Technological forecasting in textile industry: From first to fourth industrial revolution

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ABSTRACT: This paper aims at associating all the Industrial Revolution and textile industry by analyzing the main innovations in production system and machinery, consumption patterns and the importance of this industrial activity in the economy. To achieve this goal, the data collection was based on academic literature researches. Each Industrial Revolution played a fundamental role in the textile production-consumption pattern. The First Industrial Revolution allowed a general mechanization that stimulated the consumption and the necessity for renewal; the Second Industrial Revolution represented the introduction of new power sources and mass-produced goods and the revolution of consumer goods; the Third Industrial Revolution, is characterized by the transition from analog to digital technology and the segmentation of consumer markets; lastly, the Fourth Industrial consists of integrative cyber-physical systems and the consumers are active actors in the production system.

1 INTRODUCTION

The origin of the textile production is closely related to the origin of humanity. Clothing, as well as food and shelter, is considered a basic human need. In addition to this, it is a form of self-expression and sense of belonging that becomes even more important for individuals and social groups (Ha-Brookshire & Labat, 2015).

The textile industry played and still plays an important role in the Industrial Revolution. The textile chain includes raw material, spinning, weaving/knitting, dyeing/printing, confectioning and selling (Ülgen & Forslund, 2015).

Since the First Industrial Revolution, modifications are noticed on production-consumption paradigm and society's organization. Four technological innovations have profoundly changed those dynamics that triggered new eras: the steam engine, electricity, digital revolution and the Cyber Physical Systems (CPS).

Based on this context, this paper aims at associating the Industrial Revolution and textile industry by analyzing the main innovations in production system and machinery, consumption patterns and the importance of this industrial activity in the economy. To achieve this goal, the data collection was based on academic literature researches and it intends to be an additional report to the field of textile research.

2 TECHNOLOGY EVOLUTION FROM 1ST TO 4TH INDUSTRIAL REVOLUTION IN THE TEXTILE INDUSTRY

2.1 First Industrial Revolution

The First Industrial Revolution, between 1760 and 1830, began in Britain and spread through Europe and the United States (Sabo, 2015). The introduction of steam engines allowed a general mechanization that replaced the artisan's savoir-faire and in this period, the coal has begun to replace other fuels, such as wood (Schuh et al, 2014).

The First Revolution was particularly remarkable for the textile industry. In 1733, John Kay patented the flying shuttle, which increased the consumption of weaving goods. Before that, the weaver had to pass the shuttle manually that limited the fabric's width. However, it was only in 1760 that his invention became popular with the
possibility of choosing different colors and types of weft (McNeil, 1990).

James Hargreaves invented the “Spinning Jenny” in 1764, a spinning machine that replaced the method of spinning by hand. According to McNeil (1990), the manual spinning and an accident with his spinning wheel inspired this machine. After 36 years, the number of spindles increased more than fifteen times (Ribeiro, 1984).

Arkwright has many contributions to the textile machinery. First, he patented in 1769 the water frame, a spinning machine that combined the “Spinning Jenny” system, rollers and waterwheel. Second, he patented the carding machine, a “preparatory” system to start the textile production (McNeil, 1990). He noticed that he needed to mechanize all the processes to maintain the workflow, attesting the scenario described by McNeil (1990, p.830) as the “upsurge called Industrial Revolution”.

One of the most important inventions in the spinning process was the introduction of the “spinning mule” in 1779 that allowed the production of a high quality yarn. At this point, the manual spinning was completely replaced by the industrial method (Ribeiro, 1984; McNeil, 1990).

Joseph-Marie Jacquard, in 1801, combined earlier invented mechanisms to develop the Jacquard machine. He also invented the perforated cards that later were considered the foundation for the punched cards used as an external storage for computers (McNeil, 1990).

One consequence of the First Industrial Revolution was the social division between capital and labor (Troxler, 2013). According to Castells (2010), the labor was classified as generic, once the individuals were deskilled and reproduced the same tasks without any additional information or instruction.

The expansion of the textile industry stimulated the consumption and the necessity for renewal, in a so-called “consumer revolution” phenomenon (Flacher, 2005). This consumption pattern involved the elementary needs, specially clothing and feeding, that later was described by Maslow (2015) as the physiological needs.

2.2 Second Industrial Revolution

The transition to the Second Industrial Revolution took place between the 19th and 20th century in which the use of electricity had a significant impact on the industrial productivity (Schuh et al, 2014; Sabo, 2015). The classic example of this period was the mass production system implemented by Henry Ford in 1910. This revolution began not only in the USA but also in Britain and Germany. Moreover, another important factor in this change was the technological development of Japan and further growth in the population’s quality of life (Sabo, 2015).

In the textile industry, the Second Industrial Revolution represented the introduction of new power sources. The keyword was efficiency, and various changes took place.

John Thorp replaced the flyer by a traveler that slides round a ring and created a new spinning method: the ring frame. It appeared first in America and then spread to Europe; the most important characteristic of this machine was the possibility of spin a greater range of fibers and the combination of some preparatory processes in one (Ribeiro, 1984; McNeil, 1990).

