocation of resources in the production process and consumers' behaviour patterns", whereas Circular Economy is understood as the "regenerative system that promotes the minimization of waste generation by closing and extending loops, and improving eco-efficiency technologies, while maintaining its value in the economy for as long as possible".

As Kuehn (2022) states further, "sustainability is becoming more important across all sectors, including the print industry. Niche producers are already successful with a sustainable business model, but this has not yet reached the masses. Even though products are increasingly adapting to sustainability, the incentive for companies is probably not yet great enough to incur additional costs. This will only change when ways are identified in Europe and globally and incentives are offered so that large companies voluntarily commit to finding intelligent and sustainable solutions".

#### 2.3 Sustainability, and circular economy in the printing industry

What is applied for industry and society in general, concerns the printing and Packaging Industry. Effort is given by many, to specify the elements of Circular Economy and sustainability concepts for the Printing Industry. In this context, Sun Chemical categorizes three main product sustainability initiatives:

- The raw materials used and the manufacturing processes
- The function of Sun Chemical products and the environmental impact of this function and
- The end-of-life of Sun Chemical products and how they interact with recycling processes to assist Sun Chemical customers in making products easier to recycle and promoting the development of circular economies. (Sun Chemical, 2020)

Intergraf (2022), defines four print product and site relevant parameters for Circular Economy. Based on Intergraf Recommendations on CO<sub>2</sub> emissions calculation in the Printing Industry, these are:

- Materials
- Transport
- Printing
- Distribution

The Intergraf Recommendations represent a neutral and credible approach as they cover the 3 scopes of the Greenhouse Gas Protocol. Scope 1 covers all direct emissions, scope 2 covers the indirect emissions related to energy consumption and scope 3 covers all other indirect emissions from the supply chain. Scope 3 is a key element for the carbon footprint calculation in the Printing Industry as over 70 % belong to it, with the production of substrate being the main element. The Intergraf Recommendations have received international recognition with their inclusion in the ISO 16759:2013 standard (International Organization for Standardization, 2013) on the quantification and communication for calculating the carbon footprint of print media products. In figure 5, the four product and site relevant parameters for Circular Economy are analysed. (Intergraf, 2022)



*Figure 5: The four product and site relevant parameters for Circular Economy (Intergraf, 2022)* 

In regard with the involvement of the organizations of the printing industry, there are some initiatives that are operating. Among them, it is worthwhile to mention the Sustainable Green Printing Partnership (SGP) (Sgppartnership, 2022). According to the main message, the Sustainable Green Printing Partnership is a community of printing and packaging manufacturers, global brands suppliers, and supporting organizations working together to drive sustainability and meet the demands of today's customers. Their objective is to "make up the industry's leading supply chain certification authority and to set standards, advocate best practices and promote innovation toward a more accountable, sustainable supply chain". Moreover, as it is stated by SGP, "SGP certification is a multi-attribute endorsement created specifically for graphic communications facilities to be recognized by brands worldwide. To achieve certified SGP Facility status, companies must meet or exceed strict sustainability criteria in their manufacturing process, facility, product and social areas. Certification is offered to printers in the United States and Canada, as well as suppliers to the printing industry" (Sgppartnership, 2022).

A far more complete structure of Circular Economy elements in the Printing Industry, presented by Two Sides Australia (2022), emphasizes the complexity of Graphic Communications Supply Chain, which is "distinct from other sectorial or single issue corporate responsibility initiatives because it aims to promote responsible and sustainable business practices across every step of the AUS Graphic Communications Supply Chain, no matter how large or small the business". (Two Sides Australia, 2022). In Figure 6, this complexity is illustrated.



Figure 6: Graphic Communications Supply Chain (Two Sides Australia, 2022)

## 3. Disrupting developments and challenges

Prior to the investigation to the actual research fields, it is important to examine the current development of the Printing Industry and the issues occurred by the disruptions. Such issues are the print production for various segments (newspapers, books, packaging), the COVID-19 pandemic and the lockdowns, the energy and raw material prices as well as the war in Ukraine. The crisis plaguing the global economy from the late 2000s (2008–2009) to the present in conjunction with the COVID-19 pandemic has created an economic environment that cannot be described as easy for economic activity. (Gamprellis, et al., 2021)

# 3.1 The printing industry by (some) numbers

What can be considered as a fact is the expansion of digital communication and in particular the use of internet, social media, the enormous expanding of mobile devices, apps, and the web. However, the characteristics and in particular the nature of printed substrates combined with advanced technologies, such as finishing technologies reveal the strength of printing world and enhance the added value for a better communication. Haptic communication for example, is the principal driver for this enhancement (Politis, 2018). Also, despite the digital transformation, printed newspapers and magazines will continue to be a basic business segment for publishing companies in order to maintain a strong media brand across all channels. (Scherzer cited in Muller Martini, 2018)

Regarding print production, it is generally accepted that in recent years the Printing Industry has shrunk over the past few decades. The global print market is shrinking in volume but growing in value over the period 2014–2024. Output measured in billions of A4 prints (or equivalents) was 49973 in 2014 and forecast to decline very slightly to 49654 by 2024. In value terms, print output grows from a total of USD 767.4 billion in 2014 to USD 862.7 billion in 2024 – a Compound Annual Growth Rate (CAGR) of +1.18 % (Smithers, 2021). However, this contraction, although significant in some sectors of the Printing Industry, such as newspaper publishing, is non-existent in others, such as packaging, digital printing, screen printing, book production and label printing. (Gamprellis, et al., 2021)

Books are a quite interesting and influential segment in printing business. Some years ago, some have predicted that printed books would be dramatically limited and replaced by digital devices for reading. Hence, recent data provide evidence of a completely opposite picture, on reading books. According to several studies (PrintMonthly, BookMap Study – the Economist, Statista and Kurtz in Muller Martini in Panorama magazine 2019), printed book production is constantly increasing, reaching 122 USD billion sales in 2017. In the USA the number of hard and soft-cover books rose to a total of 695 million copies and sales of USD 10.3 billion in 2018 compared to 591 million copies in 2012. The same image appears for book sales in the UK and in Europe (Panorama, 2019).

In addition, according to Tsigonias (2018), and Adroit Market Research (2021) shows that the printed book production will be constantly increasing at least until 2028 (Figure 7)



Figure 7: Global Book Market (2018-2028) (Politis, 2022; Adroit Market Research, 2021)

This can be compared with the e-books in market growth of USD 6.93 billion from 2020 to 2025, at a 7 % CAGR (Maida, 2022; Technavio, 2022). As it is stated in Maida (2021) and Technavio (2022), the e-book

market is fragmented and the vendors are deploying growth strategies such as mergers and acquisitions and collaborating with schools and educational institutions to compete in the market. Finally, compared to printed books, e-books possess a percentage of 6–7 % in France and Germany (Panorama, 2019).

