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Dr. Misagh HAJI AMIRI

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[1]İbn Haldun Üniversitesi, Lisansüstü Eğitim Enstitüsü, işletme bölümü, İstanbul, Türkiye. msghamiri@email.com, Orcid ID:0000-0001-7227-3372

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TÜRKİYE TR: +90 342 606 06 75
USA: +1 631 685 0 853
E mail: iksadyayinevi@gmail.com
www.iksadyayinevi.com

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INTRODUCTION

One of the fastest-growing topics among academics is the digital revolution or Industry 4.0, which refers to the ongoing fourth industrial revolution due to the digital technology leap and pace of innovation (Okano, 2017). However, the impact of this phenomenon on the service sector, especially the food service industry, is understudied and demands extra attention (Bullinger et al., 2017; Shamim et al., 2017). Internet of things (IoT), cyber-physical systems (CPR), and real-data processing are the main topics that define the main concept of industry 4.0 (Okano, 2017). These topics may not seem very relevant to the food service industry, but in fact, their core aspects have already found their way to restaurants and cafes. For example, IoT technologies, which have the ability to embed connectivity into any intelligence device, are making a huge impact on the speed and performance of restaurants and cafes, from placing orders and pouring drinks to managing inventory and entertaining customers (Intel, n.d.). Even the futuristic approach to restaurant automation through robots and artificial intelligence (AI) is making their place not just in people's imagination but also in the actual kitchen of the restaurant for good reasons (Pieska et al., 2013).

We are living in the digital era where enterprises that neglect to adopt innovative technologies are vulnerable to falling behind their competitors, and no industry is an exception to this notion. Digital options are transforming how businesses are being done in all sectors, even those traditionally reliant on the human workforce. The food service industry, specifically restaurants and cafes, is currently undergoing a transformation (Sivalingam, 2019).

According to a study done by the consultancy company PricewaterhouseCoopers in 2018, 73% of activities performed by humans in accommodation and food service sectors have the potential for automation (Hawksworth et al., 2018).

Every day, more people upgrade their devices to "smart" versions. Today's customers are connected more than ever. It is estimated that by 2020, more than 44% of the European population will have grown up with digitization (Preveden & Tiefengraber, 2016). According to the National Restaurant Association of United States, 32 % of 18-34-year-olds stated that technologies such as mobile apps, tablets, and online and electronic ordering factor into their choice for selecting a quick service restaurant (National Restaurant Association [NRA], 2016a). The ongoing digital revolution and new technologies that it brings can create more interconnectivity leading to greater communication, which is crucial for businesses such as restaurants and cafes (Benjamin, 2018).

Studies in the hospitality and food service industry indicate that technologies such as robotics and artificial intelligence (AI) can have financial and non-financial benefits for travel, tourism and hospitality companies (Ivanov & Webster, 2017). Adopting a relevant technological system can bring potential benefits to a restaurant by increasing the speed of service, reducing processing costs, increasing volume and revenue and improving service and food quality (Dixon et al., 2009; Kimes, 2008). Technologies such as smart oil management, robotic, cloud-based systems, tabletop technology, and smart inventory systems are just a few examples of features that can be applied to a foodservice business in order to operate more efficiently in a very controlled environment (Intel, n.d.). For example, a restaurant with tabletop technology, and integrated tables with touchscreen features can significantly reduce dining time by 30% just by allowing their guest to order and pay through such systems (Susskind & Curry, 2018). In addition, new technologies and innovations not only can increase the performance of restaurants and allow them to operate faster and smother but also bring uniqueness to a business, which can attract more customers, especially millennials who are seeking for innovation and new ways of doing things (Cross, 2017). For instance, a hamburger-making robot by the name Flippy was so popular on its first day at a restaurant in Los Angeles that could not keep up with the demand and it was forced to take a break (Graham, 2018).

The service industry is the most important industry in the Turkish economy. According to the Annual Industry and Service Statistics of TurkStat (Turkish Statistical Institute), 43.2% of the active enterprises in 2017 were operating in the service sector only. In addition to that, the service industry in Turkey has the highest share of the labor force which is 36.8% of the total employment in the country. Accommodation and food service activities play an important role in the service industry and comprise

2.6% of Turkey's total gross domestic product (GDP) in 2016 (Turkstat, 2016). Meanwhile, a survey done by Turkish Statistical Institute shows that internet usage of individuals was 72.9% in 2016 and purchasing food and groceries took the fourth rank among e-shoppers in Turkey (Turkish Statistical Institute, 2018).

There are over 3,800 hotels, 5,000 catering companies, and over 200,000 restaurants and cafes in Turkey, alongside 360 shopping malls featuring food courts. (Atalaysun, 2017). These facts illustrate the importance of the service industry and especially the food service industry for Turkey. Moreover, the hospitality sector and especially the restaurants industry has always been facing major challenges such as a lack of qualified workforce, a high rate of employee turnover, a high rate of operational mistakes, and theft (Demicco et al., 2013; Kuo et al., 2017; Mathath & Fernando, 2017). These challenges and many others can be addressed by applying the right type of technology solutions. As a result, staying relevant to currently available technology and providing better service for customers with the help of recent technologies and innovations is crucial in order to face existing challenges in this industry.

INDUSTRIAL REVOLUTIONS, TECHNOLOGY AND ECONOMY

In order to fully understand the concept of industrial revolutions, it is essential to examine the history of Industrial Revolutions and how they evolved from the past to the present time. To do so, first, we take a look at industrial revolutions as a whole and later, we examine each industrial revolution one by one. Industrial revolutions started at a certain point in history, and they have kept happening since then. These events take a few decades to develop from beginning to end, and after each time, they bring radical positive changes to the overall quality of human life that cannot be ignored (De Vries, 1994). Perhaps the first person who noticed these patterns was Nikolai Kondratiev. He was a Soviet economist who attracted the attention of the world by analyzing the macroeconomic performance of leading economics of that time, which were the UK, USA, France, and Germany, between 1790 and 1920 (Tichy, 2011). Kondratiev stated that these economies went through similar cycles or waves that range between 40 to 60 years and contain alternating intervals between high sectoral growth and intervals of relatively slow growth (Kondratiev, 1935). This behavior is shown in Figure 1.