The power loom has been developed since the First Industrial Revolution; however, it was only in the 1830s that the number of powerlooms increased. At this moment, it was possible to produce complex patterns, velvet, carpet and toweling (McNeil, 1990).

A circular knitting machine was patented in 1816; some years later, in 1847, the tubular fabric became more fashionable due to the Rib pattern. In 1856, the invention of the latch needle by Townsend has simplified the hand-tufting process. Later, in 1864, William Cotton adapted a power-driven machine able to knitting few stockings simultaneously (McNeil, 1990).

One of the first mass-produced goods was the sewing machine. Although it was invented earlier, Isaac Singer patented the first domestic sewing machine in 1851, which has dramatically changed the consumption and production of clothes. Later, the sewing machine was adapted to different products, such as footwear (McNeil, 1990).

A concept strongly related to the Second Industrial Revolution is the mass-production. Mass production is a manufacturing project based on “power, accuracy, economy, system, continuity and speed” (Batchelor, 1994, p.5).

Many important aspects changed the consumption pattern. The “revolution of consumer goods” (Flacher, 2005) analyzed the consumer behavior as a continuous flow from the First Industrial Revolution that moved to an interconnected world and ended in World War and Great Depression. The author affirms that despite of the crisis, the consumption level was still increasing due to the new lifestyle that involved a better education and housing conditions and the importance of the leisure time.

2.3 Third Industrial Revolution

The Third Industrial Revolution, also known as digital revolution, is characterized by the transition from analog to digital technology with the invention of integrated circuits that supported the increasing computing capacity and lower production costs. In consequence, there was a wide adoption of Information Technology (IT) in industry.
and a relevant impact on the growth of global economic until today (Schuh et al., 2014).

The microprocessor, computer-aided design and manufacturing, fiber optics and telecommunications, biogenetics and laser-holography are seen as the major technology agents that changed the industrial dynamics (Finkelstein & Newman, 1984).

The “mass consumption revolution” was a convergence of standards through “a homogenization of consumption patterns” (Flatcher, 2005, p.8). In this context, the globalization plays a key role due to the flexibility, the lean management concept, the use of information technology, the segmentation of consumer markets, and autonomous financial markets and institutions (Kofman & Youngs, 2003).

According to Flatcher (2005), this period is characterized by the consumption of non-commercial goods mainly related to safety and love/belonging needs (Maslow, 2015).

McNeil (1990, p.42) affirms that “the brainwork is taken over by the electronic machine, the computer”, and the consequence of a networked production system is flexibility and mass customization, a concept that combines large quantities with individualized items according to the user (Davis, 1989; Fralix, 2001; Troxler, 2013). The mass customization depends on the information about consumer, product development process, product life cycle, producer capability, and available technology (Fralix, 2001).

Fralix (2001) points that garment fit and color are two limitations for the adoption of mass customization in the textile industry. Technological solutions such as body scanning, 3D modelling, and digital printing are gradually being part of the production scenario.

2.4 Fourth Industrial Revolution

In the last 20 years, Internet has changed the way people communicate. The first era (1995), Internet was an integrated hypermedia, in the second era (2000) Internet had a programming media approach, that changed to people’s web service in the third era (2005), and the fourth era—which encompasses nowadays—represents a new level of organization and management of the entire value chain on the products’ life cycle (Schuh et al., 2014).

The Fourth Industrial Revolution, namely Industrie 4.0, is an integrative cyber-physical system based on modern control systems, embedded software systems and Internet addresses (Anderl, 2015).

According to the German Academy of Science and Engineering, the Industrie (Industry, in German) 4.0 corresponds to the new industrial revolution. The Industrie 4.0 is not only a technical challenge but it will also change the industries’ organizational structure.

The Fourth Industrial Revolution is assessed a priori, not ex-post, which means a prediction of what is to happen, and not an assessment of what has passed (Hermann et al., 2015). Once the first studies were in Germany, the term Industrie 4.0 in the original language will be adopted in this paper.

The main goal of Industrie 4.0 is to improve the value chains among the product’s lifecycle. In this context, the improvement of industrial competitiveness is achieved by organizing and controlling value, new business models and networks creation process (Anderl, 2015).

The result of the Fourth Industrial revolution will be the Smart Factory, where Cyber Physical Systems (CPS), Internet of Things (IoT) and Big Data are the key technologies for achieving the production goals.

The Cyber Physical Systems (CPS) are technical systems containing both virtual (cyber) and real (physical) systems. By “cyberizing the physical” and “physicalizing the cyber” (Lee, 2010) it is possible to specify physical subsystems with software-controlled behavior (Anderl, 2015).

The Internet of Things (IoT) is an approach to equip real systems with embedded systems so that they become interconnected in the so-called “smart systems” (Anderl, 2015).