#### 3.2 Printing industry and the COVID-19 pandemic

The global economic environment still remains in a challenging position due to the COVID-19 pandemic and it was perfectly reasonable and expected that the Printing Industry would be influenced like any other activity. (Gamprellis, et al., 2021: Whattheythink, 2020)

As Byström (2020) points out, during the COVID-19 pandemic crisis, there was a dramatic growth in online shopping that drove ten years of e-commerce growth in an eight-week period. Today, 38 % of UK consumers are now buying online at least once a week – in the US it is 26 %, Benelux 22 %, Australia 21 %, Germany 20 % and Sweden 20 %. (Byström, 2020)

Furthermore, during the COVID-19 pandemic, states and local municipalities are practicing extreme caution to avoid the spread of the corona virus. Healthcare products, such as syringes, vials, and cartridges, are required on a large scale amidst this pandemic to fulfill the increasing global demand (Wood, 2020a). There will be an increase in the demand for packaging printing solutions for food & beverage and pharmaceutical applications, during COVID-19 pandemic. (MarketsandMarkets, 2021)

These facts created a huge consumption growth that led to a growth of the packaging Printing Industry. The global packaging market size during the COVID-19 pandemic is projected to grow from USD 909.2 billion in 2019 to USD 1012.6 billion by 2021 (Wood, 2020b).

According to Wassermann (2020), during the lockdown (due to COVID-19 pandemic), losses were still at –66.8 %. Since the stores reopened, however, the figures have turned significantly positive. During the initial restrictions, revenues then collapsed by more than half in some cases and were not yet able to recover fully in the post-lockdown phase (Wassermann, 2020).

Printing Industry Sectors	2020	2025	Estimated Annual Growth (%)
Press – Newspapers (millions)	157.57	149.15	-1.00
Publications – Books (billions)	117.07	122.44	+0.90
Commercial Prints (billions)	409.40	460.28	+2.24
Packaging Printing (billions)	352.10	433.40	+4.20
Labels Printing (billions)	42.70	51.89	+4.00
Security Printing (billions)	29.50	36.00	+4.10

Table 1: The estimated annual growth of the sectors of the Printing Industry (Gamprellis, et al., 2021)

As Gamprellis points out most of the Printing Industry segments will be expected to show an annual growth in the years coming (Table 1) despite the COVID 19 pandemic. The estimated annual growth for some of these Printing Industry segments will be higher than other, but in the end only the Press – Newspapers segment is expected to decrease (Figure 8) (Gamprellis, et al., 2021)



Figure 8: The estimated annual growth of the sectors of the Printing Industry 2020–2025 (Gamprellis, et al., 2021)

It seems that up to today, statements and predictions on the "decreasing" of print do not seem to be a reality. The printing field and the related sectors show a rather stable condition in terms of turnover and production, at least in Europe and North America, whereas in other continents, such as Asia, print is booming. (Politis, 2018)

3.3 Energy crisis and cost of materials

As mentioned in the previous section, the impact from the COVID-19 pandemic on the global economy is very significant. The Printing Industry, although initially was hit hard, could have overcome the difficulties caused by the COVID-19 pandemic if it had not presented a huge new economic challenge, which is nothing more than a rapid energy crisis which increases the cost of materials used by the Printing Industry.

From 2008 to 2021 the price of energy on the world market shows a slightly upward trend. This upward trend in energy price during these 14 years is also recorded by Eurostat (2021) (Figure 9).



Figure 9: Development of electricity prices for non-household consumers, EU27, 2008–2021 (Eurostat, 2021)

Energy prices are expected to continue increasing, especially in 2022. The increase in energy price is accelerating significantly due to difficult geopolitical conditions, mainly in Europe (Russian invasion in Ukraine).

For delivery in March 2022, the gas price goes up 40 %, to about  $\in$  125 per megawatt-hour (MWh). The price for the supply of electricity is also rising some 40 %, to  $\in$  300 per MWh (taxes included) (The Brussels Times, 2022). Meanwhile, natural gas prices in the U.S. are approximately 60 % higher than a year ago. (McHugh, 2022). This increase of energy prices seems to be very high, as it is a reflection of very depressed energy prices in 2020 and 2021 due to the COVID-19 pandemic. If someone compares a longer historical period (2008–2021) average to the 2022 energy prices (March 2022) in order to soften the anomaly of the COVID-19 pandemic, he will find out that electricity prices for household consumers in the EU since the first half of 2008, (without taxes, i.e. the energy, supply and network), increased slightly faster than the overall inflation rate (HICP) until the second half of 2013 when it was  $\in$  133.8 per MWh. From 2014 to 2019, it remained relatively stable. In the second half of 2021, the highest ever price observed in the collection is recorded (Eurostat, 2020; 2021)

The European association representing the paper industry (CEPI) points out that the paper industry is an energy-intensive industry and, for that reason, current energy prices are a concern. The EU Commission's Green Deal and the carbon net-neutrality 2050 target, which is supported by CEPI, will lead to higher energy prices and carbon costs. The war in Ukraine and the related sanctions will add to this trend and further increase energy prices, which have reached very high levels already today (Packaging Europe, 2022).

Locally, energy prices and availability might be further impacted by the fact that some regions in the EU are highly dependent on the supply of Russian natural gas. To compensate for this, access to clean and affordable energy should be one of the EU's top priorities. The paper industry expects concrete and prompt support measures from the EU and national authorities (Packaging Europe, 2022)

Furthermore, Russia exports more or less the same amount to the EU every year (mostly kraftliner, newsprint and uncoated wood free). If we assume trade restrictions will result in the elimination of paper and board coming from Russia, the EU could suffer short-term paper shortages in some segments – particularly kraftliner. Russia usually sends some 180 000–200 000 tones of kraftliner to Europe each year. (Mata Lopez, 2022)

## 4. Evolution in the printing industry in technology and automation

## 4.1. Digital transformation, digitization and digitalization

Digital technologies play today a quite significant role in the media and graphic arts domain. However, digital transformation, digitalization or digitization have various interpretations and different meanings. The terms "digital transformation", "digitization" or "digitalization" are often confused and in many cases, they are used as they have had the same meaning. Hence there are differences in their conceptual context which need to be mentioned.

As Irving (2021), argues a lot of people have been talking about digital transformation (again). It sounds pretty cool and sophisticated. And it is. But what many of them were actually discussing was digitization (or digitisation, for those in the UK).