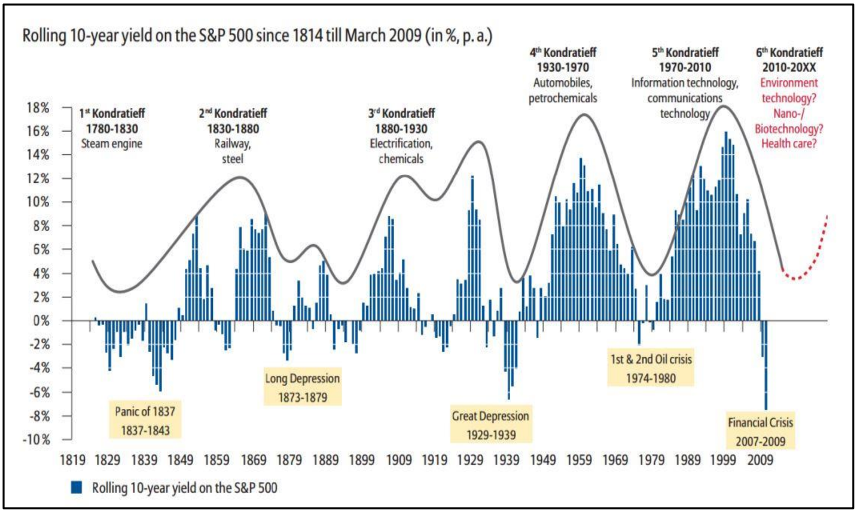

Figure 1. Kondratiev Waves from past till present
Source: (Tichy, 2011)

Kondratiev explained these economic behaviors are caused by changes in technology, wars, the birth of new countries, and the fluctuation in the production of gold (Kondratiev, 1935). Later, Joseph Alois Schumpeter, considered one of the leading economists of the 20th century, perfected Kondratiev's idea with his theory of "Economic Development and Disruptive Technology" (Emami-Langroodi, 2017). Schumpeter added some internal factors such as political reasons, economic status and social factors to explain those cycles that he named "Kondratiev Waves" (Tichy, 2011). Schumpeter was also the first person to claim that these waves were the effect of big innovations such as steam power and electricity that cause a significant change in the world's economy and caused the Industrial Revolutions (Tichy, 2011). Later, he stated his theory of Creative Destruction based on that, and today, the world knows him as a man who discovered capitalism (Emami-Langroodi, 2017).

As illustrated in Figure 2, the Kondratiev waves have 4 phases: expansion, deflationary growth, recession, and stagflation; that is the turning point between expansion and deflationary growth.

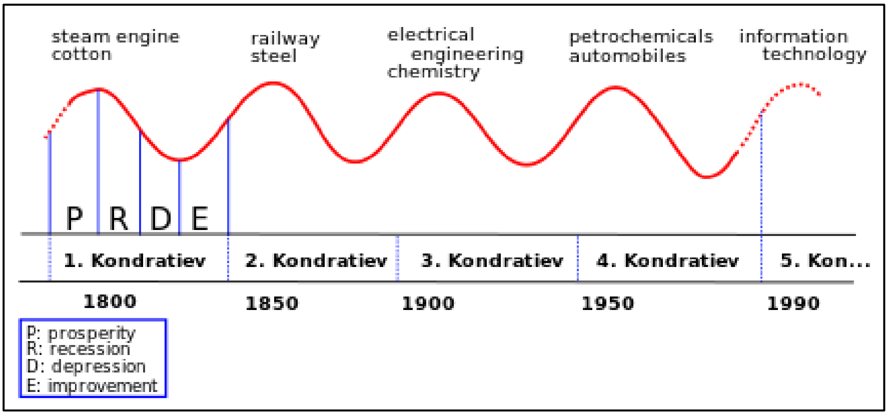

Figure 2. Stages of Kondratiev Waves
Source: (Cavusoglu, 2015)

Almost all industrial revolutions followed such wave characteristics, and in fact, the world is in the latest wave, which was caused by the innovation of the internet and its fast expansion in today's life (Cavusoglu, 2015). The industrial eras will be defined in detail in the following sections.

First Industrial Revolution

The first Industrial Revolution (Industry 1.0) started in the 1760s with the invention of steam power and it took almost 70 years to develop completely. Since this phenomenon started in the United Kingdom, it is also known as the British Industrial Revolution but soon enough, it spread all over the world (De Vries, 1994). In this period, the production cycle evolved from physical human strength to machine power, resulting in higher quantity and improved quality. This dramatic change in production made a huge impact on the structure of the world economy and its growth, for the first time in history. In fact, Angus Maddison (2007), who considered as one of the best economic historians, states that there was almost no growth in the world for about eight centuries until the British Industrial Revolution (Figure 3). Before that, Countries were rather similar and most of the people were poor and lived in agricultural environments.

After that point, income started to rise and this process spilled over continental Europe and into what Maddison called "European Offshoots" which are the United States of America, Canada, and Australia (M. Spence & Hlatshwayo, 2011).

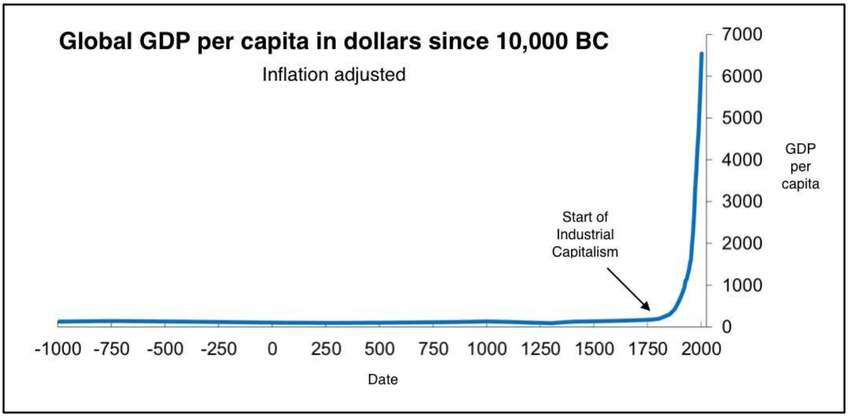

Figure 3. Average Global GDP since 10,000 BC
Source: (M. Spence & Hlatshwayo, 2011)

The first industrial revolution not only had a significant role in the world economy but also in its social structure. After that point, everyday life became significantly easier, which lead to a better quality of life and an increase in population and the average length of life. As the first Industrial revolution proceeded its journey, European countries turned to Near, Middle, and Far East countries that, resulting in more sources, production and higher trade among their markets. At the end of the first industrial revolution, not only the industrial aspect of human life evolved but also its social and international relations were shaped as well (De Vries, 1994).