Data exchange is the foundation for the Industrie 4.0; thus, the amount of data generated must be efficiently integrated during the product development process among the stakeholders. Big Data include information from a multitude of sources, and emphasize a change in data quality and not only quantity (Chandler, 2015).

In a smart factory, humans, machines and resources communicate with each other as easily as in a social network (Sabo, 2015; Kagermann et al., 2013).

3 TECHNOLOGICAL FORECASTING IN TEXTILE INDUSTRY

In the contemporary’s competitive environment, the product development process includes technological tools, the need for rapid decision-making, analytical tools, high productivity and lower cost, demand for functional products, and social and environmental responsibilities (Lu et al., 2007). The consumer needs and desires are mostly related to four concepts: speedy, smart, slim and sustainability (QFDI, 2015).

Once the future working place will be digital and flexible, a company must be data-driven and open-minded to innovation. Regarding the labor skills, Gorecky et al (2014) argue that unlike the occurred in the previous Industrial Revolution—in which machines replaced workers—the Fourth Industrial
Revolution calls for a greater integration between man and cyber-physical systems in a way that their individual skills can be fully utilized and they will act in a wider area of expertise. Castells (2010) describes this labor model as "self-programmable labor".

The Fourth Industrial Revolution forecasts a smart product and smart machines. A smart product contains information about its production processes, communicates with the production chain, and decides what steps to take. A smart machine predicts failure or quality problems, organizes the decision-making process and self-optimization (Gölzer et al, 2015).

In this context, all industrial elements will be equipped with data processing able to communicate with each other that will compose a more complex process management. The Fourth Industrial Revolution foresees the need for connection between all information flows.

One interesting aspect is the change in the product lifecycle with the inclusion of sustainability as a design requirement. The increasing environmental awareness modifies the consumer behavior. Consumers are active actors in this scenario, and the purchase decision will be based on the initiatives of companies.

The trend of sustainability and information technology is analyzed through the Kondratieff long waves and Industrial Revolutions. The 6-Kondratieff waves (K-waves) are a forecast of the future growth based on society's indicators (Mohajan, 2015). In turn, the Industrial Revolutions are recognized by promoting changes in the production process, social dynamics and global economic structure, as shown in Figure 1 (Kagermann et al, 2013).

Both theories present the changes in production paradigm when an event interferes in the current system by disorganizing and reorganizing it in order to create new patterns (Rodrigues et al, 2016).

The 6th Kondratieff’s wave corresponds to the age of the sustainable technologies that advocates the incorporation of social and environmental requirements (Mohajan, 2015). The Fourth Industrial Revolution is also in this age; consequently, it can be inferred that the 6th wave could induce the adoption of sustainable practices in the 4th Industrial Revolution.

Kagermann et al (2013) suggest that the technological tools will support the remote tracking of an entire production chain and the environmental impacts throughout the design process.

Cheng (2015) suggests the alignment of the Fourth Industrial Revolution with sustainability by adopting the 17 goals described by the United Nations (Sustainable Development Goals—SDGs) to be met by the year 2030.

Once ethics, environmental and social impacts are directly related to the production processes, and the K-waves emphasize this trend, they represent an ongoing movement that should be considered as an active part in the contemporary society (Honoré, 2009).

Bruno (2016) describes the future of production-consumption paradigm as the end of advantages of low-cost labor in the production system, intensive use of ubiquitous technology and new production systems (mini-factories, digital factories, 3D printing).

The future trends on textile and apparel production is the increasing in the labor skill level, new production technologies, pressure from consumers towards an environmentally production, and international campaigns for better work conditions (Allwood et al, 2006).

In the textile machinery, Gloy et al (2013) suggested a new configuration that changes the conventional textile industry to a flexible factory in which machine communicates through IoT platform its real-time status and upcoming problems. In addition, the same IoT platform could guide the consumer through a mobile app for the use-phase (washing, e.g.) and disposal, two critical phases in a textile life cycle assessment.

Although Kagermann et al (2013), Schwab (2015) and Cheng (2015) agree that the Fourth Industrial Revolution can generate a truly global culture that will lead to a more inclusive, sustainable and harmonious society, the inclusion of developing countries is still a challenge (Cheng, 2015; Chakravorti, 2016).

4 CONCLUSIONS

The First Industrial Revolution allowed a general mechanization that stimulated the consumption and the necessity for renewal; the Second Industrial Revolution represented the introduction of

Figure 1. The Four Industrial Revolutions (Kagermann et al, 2013).
new power sources and mass-produced goods and the revolution of consumer goods; the Third Industrial Revolution, is characterized by the transition from analog to digital technology and the segmentation of consumer markets; lastly, the Fourth Industrial is an integrative cyber-physical system and the consumers are active actors in the production system. By looking at the inventions of each Industrial Revolution, it is noticed that they played a fundamental role in the textile production-consumption pattern. The predictions of the ongoing Fourth Industrial Revolution, unlike the other Industrial Revolution, are a challenge. However, it is possible to notice that some deep changes will be required on production and business models due to an active and engaged consumer.

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