Irving provides an explanation regarding the term of digital transformation, stating that digital transformation is less about technology and more about people. The ability to adapt to an even more digital future depends on developing the next generation of skills, closing the gap between talent supply and demand, and future-proofing human capitals' potential. Therefore, digital transformation is a state of mind and a way of working and it is about learning and knowledge transfer. As such it is a holistic approach. (Irving, 2021) In addition, as it is stated by Irving (2021), "Digital transformation is the process of using digital technologies to create new – or modify existing – business processes, culture, and customer experiences to meet changing business and market requirements. This reimagining of business in the digital age is digital transformation. As such, digital transformation begins and ends with how you think about, and engage with, customers. And as we move from paper to spreadsheets to smart applications for managing our business, we have the chance to reimagine how we do business – how we engage our customers – with digital technology on our side". (Irving, 2021)

Furthermore, according to Saleforce (2022), "digitization is most often mistaken for transformation. Digitization is the process of taking an existing process and digitizing, however this is not transformational. Therefore, digitization is an essential stepping stone to start digital transformation. In addition, there is a difference between digitization and digitalization; Digitization means to convert something into a digital format, and usually refers to encoding of data and documents whereas Digitalization means to convert business processes over to use digital technologies."

A more concrete distinction is presented by Thisisthelatest.news (2022). According to Thisisthelatest. news, digitization focuses on converting analogue information into digital formats. This is an important part of digital transformation. It is the process of transferring information from analogue to a digital format that can be accessed through computer systems and mobile devices. It can also be applied in business settings. In contrast, digitalization focuses more on processes and business models. It is the conversion of physical things to digital formats. Finally, digital transformation is more a holistic strategy in transforming the totality of doing business with digital tools and elements (such as Industry 4.0 settings and technologies), enabling organizations and businesses to adapt to changing market conditions and reimagine business processes and be more responsive to market changes and better serve their customers.

The interrelation of these three terms is presented in Figure 10.



Figure 10: Digitization Vs Digitalization Vs Digital Transformation (Thisisthelatest.news, 2022)

Based on previous data, Digital transformation can be defined as a holistic development strategy. As it is argued by ionology.com (2022), "Digital transformation describes how an organization must evolve in the age of digital disruption; continually changing, innovating and reinventing rather than simply enhancing or supporting the traditional methods of its industry". Ionology organization, suggests five crucial steps for the development of a digital transformation strategy as presented in Figure 11.



Figure 11: Five steps for a digital transformation strategy according to ionology.com (Irving, 2021)

The analogy of all three terms to the printing business and industry can be structured at the following example:

- Digitization: Inventory of printed jobs from paper to a digital file
- Digitalization: Automation of print management with the application of an MIS and use of digital data
- Digital Transformation: Integration of management, production workflows and business models in digitized platform(s) following a specified strategy.

Such classification provides evidence to clarify strategies for the printing business with the application of advanced technologies and Industry 4.0 is the most prominent step towards a new era for printing in the digital domain.

#### 4.2 Industry 4.0 in the printing industry

Industry 4.0 is described as the 4<sup>th</sup> industrial revolution. Industrial revolution is an old term, used principally to classify the various steps of evolution in industrial operations and processes. However, the concept of Industry 4.0 appears as a global trend regarding the evolution in industrial manufacturing in the years to come. As such, it seems as a necessity for all industrial and manufacturing sectors to take under consideration the evolution that this concept brings. Hence, the term consists of several elements, which need to be carefully addressed and analyzed. This analysis should lead to the determination of potential benefits for manufacturing operations and processes in various sectors. (Drexler, 2016)

As it concerns the graphic/media, printing and packaging industries, the generic Industry 4.0 trend is applied with the combination of certain elements that fit better to the nature of processes and operations in the industry. As such, vendors, scientists and manufacturers are taking position within Industry 4.0 which is interpreted as Print 4.0, Finishing 4.0, Packaging 4.0 and Paper 4.0 (Politis, 2017).

A clear message from the investigation in the Printing Industry sector is that not all Industry 4.0 elements are applicable at all sectors. The investigation for the graphic arts and related industries (printing, packaging, paper and finishing) show that generic elements of Industry 4.0 are adapted into specific applications in a more concrete manner by the industry. (Politis, 2017, 2018)

According to Blogdrupa (2021a) quite recently, system integration and workflow automation were a top priority for printers and manufacturers. The truth is that in the Printing Industry there are a lot of repeatable tasks and processes, even though each job ticket is unique, and each printing job might be completely different than the previous or the next one. To keep the cost price as low as possible, many software

solutions offer automated workflows with the use of JDF files. The advantages of these include "increased production efficiency as well as profitability, raising the output, an increase of volume of shorter run work and avoiding bottlenecks". (Blogdrupa, 2021a)

Hence, Industry 4.0 is not only about automation of processes, use of robotics and big data. It's also about the use of cloud computing in all kinds of industries. And Printing Industry is not an exception of this rule. Newest technologies and developments include web2print, online file checking, color management and more print cloud solutions. These solutions aim of developing comprehensive AI based software solutions that aid printers in becoming more efficient, profitable and automated. Other focus on eliminating the burden on IT teams, reduce operating costs and accelerate digital transformation. (Blogdrupa, 2021b)

The current trend is the moving from many different aspects to as much as possible integrated systems, like ERP and MIS functionality with collaboration tools, web-to-print, cloud services and so on. The more the integrated systems, the less time is needed on the user's side. Following this, IoT devices and sensors make available for organizations to have access to greater insights from new analytics capabilities, which enables them to make faster, more knowledgeable business choices connected to their print ecosystem.

Cloud can also be used as a central service platform for remote maintenance and other remote services. This way, efficient and comprehensive support for machine operations, productivity improvements and troubleshooting can be provided and the whole print management of a printing company can move nowa-days to cloud. (Blogdrupa, 2021b)

## 4.3 Robotics

A significant trend is the application of artificial intelligence and robotics into manual jobs. Although the news often puts humanoid robots and artificial intelligence (AI) in the spotlight, there's no shortage of exciting innovations in industrial robotics. From medicine and agriculture to production and printing, robotics plays a vital role in various industries, helping businesses become more efficient and cost effective.



Figure 12: Annual installation of industrial robots (IFR, 2021)

Although robots have been used in industry since the 1960s in manufacturing, new technological capacities have made them versatile. New technologies like drones, collaborative robots with sensors and the incorporation of artificial intelligence and automation have opened the doors for robotics. As robotics and automation technology develop, we expect to see increased innovative uses applied to various industries (Figure 12). From medical robotics to automation in transport, we can expect to see the automation and robotics sector expand and grow. In fact, the World Robotics 2021 Industrial Robots report shows a record of 3 000 000 industrial robots now operate in factories around the world. (IFR, 2021)

In printing business, there is an increased use of robotic functions to improve precision and productivity and reduce time, while the use of automation and artificial intelligence help to coordinate and optimize production and operation (Heidelberg, 2022). Furthermore, according to Frey and Osborn (2013), print finishing and bindery operatives have a 95 % probability of a robot doing their job, ranked as 618 most likely out of 702 occupations. It is certainly feasible that manual loading and unloading operations could be replaced, and in many cases automatic palletization has replaced manual labor while robotic hoists are commonplace in loading logs of printed sections into gatherers for binding.

Relevant robots in the Printing Industry (Frey and Osborn, 2013)

- Collaborative robots
- Loading and unloading of machine
- Service and communication robots
- Transport and logistics
- Transport and service

The application of Industry 4.0 elements within a Circular Economy is a matter of high importance. An example on the relation of Circular Economy with industry 4.0 in an industrial setting, is presented in Figure 13.