Second Industrial Revolution

The second Industrial Revolution does not happen immediately after the first one. Although it usually dates between 1870 and 1915, some of its characteristics started in 1850 (Mokyr, 1998). In general, the second industrial revolution, or Industry 2.0, accelerated the mutual feedback between science and technology. It extended the limited and localized achievements of the First Industrial Revolution to a much broader range. The purchasing power of money for the middle and working class increased rapidly, leading to higher living standards (De Vries, 1994). The second industrial revolution turned the large technological system from exceptions to commonplaces. Basically, Industry 2.0 was a chain of innovation and success that led one to another and the final result of them was mass production and abundance of products. Electricity was the most important innovation of that era, which was superior to steam power and ensured that the machines are further advanced for mass production. Electricity made the production of steal cheaper and easier which lead to its mass production and expansion of railroads that allowed products and raw materials to move much faster for long distances. Meanwhile, the telephone or “talking telegram” was invented, which was a huge step by the means of communication. There were also some achievements in other sectors such as agriculture and food processing, household technology and human welfare but they were not as significant as those mentioned. These innovations and achievements led to heavy industry development and prepared the way for the upcoming industrial revolutions (Mokyr, 1998).

Third Industrial Revolution

After World War II, the world was ready for its Third Industrial Revolution in the 1960s. This industrial revolution was directed by the shift of mechanical and analog electronic technology to digital electronics. It all started with the development of digital technology and the invention of an electrically driven mechanical calculator that led to basic modern computers. This was a huge step in the development of communication technologies along with supercomputers. For the first time in history, the man was capable of solving multiple and complex problems in a very short time which allows him to reach beyond its imagination. At the same time, new types of energy such as nuclear, wind, thermal and solar were emerging to decrees the level of dependency of humans on oil and other fossil fuel energies. The turning point in this era was the discovery of the internet, which connected the world more than ever and resulted in an explosion of knowledge that led to numerous innovations in almost all sectors. Fields such as nanotechnology, biotechnology, artificial intelligence (AI), robotics, quantum computing, and 3-D printing are the most recent and still advancing topics that are the result of this breakthrough technology (Rifkin, 2012).

Fourth Industrial Revolution

The term "Industry 4.0" was introduced for the first time in 2011 at the Honnavor Trade Fair, and it originated from a project related to the high-tech strategy of the German government. Experts suggested that the modern industrial revolution arrived in the information era, and when the German government took these suggestions seriously, the fourth industrial revolution, in the name of Industry 4.0, was established. After the trade fair, a working group on Industry 4.0 was formed. One year later, the group presented the final report on the actual implementation of Industry 4.0 to the German government at the Hannover Fair in 2013 (Okano, 2017).

Industry 4.0 contains a vision for tomorrow's manufacturing, where products find their way independently through the production process (Moavenzadeh, 2015). Intelligent factories, machines, and products communicate with each other and cooperatively drive production where raw materials and machines are interconnected within the Internet of Things (IoT). The objectives of Industry 4.0's vision are highly flexible, individualized, and resource-friendly mass production (Deloitte, 2015).

Three paradigms can explain the core aspect of Industry 4.0 according to experts (Okano, 2017; Weyer et al., 2015); the smart product, the smart equipment or machine, and the augmented operator. The smart product refers to the role of the final output as an active role of a system that has a memory and collects data and information after production. The second paradigm refers to smart equipment that uses edge technology and sensitive sensors in an interconnected platform to operate side-by-side with humans. Such a platform is described as a Cyber-Physical Production System (CPPS). The last paradigm, which is the augmented operator, targets the worker who needs to operate in the explained environment while providing the required technical support to that environment (Weyer et al., 2015).

Characteristics of Industry 4.0

Industry 4.0 can be considered the next generation of manufacturing digitalization, enabling firms to customize their output at a lower cost and with better quality. Such smart businesses with a high level of automation and efficiency can vary widely from one industry to another; however, they share some mutual specifications and characteristics (Nilsen & Nyberg, 2016). Literature research reveals that there are four main characteristics for defining Industry 4.0; vertical networking of smart production, horizontal integration through value chain network, end-to-end engineering, and exponential technologies (Deloitte, 2015; Nilsen & Nyberg, 2016) (Figure 4).

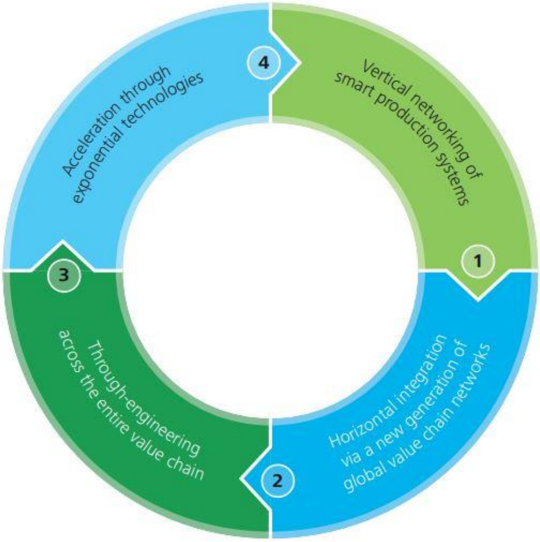

Figure 4. The four characteristics of Industry 4.0
Source: (Deloitte, 2015)

The first main characteristic of Industry 4.0 is the vertical networking of smart production in a factory. This characteristic can be achieved by connecting machines and devices within a system inside the firm that it is highly dependent on information sharing through sensors, control systems, and cloud-based solutions. Such a system is called a Cyber-Physical Production System (CPPS) or Cyber-Physical Production (CPS), which allows the production of customer-specific and individualized products.

CPS creates an autonomous organization of production management that increases a firm's performance and resource efficiency (Deloitte, 2015).

The second main characteristic of Industry 4.0 is horizontal integration via a new generation of the global value chain. This means that a firm should consider itself as a part of a global value chain network and position itself accordingly (Nilsen & Nyberg, 2016). Various departments of a firm, such as a warehouse, R&D, purchasing, production, and sales, cannot only monitor and exchange product data in real time but also access the history of any part or product at any time. This enables integrated transparency within the firm and achieves a high level of flexibility that allows it to respond more rapidly and accurately to problems and challenges that occur within an organization or market. Moreover, this kind of horizontal integration facilitates global optimization and generates completely new business models and new models of cooperation in the future (Nilsen & Nyberg, 2016).

The third main characteristic of Industry 4.0 is lifecycle management and end-to-end engineering through the entire value chain. Engineering the product life cycle to obtain a model is an achievable goal with the help of rapid development within the area of virtualization and communication. Designing and developing new products or services need seamless engineering through the product lifecycle. This coordinated production system enables new synergies to be created between product development and the production system itself (Deloitte, 2015).

The last and fourth characteristic of Industry 4.0 is the impact of exponential technology on industrial processes. This characteristic can be considered the most important one because it helps and feeds other characteristics of Industry 4.0 by acting as an accelerant or catalyst (Deloitte, 2015). For example, advanced robotics and sensor technology, with the help of Artificial Intelligence (AI), have the potential to allow individualized solutions, flexibility, and cost savings for industrial processes. Another good example is additive manufacturing or 3D printing, which allows new manufacturing solutions and new supply chain solutions, or a combination of both, to create new business models (Nilsen & Nyberg, 2016).

FOOD SERVICE INDUSTRY AND TECHNOLOGY

The evolution of food service technology from low-tech to high-tech has a very long history. The turning point started in the 1990s with the introduction of new packaging systems and the convenience/availability of high-tech devices in the kitchen, which allowed the development of new, highly effective business models into the market (Pantelidis, 2009). The rapid leap and development in digital technology raise the question of how these technologies will enhance and improve customers dining experience in the coming years. People in the field believe that there is emendous scope for revolutionizing the experience and even behavior of our eating and drinking by means of the intelligence marriage of dining with the latest digital technology (Spence & Piqueras-Fiszman, 2012: 311).

New technologies and innovations not only can increase the performance of restaurants and allow them to operate faster and smother but also bring uniqueness to a business, which can attract more customers, especially millennials who are seeking innovation and new ways of doing things (Cross, 2017). Literature review indicates that there are various studies that show applying the relevant type of technology for proper restaurants can be beneficial for the business in topics such as; revenue, efficiency, speed, quality of service, management, customer satisfaction, and safety (Dixon et al., 2009; Frontline, n.d.; Kansakar et al., 2017; Kimes, 2008; H.-Y. Wang & Wu, 2014). Adopting a relevant technological system can bring potential benefits for a restaurant by increasing the speed of service, reducing processing cost, increasing volume and revenue and improving service and food quality. Systems such as kitchen display systems (KDS) and table management systems can result in advancing food production and tightening service time while communications technologies and handheld devices can reduce the order-taking time and shorten payment (Kimes, 2008). Technologies such as Self-Service Technology (SST) enable customers to consume different benefits and services on their own, independent of the involvement of an employee at a company, which results in an increased level of satisfaction in customers, lowering costs and creating brand loyalty for the business (Kincaid & Baloglu, 2008). Self-service technologies and off-site ordering/reservation systems will assist staff and can result in lowering labor costs in the restaurant. Moreover, online reservations or ordering makes the restaurant more accessible to customers, which results in higher revenue for the restaurant (Kimes, 2008).

According to Spence (2014), there has been an enormous growth in modernist cuisine in recent years that relied on the development and use of new technologies in the kitchen. Although one may see the major use of such technologies in press releases or news stations, various technologies have already found their way unannounced in many restaurant environments (Spence & Piqueras-Fiszman, 2014: 312).

The level of technology does not necessarily need to be very high or complex to provide a unique dining experience. A good example to illustrate this point is a famous seafood dish called "The sound of the sea" served in The Fat Duck restaurant in Bray, UK. This dish has been a signature of this successful restaurant for so many years. The stylish dish with a seashore theme comes with an empty seashell that has iPod earphones (Figure 5). The iPod plays a soundscape of crashing waves and seagulls that a London-based sonic design agency developed. Such simple technology involvement with the perfect dish has the potential of transforming dining into a strong emotional experience for some people (Spence & Piqueras-Fiszman, 2012: 315-316).

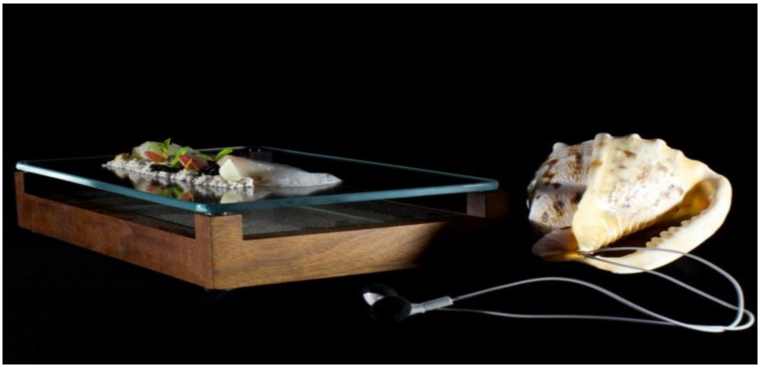

Figure 5. The dish "The Sound of the Sea" in "The Fat Duck Restaurant"
Source: Spence (2014)

Restaurant technology can also come with Human-Computer Interaction (HCI) as a form of food-related augmented reality (AR) or virtual reality (VR). Although it may seem like a weird and strange concept for a dining experience, it has attracted a growing amount of research in the

Human-Computer Interaction community over recent years (Tanaka et al., 2011). For instance, "Chewing Jockey" is a decent food-related augmented reality (AR) that enhances the eating experience by creating or filtering sound effects with jaw motion (Figure 6). This system consists of three main elements for designing/filtering sound effects: bite detection and self-feedback. The creators of Chewing Jockey believe their creation can enhance the eating sensation for denture users or those who are not able to bite strongly because of their medical condition. They also claim that their device can be used for entertainment and a chewing game experience, such that when the user starts to chew, they will hear sounds (e.g., screaming) that make the food feel like a living creature inside the user month. Alternatively, it can make the sound effect of super crispy potato chips for each bite (Koizumi et al., 2011).