Figure 13: Convergence of Circular Economy with industry 4.0 in an industrial setting (UNIDO, 2017)

#### 5. Print-media business models – advances and evolution

#### 5.1 Business models – definitions and classifications

What is a business model? An answer is not easy to be given, since business models constitute purely conceptual frameworks. In other words, everyone can interpret the term by his/her own and unique way. Searching in the literature provided efforts by numerous scientists, in an attempt to define business models. For example, a look through Harvard Business Review - HBR's archives shows that "business thinkers use the concept of a "business model" in many different ways, potentially skewing the definition" (Ovans, 2015).

As it can be derived from Ovans (2015), the meaning of the term, can be described as an interplay of various concepts and opinions by many, such as "business strategy", "assumptions about what a company gets paid for" or "better business model into an existing market is the definition of a disruptive innovation".

Regarding the definition, it is argued that the business model concept is a particularly helpful unit of strategic analysis tailored to today's competitive business environment. It helps executives as well as entrepreneurs increase their capacity to manage continuous change and constantly adapt to rapidly changing business environments by injecting new ideas into their business model. Hence, there is often a lack of a more precise and shared understanding of what a business model is. Yet, such a common understanding is required if we want to have high quality discussions of one's business model and make important business model decisions.

A more concrete definition has been provided by Osterwalder (2005). According to Osterwalder "A business model is nothing other than a representation of how an organization makes (or intends to make) money". This definition is further implemented as follows: "A business model is a conceptual tool that contains a set of elements and their relationships and allows expressing the business logic of a specific firm. It is a description of the value a company offers to one or several segments of customers and of the architecture of the firm and its network of partners for creating, marketing, and delivering this value and relationship capital, to generate profitable and sustainable revenue streams". (Osterwalder, Pigneur and Tucci, 2005)

According to e=mc<sup>3</sup> (n.d.), "if managers want to overcome past barriers and experiment with alternative business models, they must construct maps of business models, to clarify the processes underlying them, which then allows them to become a source of experiments considering alternate combinations of the processes. One example of a mapping approach comes from Alex Osterwalder who, following his dissertation at Lausanne, has consulted, and spoken widely on business models and business model innovation (Osterwalder, 2005). His empirical focus utilizes a 9-point decomposition that characterizes a business model, namely the Business Model Canvas – BMC. The nine key elements, comprising the basis for any business model, can be viewed in Figure 14.



Figure 14: Osterwalders' Business Model Canvas – BMC (e=mc<sup>3</sup>, n.d.)

The Business Model Canvas, can be considered as the basis for the conceptualization of the rather vague ter. According to  $e=mc^3$  (n.d.), "although, like other models it is a simplified description and representation of a complex real world object, it describes the original in a way that we understand its essence without having to deal with all its characteristics and complexities. In the same line of thought we can define a business model as a simplified description of how a company does business and makes money without having to go into the complex details of all its strategy, processes, units, rules, hierarchies, workflows, and systems".

What is essential and highly innovative from the work of Osterwalder, as it regards the context of business models, is the introduction of "blocks" or "pillars" or "elements" in the form of a canvas, which immediately changes the process of conceptualizing a model of a business, or any other type of organization public or private, profit or non-profit. The canvas just happens to fit perfectly with the principles of the Lean Startup process, especially the emphasis it lays on experimentation, hypothesis testing, and systematic learning. (Fielt, 2014; e=mc<sup>3</sup>, n.d.)

Regarding business models classification, Elearnmarkets (2022), suggest a different approach in defining and classifying business models; "Every business or companies makes a plan for generating profit. They create a model for identifying products and services to sell, the market they want to target and also take into account anticipated expenses. This is known as business models. Even if the business is already established or even if it is a new business, plan needs to be made. Businesses need to regularly update their plans and strategy as they need to take into accounts the challenges and trends for the future models. (Elearnmarkets, 2022)

Elearnmarkets classify four types of business models as follows:

- Business to Business Model B2B
- Business to Consumer Model B2C
- Subscription based Business Model
- On Demand Business Model (Elearnmarkets, 2022)

Regarding conceptualization of business models, Fielt (2014), suggests that "a business model describes the value logic of an organization in terms of how it creates and captures customer value and can be concisely represented by an interrelated set of elements that address the customer, value proposition, organizational architecture and economics dimensions". Field (2014) suggests further the following conceptualization of business models based on his analysis of business model definitions, elements, and archetypes and constructed by the following 5 main fields:

- explicitly including the customer value concept in the business model definition and focussing on value creation
- presenting the core dimensions that business model elements need to cover
- arguing for flexibility by adapting and extending business model elements to cater for different purposes and contexts (e.g. technology, innovation, strategy)
- stressing a more systematic approach to business model archetypes by using business model elements for their description, and
- suggesting to use business model archetype research for the empirical exploration and testing of business model elements and their relationships.

#### 5.2 Business models in the printing industry

As it is stated by Bohan (2017), printing companies today have to navigate the requirements of shorter run lengths, faster turnaround times and increasing costs, all while facing relatively stable print prices and higher consumables prices. With all of these challenges, it's virtually impossible to maintain, yet alone increase, profitability without making changes to current business model or operations. According to Bohan,

the key to profitability and the solution to current challenges may be no further than workflow. An advanced workflow, should consider whether or not it drives positive impact on six key areas of printing business:

- Enhancing Customer Interaction
- Reducing Touchpoints
- Driving Productivity and Uptime
- Reducing Waste and Inventory
- Optimizing Consistency and Repeatability
- Providing Business Intelligence

Furthermore, as it is stated by Bondy, Peterson and Webb (2015), numerous management methods are deeply ingrained in the Printing Industry. Unfortunately, many no longer apply in the current market and environment. The development of "UnSquaring The Wheel", introduced the concept of a generic overview of the print management and workflow, designed to create a new and durable competitive advantage for graphic communications firms (printing companies). The approach, examines the entire business, not just one department at the expense of others. There is no one aspect of a company that can be changed and by itself create a sustainable advantage without this generic approach. (Bondy, Peterson and Webb, 2015)

Another concept under the name "Digital Supply Chain – New ideas for more efficient procurement of pharmaceutical packaging" has been introduced by Faller Packaging (2020). According to Faller Packaging white paper, "The digitized supply chain turns an order-driven process into a data-driven one that continuously monitors and optimizes itself. The basis for this is the fullest possible exchange of relevant information between pharmaceutical and packaging manufacturers. Analysis and segmentation of this item-related data makes it possible to select the best possible supply chain strategy for each product and to derive recommendations for action to improve specific process steps along the entire value creation chain".