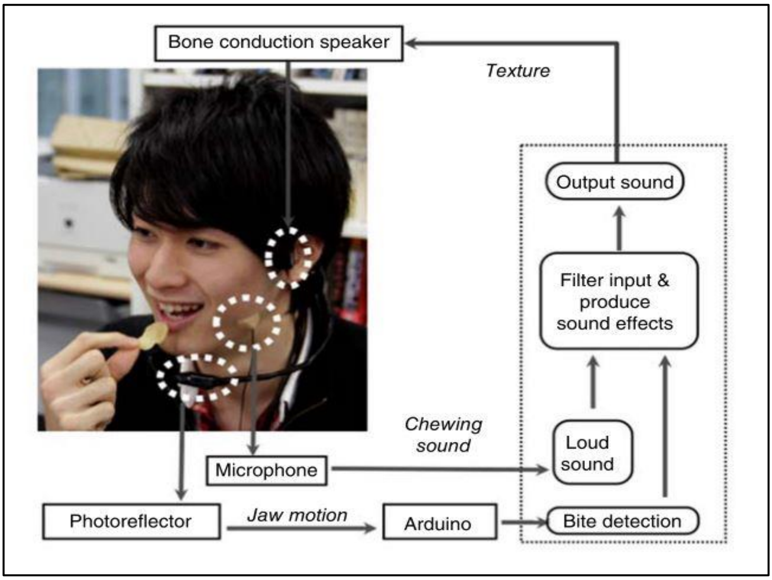

Figure 6. Chewing Jockey, an augmented reality device
Source: (Koizumi et al., 2011)

Benefits of Technology for Customers and Guest Experience

Technology systems in a restaurant can benefit customers by improving their dining experience. Improved convenience and increased control are the two main benefits of technology for customers in a restaurant. When customers are provided with more substantial control over their provided service, they are more likely to be satisfied (Dixon et al., 2009). Increased control of customers in a restaurant can appear as behavior control, cognitive control, and decisional control. Behavioral control relates directly to customers' influence and power to modify their service. For example, customizing orders and choosing the time of serving at the desired table can enhance behavioral control for customers in the restaurant. Cognitive control concerns the predictability of a situation for customers in the restaurant. For instance, providing the estimated time for delivering a service to customers can enhance their cognitive control over their provided service. Decisional control is the degree of freedom that customers can have by choosing among a selection of outcomes and goals. For example, the paging system can give options for customers who are waiting to be seated whether to stay in the restaurant or leave and return when their table is ready (Dixon et al., 2009; Kimes, 2008)

Effect of Technology on Dining Experience

Depending on the dining stage, technology can play an important role in the dining experience in restaurants. Various types of technology can be applied to enhance the management of the customer dining experience. In general, the dining experience consists of six stages (Kimes, 2008):

- Pre-arrival: The time period from when customers decide to go to a restaurant until they actually arrive at the restaurant
- Post-arrival: The time period from the arrival of customers until they are seated at their table
- Pre-process: Time period from when customers are seated until they place their order
- In-process: Time period from when customers receive their order until they ask for their cheek
- Post-process: Time period from when customers request a check until they leave the restaurant
- Table turnover: The time period from when customers leave their table until the table is reseated again

Each stage of the dining experience can benefit from technology systems specifically designed to enhance the restaurant's performance. During the pre-arrival stage, the restaurant should provide options such as preordering (whether online or with a phone call) and online reservation/ordering in order to give customers more control over managing their time. The goal of the post-arrival stage is to minimize the waiting and seating process for customers or at least make it predictable. Table management systems (TMS) and communication systems provide tools for restaurant operators to achieve these goals. With the help of such technologies, restaurant managers can track when tables are available and accurately specify the waiting times. Moreover, it allows managers to determine the table that best fits the party and customers' preferences. The pre-process stage can benefit from two primary technologies, handheld devices and communication systems, which allow for the speeding up of ordering time. Handheld order-taking technology is specifically designed to reduce order time and improve the quality of service provided by allowing servers to give more attention to customers and provide them with more detail and information on items that are being ordered. During the in-process stage, technologies such as kitchen display systems (KDS), TMS, communication, and paging devices can control the pace at which the meal is prepared and ensure that orders are prepared in a timely fashion. Tightening the post-process stage is crucial not only to improve customer satisfaction but also to allow more customers to be seated during busy times. Besides TMS and communication systems discussed above, different types of payment methods through handheld devices can speed up the payment process (Kimes, 2008).

RESTAURANT TECHNOLOGY APPLICATIONS/SYSTEMS

Nowadays, many restaurants apply various types of technology in their businesses in order to operate with fewer mistakes, higher productivity, and improved marketing know-how. The digital age has created a wave of technological applications and systems that have changed the way restaurants operate and monitor their actions (Frederick et al., 2013:

116). In general, the restaurant’s structure is divided into two main parts, which are Front of the House (FOH) and Back of the House (BOH). Any operation related to customers in the dining areas, such as taking orders, delivering food and completing payment belongs to the front of the house (Walker, 2010). Back of the house or back-office are areas that relate to purchasing, receiving, storage, food preparation, service, dishwashing area, sanitation, accounting, budgeting and control (Meyer & Vann, 2013: 152). Technologies used in restaurants are also split into two main groups; systems/applications that are used in FOH operations and those used in BOH operations. Moreover, there are systems that integrate both parts so that operators can input and extract information from both programs (Walker, 2010: 392). There are also technologies such as robots and artificial intelligence (AI) that can be applied to both the front of the house and the back of the house (Mathath & Fernando, 2017: 293). In this section, first we discuss this technology and later, we take a look at technologies related to BOH and FOH separately.

Robots, Artificial Intelligence, and Service Automation

According to a study done by PricewaterhouseCoopers worldwide in 2018, 73% of activities performed by humans in the accommodation and food service sector have the potential for automation (Figure 7). In their study, they also mentioned Turkey as having 33% potential jobs at risk of automation. Moreover, Turkey is considered a country with relatively high exposure to later waves of automation but relatively lower exposure in the short term (Hawksworth et al., 2018).

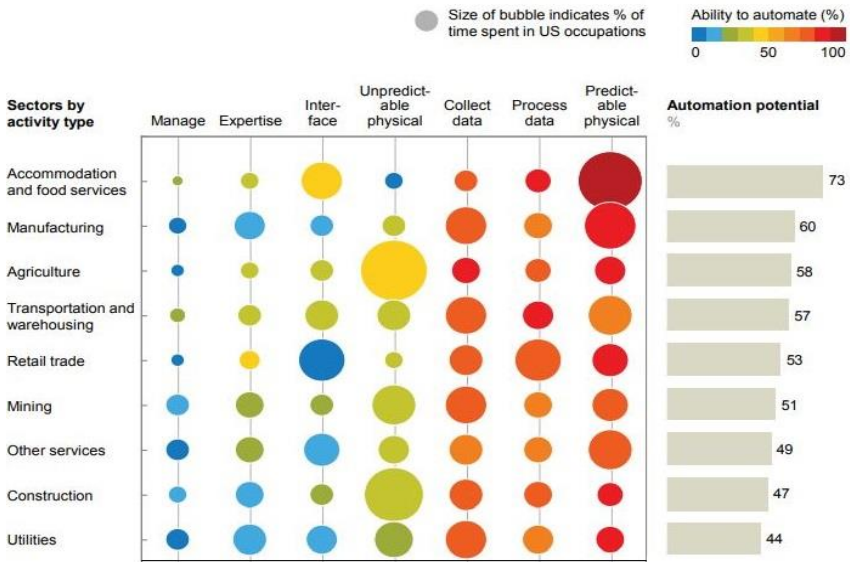

Figure 7. The technical potential for automation across sectors varies depending on the mix of activity types

Source: (PricewaterhouseCoopers, 2018)

Robots, Artificial Intelligence, and Service Automation (RAISA) can address some of the main challenges faced by the hospitality industry. Challenges such as labor shortages, an increase in non-English speaker international travelers and a large volume of customer data are a few of them (Bowen & Morosan, 2018). The shortage of qualified workforce and the high rate of employee turnover in the hospitality sector are becoming critical issues for some countries (Kuo et al., 2017; Mathath & Fernando, 2017). For example, It is estimated that there will be a shortage of 60,000 workers a year for the hospitality sector in the UK only if restrictions for immigration are too tight due to Brexit (The impending withdrawal of the United Kingdom from the European Union) (Kamal, 2017). It is predicted that by 2030, companies that effectively adopt and implement RAISA into their businesses will have a competitive advantage over those that do not (Bowen & Morosan, 2018).

Benefit and Shortcomings of RAISA

Applying RAISA has its benefits and costs like any other technology. Mathath & Fernando (2017), mention the benefits of robots for the food industry in minimizing errors, increasing efficiency, reducing capital costs, increasing productivity, reducing operational costs, improving product quality and consistency, increasing accuracy, increasing flexibility, reducing labor turnover and higher repeatability (Mathath & Fernando, 2017: 288-291).

Costs and benefits can be both financial and non-financial when applying for RAISA in the hospitality industry (Ivanov & Webster, 2017). The most important financial benefit of RAISA is the labor cost savings that result by using 24/7 service robots, chatbots and self-service kiosks instead of human employees. In addition to that, chatbots can provide services for multiple customers at the same time, which is not possible with the traditional way. Adopting these technologies does not necessarily mean eliminating human forces but rather enhancing employees with their tasks and improving productivity. Robots and artificial intelligence can also have a positive contribution to sales due to being interesting and unique for some customers especially in the early stage of adaptation of technology in the sector.

The main non-financial benefit of applying RAISA is enhancing the perceived service quality through unique methods of servicing, communicating and engaging customers. For example, the limited scope of languages by staff can be eliminated easily by applying RAISA and communicating through multiple languages with customers is easily feasible inside the business. RAISA can also create value for customers by providing service in a fun and entertaining way. Furthermore, RAISA would solve the problem of sectoral employee turnover and eliminate any law-related problem with hiring and firing staff (Ivanov & Webster, 2017).

On the other hand, there are financial and non-financial costs for adopting RAISA in the hospitality industry. Financial expenses include the cost of acquisition, installation, maintenance, software update, staff training or hiring specialists and costs for adapting the environment to facilitate robot's mobility. There can also be non-financial costs related to the resistance of employees to adopting RAISA into their work environment. Adopting any new technology into business requires reengineering the processes inside the organization. This may include training staff to use new technology and redefining the operations manual for them, which may push some people out of their comfort zone.

Furthermore, employees may consider new technology as a threat to their jobs. Resisting to adopt new technology can also extend to customers as well. Some people might feel uncomfortable and unsure about how to use new technology or they may just prefer the touch of humans rather than high-tech devices to provide service for them (Ivanov & Webster, 2017). In other words, the acceptance of customers and employees are two determining factors for the success of new technology in the business. Even if financial calculation for adopting new technology is favorable, managers still need to consider customers and employees and understand their perception of adopting new technology (Dixon et al., 2009; Kimes, 2008).

Chef Robots

Although the concept of using Artificial Intelligence (AI) in the kitchen may sound like a very new topic, in fact, the first prototype was designed more than a decade ago (Hashimoto et al., 2008), Kyoto University in Tokyo with the help of the National Institute of Information and Communications Technology of Japan designed and built a bright kitchen where AI observe and learn the process of cooking with the help of smart sensors, motion detector cameras and thermal cameras (Hashimoto et al., 2008).