More over, according to Salwin, et al. (2020), in the light of intensifying competition, growing customer needs and requirements, and bigger awareness of environmental impact, entrepreneurs are looking for new ways to improve and develop their operations. Therefore, seeking new business models seems extremely important as they may improve customer satisfaction and experience with the way products are offered to them and, at the same time, bring a number of benefits to entrepreneurs. Product-Service System (PSS) is a combination of products and services to meet specific customer needs and a concept that allows companies to build a competitive edge and supports sustainable development. The created PSS model provides the printing house with tools in the form of services that will eliminate production problems, improve production efficiency, minimize the adverse impact of printing production on the environment and affect the extension of the machine life cycle. (Salwin, et al., 2020)

In addition, Couckuyt (2019) in his analysis on the Printing Industry trends from the Graphics Canada 2019 trade show in Toronto suggested seven trends impacting the business models in the Printing Industry as the "impactful trends percolating into the business world in general and into the Printing Industry more specifically of those key trends that'll remake our (printing) business over the next five years". The trends are presented below:

- Accelerated Convergence of Technology and Business Verticals
- Increasing Consolidation Levels
- Increased Automation
- Shorter Run Lengths and Faster Turnaround Times
- Shift of Skill Set Requirements
- Increased Level of Machine Learning and Artificial Intelligence (AI)
- Management Sophistication

Couckuyt argues further that "in the last decades, the print industry has gone through accelerated technological changes that have fundamentally changed the conventional business model. The digitization of production processes has shifted the pendulum from Graphic Arts to Graphic Science and it is now very common for the printing model to be expanded by adding upstream and downstream services. Upstream, printers are adding web-to-print, design, and data management services. Downstream, printers are adding kitting, fulfillment, and distribution services. Couckuyt concludes his analysis by stating that "The print industry has grown into a complex, sophisticated business. Successfully managing such a diverse and sophisticated business model requires highly skilled teams. Navigating the challenges created by rapid technology changes, increasing environmental demands and a shift in human resources requirements will continue to put pressure on the management skills within the industry". (Couckuyt, 2019)

Finally, Roos (2016), claims that printing industries all over the world have to find new successful strategies and business models. The reason for the necessary changes is based on the ongoing shift from analog to digital production technologies and media products, bringing about new business opportunities on the supply side in combination with changes in the media use on the demand side. The task for printers is to understand which technologies, processes and markets fit best to implement successful business.

Roos (2016) suggests the following direction for consideration as it regards business models in the Printing Industry:

- New successful business models are individual, not limited to new technologies.
- There is an increasing field of printing technology applications outside media.
- IT Innovations are the strategic key for most of the new business models.
- Profit is often related to the control of larger parts of the value chain.
- The work force in the printing industries needs new IT skills for designing processes, skills for global operations and management skills such as Lean Printing.

# 6. Discussion and conclusions: from the theoretical to the conceptual framework for implementing circular economy in printing industry business models

Trying to transform various theoretical and mostly generic frameworks into specific conceptual structures in a particular industrial setting such as the Printing Industry is a rather challenging task. Such study as the one in the present paper is by default a difficult task.

In the paper effort has been given in order to investigate the various concepts that affect printing business and the way that their application influences the business strategies and creates new requirements for business models.

Therefore, a step-by step procedure has been selected for presenting data and evidence on the topic of the characteristics of business models by the application of Circular Economy concepts. Given the limitations of space and time, the present study has been based on a step-by-step procedure. This methodological procedure revealed that printing business is alive and it is evolving not only in traditional fields such as book and packaging despite the digital environment in communication, but it is also expanding into new segments such as industrial and functional printing.

Research conducted, provided evidence that the Printing Industry is already rapidly transforming, with the implementation of various elements ranging from continuous improvement and lean philosophies, to industry 4.0 and the so-called digital transformation at all levels, namely at operation and business, management, technology and production. The current roadmap of the industry is to implement new / advanced business models.

Furthermore, the study concluded that indeed Circular Economy is nowadays the key word summarizing environmental protection, energy efficiency and sustainability. No matter the challenges created by recent global negative issues, Circular Economy is here to stay. The study revealed further that the effective implementation of innovative concepts such as those of Circular Economy in the printing and Packaging Industry, can reach a certain degree of implementation that concerns the print production itself. Cooperation with suppliers (the "before") and end-customers (the "after"), is a prerequisite for an effective implementation of a Circular Economy structure in printing business and production.

Further, the study provided evidence that such business strategies, should be based on the further and dynamic evolution of business models, suitable to accept and enhance the production under the Circular Economy setting. The study revealed that the current evolution of other concepts such as continuous improvement, Industry 4.0 and digitalization / digital transformation, should be considered as parts of a holistic transformation of the printing business and operation. Circular Economy should be considered as an additional parameter in the already complex business environment of the printing, finishing and packaging production industries.

One of the difficulties / obstacles is that, by its nature, Circular Economy needs to be applied from the beginning to the end of a product life-cycle. As a result, it is much more difficult to be implemented in an advanced business model in the Printing Industry in its full dimension. Quite obviously, the reason is that print production is an intermediate part in the life-cycle of a printed matter. And it is true that it was much easier to manage, adapt and implement recycling and energy efficiency policies in the printing and finishing processes.

What Couckuyt (2019) stated in his analysis with his "Upstream and Downstream" structures, can be the way towards Circular Economy integration in the Printing Industry and the transformation of its business models. Circular Economy integration demands efforts from the industry, towards the "before" and the "after" in addition to the core print production.

In other words, companies need to consider materials used in production such as printing substrates, inks and glues and the printed matter after its production in the printing, finishing and packaging production steps, in a totally new mindset, within the Circular Economy structure. Cooperation with suppliers (the "before") and end-customers (the "after"), is a prerequisite for an effective implementation of a Circular Economy structure in printing business. Here ideas should be derived by Two Sides Australia (2022) and the diagram, illustrated in Figure 6.

This mindset provides a roadmap from the theoretical to the conceptual framework for business models on the improvement of business operations. One critical aspect is the possibility of incorporating any new concept that may arise in the future.

Moreover, it is obvious that innovative trends will continue to influence the industry. Such trends can be summarized as follows:

- The Printing Industry is evolving further despite the evolution of the digital world.
- Digitization, digitalization and digital transformation are applied throughout the design, management and production settings of the industry.
- Digitalization is applied in many ways, and the key-issue nowadays is the efficient digital transformation, as a part of the holistic business transformation.
- New technologies and philosophies (such as Industry 4.0 and continuous improvement) are present in the holistic transformation of the printing business.
- Circular Economy and sustainability are definitely key-parameters in present and future evolution of the Printing Industry.

• Business models applied, require a constant restructuring in order to coop with new / additional concepts that need to be integrated in printing business.

As a result, the present study suggests that new/advanced, dynamic and flexible business models are certainly required for the printing, finishing and packaging industries. A first attempt to describe the parameters regarding the characteristics of an appropriate business model for the Printing Industry where future innovations and concepts could be implemented, is presented in Table 2.

Characteristics of business models development for the Printing Industry in relation with the integration of new concepts such as Circular Economy			
Procedure	System / field to be explored, customized and applied		
Operation, leadership, strategy,	Lean Manufacturing / Continuous Improvement		
Technology, design, management, workflow, production	Digitalization / Digital Transformation pplication of Specific Industry 4.0 elements		
Customer, Product, Supplier, Materials, Consumer, End-user	Life Cycle and Characteristics of Printed products		
Circular Economy	Resources, Energy efficiency, Sustainability, Recycling, Waste management		
People and the Human Capital Development	Enhancement of Knowledge with Education and Training, Improvement of Competences and Skills A timeless – ongoing procedure		

Table 2: A suggested multilevel framework for an advanced business model in the Printing Industry

Given the elements presented in Table 2, it is fully understood that there is a particularly high degree of complexity. This occurs because the various fields need to interact smoothly in order to achieve an efficient business operation at all levels and activities.

This framework is by far not complete. Intensive further research is required in an effort to bring all the pieces of the puzzle together – such as continuous improvement, industry 4.0, digital transformation and Circular Economy. Additional parameters need to be considered, such as the various segments of the industry – namely commercial or packaging printing, and paper, carton and flexible printing production. Different specific production segments in the printing companies require a high degree of customization at all fields mentioned in the framework. Last but not least, the it is of high consideration the people and the human capital that should be capable to work in such complex environments. it is suggested that further research should focus in transforming the concepts applied in the Printing Industry with specific elements of advanced business models.

As a final comment, this framework can be considered as a starting point only for printing companies that they want to transform their business and operation with new tools and integrate new concepts such as Circular Economy in their business models.

#### References

Adroit Market Research, 2021. *Books market size & share | industry growth report analysis, 2021–2028*. [online] Available at: <a href="https://www.adroitmarketresearch.com/industry-reports/books-market">https://www.adroitmarketresearch.com/industry-reports/books-market</a>> [Accessed April 2022].

Blogdrupa, 2021a. How far we've come! Workflow automation in 2021. *drupa blog*, [blog] 27 July. Available at: <a href="https://blog.drupa.com/de/workflow-automation-2021-2">https://blog.drupa.com/de/workflow-automation-2021-2</a> [Accessed 25 May 2021].

Blogdrupa, 2021b. Cloud-based print solutions by Kodak and Ricoh. *drupa blog*, [blog] 23 November. Available at: <a href="https://blog.drupa.com/de/cloud-based-print-solutions-kodak-ricoh">https://blog.drupa.com/de/cloud-based-print-solutions-kodak-ricoh</a> [Accessed 25 May 2021].

Bourguignon, D., 2016. *Closing the loop: new circular economy package, Briefing January 2016*. Brussels, Belgium: European Parliamentary Research Service.

Bohan, M., 2017. How Prinect production manager will reshape your business. *heidlebergusa* [online] Available at: <a href="https://newsheidelbergusa.com/author/bohanmar">https://newsheidelbergusa.com/author/bohanmar</a> [Accessed 30 May 2021].

Bondy, C., Peterson, W. and Webb, J., 2015. Breakthrough business model for the printing industry, "Unsquaring The Wheel" introduced by Webb, Bondy, Peterson. *WhatTheyThink*, [online] 20 August. Available at: <a href="https://whattheythink.com/news/75047-breakthrough-business-model-printing-industry-unsquaring-wheel-introduced-webb-bondy-peterson/">https://whattheythink.com/news/75047-breakthrough-business-model-printing-industry-unsquaring-wheel-introduced-webb-bondy-peterson/</a> [Accessed 25 June 2022].

Byström, M., 2020. COVID-19: From impact to action in the packaging industry. In: *COVID-19: From impact to action in the packaging industry*. [pdf] Gent, Belgium: ESKO. Available at: <a href="https://www.esko.com/en/lp/ebooks/follow-up/covid-19-download">https://www.esko.com/en/lp/ebooks/follow-up/covid-19-download</a>> [Accessed July 2022].

Closed loop, 2022. *Pioneering the circular economy*. [online] Available at: <https://closedloop.com.au> [Accessed April 2022].

Couckuyt, A.G., 2019. 7 trends impacting the business models in the printing industry. [Linkedin] 14 April. Available at: <a href="https://www.linkedin.com/pulse/7-trends-impacting-business-models-printing-industry-alec-g-couckuyt">https://www.linkedin.com/pulse/7-trends-impacting-business-models-printing-industry-alec-g-couckuyt</a>> [Accessed 23 July 2022].

Drexler, S., 2016. The 5 Factors of Industry 4.0. *ARC Advisory Group*, [blog] 15 August. Available at: <a href="https://www.arcweb.com/blog/5-factors-industry-40">https://www.arcweb.com/blog/5-factors-industry-40</a> [Accessed 23 April 2022].

e=mc<sup>3</sup>, n.d. *Alex Osterwalder's business model canvas*. [online] Available at: <https://e-equalsmc3.com/alex-osterwalders-business-model-canvas/> [Accessed April 2022].

Elearnmarkets, 2022. Business models – example, types, importance & advantages. *Elearnmarkets*, [blog] 25 June. Available at: <a href="https://www.elearnmarkets.com/blog/what-are-business-models/>">https://www.elearnmarkets.com/blog/what-are-business-models/></a> [Accessed 25 July 2022].

European Parliament, 2015. Circular economy: definition, importance and benefits. *News European Parliament*, [online] 2 December. Available at: <a href="https://www.europarl.europa.eu/news/en/headlines/economy/20151201ST005603/circular-economy-definition-importance-and-benefits">https://www.europarl.europa.eu/news/en/headlines/economy/20151201ST005603/circular-economy-definition-importance-and-benefits</a> [Accessed April 2022].

Eurostat, 2020. Digital economy and society statistics – households and individuals. [online] *Eurostat*. Available at: <https://ec.europa.eu/eurostat/statistics-explained/index.php/Digital\_economy\_and\_society\_ statistics\_-\_households\_and\_individuals> [Accessed 5 February 2021].

Eurostat, 2021. Electricity price statistics: electricity prices in purchasing power standard. [online] *Eurostat*. Available at: <a href="https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity\_price\_statistics#Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity\_price\_statistics#Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity\_price\_statistics#Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity\_price\_statistics#Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity\_price\_statistics#Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics+Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics+Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics+Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics+Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics+Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics+Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics+Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics+Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics+Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics+Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics+Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics+Electricity\_prices\_for\_non-household\_consumers>">https://ec.europa.eu/eurostat/statistics+Electricity\_prices\_for\_non-household\_consumers>">https://ec.e

Faller Packaging, 2020. *Digital supply chain: new ideas for more efficient procurement of pharmaceutical packaging*. [pdf] Available at: <a href="https://www.faller-packaging.com/fileadmin/user\_upload/user\_upload/">https://www.faller-packaging.com/fileadmin/user\_upload/user\_upload/</a> Dokumente/Whitepaper/2021-04-21\_WP\_Digital\_Supply\_Chain\_EN\_FINAL.pdf > [Accessed 25 May 2022].