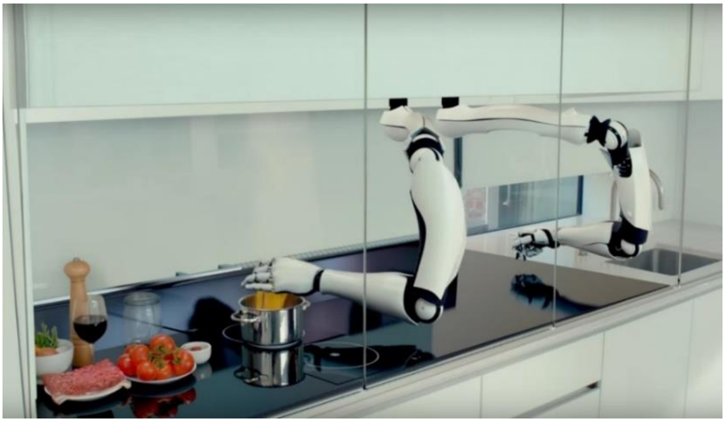

Figure 8. The world's first robotic kitchen created by the Moley Company
Source: (Gibson, 2015)

A British company by the name of Moley Robotic perfected this idea by combining it with perfectly designed robotic arms and created the world's first fully automated and intelligent cooking robot in 2015 (Figure 8). Their robot can learn up to 2,000 recipes and mimic the motion of a chef human with the help of 20 motors and 130 sensors (Gibson, 2015).

Figure 9. Spyce, a robotic restaurant in Boston, USA
Source: (Holey, 2017)

The above-mentioned robots are specially designed for household tasks and not suitable for restaurants and businesses. Robotic technology and robot chefs come in a variety of types for the restaurant industry. Perhaps the most successful and recent one is Spyce, which was founded by four MIT graduate students (Holey, 2017). Spyce currently runs a Boston restaurant that relies on seven autonomous cooking pots that rotate and prepare freshly made dishes for customers (Figure 9). As of March 2018, Spyce is capable of preparing seven different bowls from seven different parts of the world. Each bowl takes 3 minutes or less to prepare and costs just 7.5$ (Spyce, 2017).

Figure 10. Flippy, the world's first autonomous robotic kitchen assistance by MISO
Source: (Bandoim, 2018)

The world's first autonomous robotic kitchen assistant by the name of Flippy, gained media attention when it started his job at the Caliburger restaurant in Los Angeles (Godwin, 2018; Graham, 2018; Holey, 2017). Flippy is a robotic arm with Artificial Intelligence (AI) that is made by MISO robotics (Figure 10). It is designed specifically for use in the commercial kitchen and fast-food restaurants. This robotic arm is capable of making burgers up to 1,000 a day, according to David Zito, CEO of Miso Robotics (Bandoim, 2018; Graham, 2018). It has different arms/tools for flipping the meat, removing cooked meat from the heat and cleaning the grill for after cooking. Flippy is food-safe device and it is equipped with laser sensors that allow staff to collaborate with Flippy safely. Moreover, it has 3D and thermal scanners for eyes and manufacturer-cloud-connected AI for the brain (Bandoim, 2018). The cloud-connected artificial intelligence of Flippy enables it to learn from its surroundings and learn new skills over time. CaliBurger plans to expand Flippy to more than 50 of its franchises worldwide by the end of 2019 (Owano, 2017).

Waiter Robots

Deploying robotic technologies and automation for the front of the house in a restaurant means fewer waiters/waiters for delivering orders to customers (Asif et al., 2015). Many think digital technologies may just assist the waiter in taking and transferring orders to the kitchen. However, it may not be too long before the waiter is eliminated in the first place for taking orders. A successful example of this idea is the Baggers Restaurant in Germany (Pantelidis, 2009), which uses clever engineering that relies on gravity to deliver food and drinks on the table (Figure 11).

Figure 11. Baggers Restaurant in Nürnberg, Germany
Source: (Pantelidis, 2009)

Exactly the same concept is applied in nine branches of Rollercoaster Restaurants in Europe and the Middle East. These restaurants operate with no waiter to deliver orders, and customers can place their orders through tablets that are handed to them. These tablets are integrated with the POS system and the restaurant's kitchen display system for real-time communication between FOH and BOH. Moreover, detailed information about menu items and their nutritional facts are provided for customers through the same device. Customers just place their orders through those tablets and after a while, their food or drinks slide spirally from the upper floor (kitchen of the restaurant) to their table (Alton Towers, 2016).

Using robots in restaurant environments is becoming more common as robotic technology advances daily. Social service robots are the type of robots that can do the jobs of a servant in a restaurant (Pieska et al., 2013). According to IFR (International Federation of Robotics), a service robot is a robot that automatically provides useful services for humans or other machines, excluding manufacturing operations (https://www.ifr.org/service-robots/). Social robots are those that are designed to communicate and interact with humans and are capable of understanding social terms (Asif et al., 2015).

The first restaurant that used robots to deliver its food to customers was a Chinese restaurant in Pasadena, California, in 1983. Those robot waiters were huge in size and were not practical due to the low level of robotic technology of that time (Davis, 2012). Nowadays, several restaurants and cafes worldwide use robots not only for delivering orders to customers but also for entertainment (Mathath & Fernando, 2017; Pieska et al., 2013). Hajime is a Japanese robotic restaurant with a samurai theme that is located in Bangkok, Thailand. Customers place their orders through a user-friendly touch screen installed in front of them, and a legless robot dressed as a samurai wheels down to the kitchen and delivers orders when ready (Pieska et al., 2013). For safety reasons, the restaurant is designed so that no customers can be in the robot's path and only through windows can they pick up their delivered dishes (Figure 12, right).

Figure 12. FU-RO the waiter robot (left) and Hajime restaurant in Bangkok, Thailand (right)
Source: (Pieska et al., 2013)

Another great example of waiter robot is FU-RO restaurant robot that is produced by South Korean Robotics Company by the name of Future Robot Co. Ltd. This practical restaurant robot is specially designed for restaurants such that it can be integrated with POS and other operating of restaurants (Figure 12, left). Customers and waiter robots can easily interact with each other through specially designed HRI (Human-Robot Interaction) service technology by the company. With the help of FU-RO customers can access to the menu, order and even pay with their bank or credit card (Pieska et al., 2013).