Fielt, E. 2014. Conceptualising business models: definitions, frameworks and classifications, *Journal of Business Models*, 1(1), pp. 85–105. https://doi.org/10.5278/ojs.jbm.v1i1.706.

Frey, C.B. and Osborn, M.A., 2013. *The Future of employment: how susceptible are jobs to computerization?* Oxford, UK: Oxford Martin School. [pdf] Available at: <a href="https://www.oxfordmartin.ox.ac.uk/downloads/academic/The\_Future\_of\_Employment.pdf">https://www.oxfordmartin.ox.ac.uk/downloads/academic/The\_Future\_of\_Employment.pdf</a> [Accessed April 2022].

Fujifilm, 2022. *Digital print technology for a circular economy*. [online] Available at: <https://print-emea. fujifilm.com/resource/digital-print-for-a-circular-economy/> [Accessed 22 January 2022].

Gamprellis, G., Politis, A.E., Sofias, Y., Tsigonias, A., Vonitsanos, G., Tsigonias, M. and Macro, K.L., 2021. Challenges for the printing industry in the modern digital and meta-pandemic era. In: C. Ridgway, ed. *Advances in Printing and Media Technology: Proceedings of the* 47<sup>th</sup> *International Research Conference of iarigai*. Athens, Greece, 19–23 September 2021. Darmstadt: iarigai. https://doi.org/10.14622/Advances\_47\_2021. Heidelberg, 2022. *Robotics & automation by Heidelberg*. [online] Available at: <https://www.heidelberg.com/global/en/other\_business\_areas/robotics\_by\_heidelberg/robotics\_automation.jsp> [Accessed 27 April 2022].

IFR, 2021. IFR presents World Robotics 2021 reports: robots sales rise again. *International Federation of Robotics*, [online] Available at: <a href="https://ifr.org/ifr-press-releases/news/robot-sales-rise-again">https://ifr.org/ifr-press-releases/news/robot-sales-rise-again</a> [Accessed 23 April 2022].

Intergraf, 2022. *Print's carbon footprint: assessing carbon footprint in the printing industry*. [online] Available at: <a href="https://www.intergraf.eu/about-print/print-carbon-footprint">https://www.intergraf.eu/about-print/print-carbon-footprint</a> [Accessed 29 April 2022].

International Organization for Standardization, 2013. *ISO 16759:2013 Graphic technology – Quantification and communication for calculating the carbon footprint of print media products*. Geneva: ISO.

Ionology.com, 2022. *What is digital transformation?* [online] Available at: <https://www.ionology.com/digital-transformation> [Accessed 24 July 2022].

Irving, K., 2021. Digital transformation vs digitization: what's the difference? <sup>+</sup>*UP*, [blog] 26 August. Available at: <a href="https://www.upthereeverywhere.com/blog/digital-transformation-vs-digitization-whats-the-difference">https://www.upthereeverywhere.com/blog/digital-transformation-vs-digitization-whats-the-difference</a> [Accessed 22 July 2022].

Kholod, D., 2019. 4 principles of the circular economy: do you know them all? *We share ventures,* [blog] 18 March. Available at: <a href="https://medium.com/@we\_share\_ventures/4-principles-of-the-circular-economy-do-you-know-them-all-2c4619b83df6">https://medium.com/@we\_share\_ventures/4-principles-of-the-circular-economy-do-you-know-them-all-2c4619b83df6</a>> [Accessed 21 April 2022].

Kuehn, L., 2022. *Intergraf young talent award 2022: sustainability in the print industry*. [online] Available at: <a href="https://www.intergraf.eu/image/young-talent-award">https://www.intergraf.eu/image/young-talent-award</a> [Accessed 25 July 2022].

Maida, J., 2022. E-book market: 6.04 % Y-O-Y growth rate in 2021 | market size, share, facts & factors. *CISION PR Newswire*, [online] 20 January. Available at: <a href="https://www.prnewswire.com/news-releases/e-book-market-6-04-y-o-y-growth-rate-in-2021--market-size-share-facts--factors-301463965.html">https://www.prnewswire.com/news-releases/e-book-market-6-04-y-o-y-growth-rate-in-2021--market-size-share-facts--factors-301463965.html</a> [Accessed 27 May 2022].

MarketsandMarkets, 2021. *Packaging printing market*. [online] Available at: <https:// www.marketsandmarkets.com/Market-Reports/packaging-printing-market-153207109. html?gclid=CjwKCAjw8ajcBRBSEiwAsSky\_ecQnTHgr4mN972nMDuCrB1C2b4npfF9cDby3B1AvIbF4UwiwTxc\_ BoC\_scQAvD\_BwE> [Accessed 2 February 2021].

Mata Lopez, A., 2022. How Russia's invasion of Ukraine impacts the European pulp and paper industry. *Fastmarkets*, [blog] 7 March. Available at: <a href="https://www.fastmarkets.com/insights/how-russias-invasion-of-ukraine-impacts-the-european-pulp-and-paper-industry">https://www.fastmarkets.com/insights/how-russias-invasion-of-ukraine-impacts-the-european-pulp-and-paper-industry</a> [Accessed 16 April 2022].

McHugh, D., 2022. What does Ukraine invasion mean for energy bills? *USA Today*, [online] 27 February. Available at: <a href="https://eu.usatoday.com/story/money/2022/02/27/ukraine-invasion-russia-energy-bills/6964171001/">https://eu.usatoday.com/story/money/2022/02/27/ukraine-invasion-russia-energy-bills/6964171001/</a>> [Accessed 8 April 2022].

Morales, M.E., Batlles-delaFuente, A., Cortés-García, F.J. and Belmonte-Ureña, L.J., 2021. Theoretical research on circular economy and sustainability trade-offs and synergies. *Sustainability*, 13(21): 11636. https://doi.org/10.3390/su132111636>.

Muller Martini, 2018. Why is print still the anchor for strong media marketing? *Muller Martini*, [online] 11 December. Available at: <a href="https://mullermartini.com/en/newsroom-en/mm-blog/market-trend/why-is-print-still-the-anchor-for-strong-media-marketing/">https://mullermartini.com/en/newsroom-en/mm-blog/market-trend/why-is-print-still-the-anchor-for-strong-media-marketing/</a>> [Accessed 10 February 2021].

Osterwalder, A., 2005. What is a Business Model? *Strategyzer*, [blog], 5 November. Available at: <https://www.strategyzer.com/blog/what-is-a-business-model#:~:text=Written%20by%20Alexander%20Osterwalder%20 on,or%20intends%20to%20make)%20money> [Accessed 25 July 2022].

Osterwalder, A., Pigneur, Y. and Tucci, C.L., 2005. Clarifying business models: origins, present and future of the concept. *Communications of the Association for Information Systems*, 15, pp. 1–25. https://doi.org/10.17705/1CAIS.01601.

Ovans, A., 2015. What is a business model? *Harvard Business Review, 23.* [online] Available at: <https://hbr. org/2015/01/what-is-a-business-model> [Accessed 24 July 2022].

Packaging Europe, 2022. How will the war in Ukraine affect the paper and pulp industry? *Packaging Europe*, [online] 4 March. Available at: <a href="https://packagingeurope.com/comment/how-will-the-war-in-ukraine-affect-the-paper-and-pulp-industry/7947.article">https://packagingeurope.com/comment/how-will-the-war-in-ukraine-affect-the-paper-and-pulp-industry/7947.article</a> [Accessed 15 April 2022].

Panorama, 2019. Momentum on the book market. *Panorama: Muller Martini Magazine*, Fall 2019, pp 6–7.

Pigosso, D. and McAloone, T., 2017. How can design science contribute to a circular economy? In: *Proceedings of the 21st International Conference on Engineering Design (ICED17).* Vancouver, Canada, 21–25 August 2017. Technical University of Denmark.

Politis, A., 2017. The graphic-media communication science – fields, trends and the contribution of research organizations. In: *Scientific conference Evolution Innovation in Graphic-media Science: Research, Industry Innovation and the Role of Education*. Athens, Greece, 22 March 2017. Athens, Greece: HELGRAMED.

Politis, A., 2018. Industry 4.0: what does it mean for the graphic arts industry? In: C. Ridgway, ed. *Advances in Printing and Media Technology: Proceedings of the* 45<sup>th</sup> *International Research Conference of iarigai*. Warsaw, Poland, October 2018. Darmstadt: iarigai.

Politis, A.E., 2022. The print-media science and technology in the modern era. Trends and evolution. 8<sup>th</sup> ICTVC Conference. Thessaloniki, Greece, 5–9 July 2022.

Quincy Recycle, 2020. Closed loop economy: what does it mean and how does it work? *Quincy recycle*, [online] 2 December. Available at: <a href="https://www.quincyrecycle.com/closed-loop-economy-what-does-it-mean-and-how-does-it-work/#:~:text=A%20closed%2Dloop%20economy%20is,the%20creation%20of%20">https://www.quincyrecycle.com/closed-loop-economy-what-does-it-mean-and-how-does-it-work/#:~:text=A%20closed%2Dloop%20economy%20is,the%20creation%20of%20</a> something%20new> [Accessed 25 May 2022].

Roos, A., 2016. Business models and strategy finding for the printing industries. *International Circular of Graphic Education and Research*, 9, pp. 71–82.

Saleforce, 2022. *What is digital transformation?* [online] Available at: <https://www.salesforce.com/eu/products/platform/what-is-digital-transformation> [Accessed 1 May 2022].

Salwin, M., Santarek, K., Kraslawski, A. and Lipiak, J., 2021. Product-service system: a new opportunity for the printing industry. In: V. Tonkonogyi, V. Ivanov, J. Trojanowska, G. Oborskyi, A. Grabchenko, I. Pavlenko, M. Edl, I. Kuric and P. Dasic, eds. *Advanced manufacturing processes II*. Cham: Springer, pp. 83–95.

Selke, S., 2015. On biodegradable plastics. *Packaging World*, [online] 27 September. Available at: <a href="https://www.packworld.com/issues/sustainability/blog/13368637/on-biodegradable-plastics2939">https://www.packworld.com/issues/sustainability/blog/13368637/on-biodegradable-plastics2939</a> [Accessed 10 February 2022].

Sgppartnership, 2022. *Sustainable Green Printing Partnership*. [online] Available at: <https://sgppartnership. org/> [Accessed 28 July 2022].

Smithers, 2021. *How Smithers forecasts the global security printing market to reach \$36 billion in 2024*. [online] Available at: <a href="https://www.smithers.com/resources/2020/april/smithers-forecasts-global-security-printing-market">https://www.smithers.com/resources/2020/april/smithers-forecasts-global-security-printing-market</a> [Accessed 20 July 2021].

Sun Chemical, 2020. *Guide to sustainable packaging*. [online] Available at: <www.sunchemical.com> [Accessed 20 June 2020].

The Brussels Times, 2022. European electricity and gas prices rise 40 % due to Russian invasion of Ukraine. *The Brussels Times*, [online] 24 February. Available at: <a href="https://www.brusselstimes.com/208157/european-electricity-and-gas-prices-rise-40-due-to-russian-invasion-of-ukraine">https://www.brusselstimes.com/208157/european-electricity-and-gas-prices-rise-40-due-to-russian-invasion-of-ukraine</a>> [Accessed 10 May 2022].

Thisisthelatest.news, 2022. *Digital transformation vs digitalization*. [online] Available at: <https://thisisthelatest.news/digital-transformation-vs-digitalization/> [Accessed 24 July 2022].

Two Sides Australia, 2022. *From tree to page*. [online] Available at: <https://twosides.org.au/from-tree-to-page/> [Accessed 29 April 2022].

UNIDO, 2017. New UNIDO report explores potential of Industry 4.0 to accelerate transition towards sustainable energy. *United Nations Industrial Development Organization*, [online] 30 August. Available at: <a href="https://www.unido.org/news/new-unido-report-explores-potential-industry-40-accelerate-transition-towards-sustainable-energy">https://www.unido.org/news/new-unido-report-explores-potential-industry-40-accelerate-transition-towards-sustainable-energy</a> [Accessed April 2022].

Wassermann, K., 2020. The book market fights back. *Muller Martini*, [online] Available at: <https://mullermartini.com/en/newsroom-en/mm-blog/solutions-processes/the-book-market-fights-back/>[Accessed 16 January 2021].

Whattheythink, 2020. European Print Industry Snapshot: Spain. *WhatTheyThink* [online] 3 November. Available at: <a href="https://whattheythink.com/data/103158-european-print-industry-snapshot-spain/">https://whattheythink.com/data/103158-european-print-industry-snapshot-spain/</a> [Accessed 3 February 2021].

Wood, L., 2020a. Global commercial printing market report 2020–2025 assessed by type, application and region. *CISION PR Newswire*, [online] 25 June. Available at: <a href="https://www.prnewswire.com/news-releases/global-commercial-printing-market-report-2020-2025-assessed-by-type-application-and-region-301083732">https://www.prnewswire.com/news-releases/global-commercial-printing-market-report-2020-2025-assessed-by-type-application-and-region-301083732</a>. html> [Accessed 8 February 2021].

Wood, L., 2020b. \$1 billion global packaging industry to 2021 – growing demand for FMCG and pharmaceutical packaging presents opportunities. *Globe Newswire* [online] 12 May. Available at: <https://www.globenewswire.com/news-release/2020/05/12/2031745/0/en/1-Billion-Global-Packaging-Industry-to-2021-Growing-Demand-for-FMCG-and-Pharmaceutical-Packaging-Presents-Opportunities.html> [Accessed 3 February 2021].