Figure 13. Ada, the Turkish waiter robot in Cafe Cadde Meram in Konya, Turkey
Source: (Akinsoft, 2018)

The Turkish example of using a robot as a waiter is Cadde Meram cafe in Konya, Turkey. This place is not only a cafe but also a robotic application center for a Software Engineering Company by the name Akinsoft. The robot named "Ada" serves humans by delivering orders and greeting customers in the cafe for the first time in Turkey (Figure 13) (Anadolu Ajansi, 2015). This robot is 150 cm long and weighs around 30 kg. There are special paths for robots in the restaurant in order to move and provide services for tables without any accidents (Akinsoft, 2018).

Anthropomorphism is an important concept that needs to be taken into consideration for using waiter robots in a restaurant or in the hospitality sector in general. Human responses and likeness toward robots is not linear and can change dramatically according to robot autonomy, capabilities and anthropomorphic differences (Murphy et al., 2017). This idea is known as The Uncanny Valley and Masahiro Mori, a robotics professor at the Tokyo Institute of Technology in 1970, first brought it up. Mori observed that as robots become more and more human-like, people start to feel more comfortable around them until a certain point (Figure 14). Some people start repulsing robots and feeling uncomfortable after that point but the relation becomes positive again as the robots look more like healthy humans (Mori, 2012). In other words, the degree to which robots move, act, and resemble humans can affect customers' acceptance, affective reaction, and loyalty toward the waiter robot (Murphy et al., 2017).

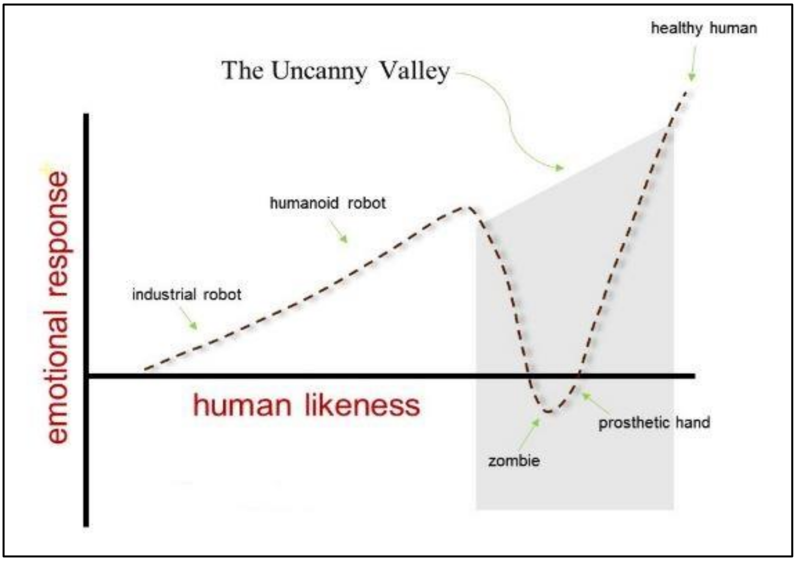

Figure 14. The Uncanny Valley
Source: (Mori, 1970)

Back of the House (BOH)

The back of the house or back office are areas that relate to purchasing, receiving, storage, food preparation, service, dishwashing, sanitation, accounting, budgeting, and control (Meyer & Vann, 2013: 152). Similarly, BOH technology consists of product management systems for purchasing, managing inventories, managing menus, controlling labor costs, and displaying kitchen systems. Most of these systems and applications come in the form of software programs that allow operators to be up-to-date and have accurate information for better decision-making (Walker, 2010: 392). According to the American Hotel & Lodging Association (AH & AL), BOH computer-based systems include labor management and scheduling, inventory/purchasing management, menu analysis, and business intelligence/ data analysis (AH&AL, 2006). Kitchen Display System (KDS), Smart Oil Management and Customer Relationship Management (CRM) system are types of technologies which are further discussed in the following sections.

Kitchen Display System

The Kitchen Display System (KDS) enables kitchen staff to manage and control kitchen efficiency smoothly with the help of highly real-time and visible information the system provides. This system is usually applied to quick service and high-volume restaurants in order to expedite the preparation and tracking of orders (Demicco et al., 2013: 130). A typical kitchen display system consists of four main components; the controller (receive, manage and control orders), the monitor (provides clear, legible and informative display for staff in kitchen), the bump bar (allow kitchen staff to manage order manually) and software (run the system and integrate with POS) (Cavusoglu, 2015).

A Kitchen Display System (KDS), sometimes referred to as a video monitor, has a variety of features and applications in the back of the house. This system can be installed with specified priorities, such as preparation time. The chef can set a preparation time for items on the menu, and when an order takes longer than the limit, the color of the order changes on the kitchen display screen. If it takes significantly more time to prepare an item than it should, the item in the screen blinks, and the manager is paged to take action. In addition, kitchen staff can customize the display screen to remind them of important notes (e.g., "No salt") or set various colors for certain types of dishes (e.g., blue for cold food) (Demicco et al., 2013: 130). Another useful feature is that the display monitor can remind important notes for staff and even play videos and display the image of the ordered dish. Watching a video about how to prepare a menu item in KDS will ensure that the menu items prepared in the kitchen will be consistent. Even new kitchen staff can prepare the items based on the standard operating procedures (Walker, 2010: 396).

The Kitchen Display System (KDS) can be integrated with the handheld ordering system and restaurant's PDA (Personal Device Assistance) devices, resulting in real-time communication for the waiter and the kitchen. This technology speeds up kitchen performance, removes reheats, reduces labor costs and enhances guest rapport (Walker, 2010: 395-396). Businesses applying such technology report reduction in food spoilage and production time and at the same time increase in the kitchen volume and table turnover. Moreover, this system helps restaurants to identify their bottlenecks with the help of reports and statistics that they provide. It develops better control over in the kitchen while it assists managers to increase their control of consistency for both preparation and delivery (Kimes, 2008).

Smart Oil Management System

Changing the fryer oil in the restaurant is a risky task by its nature and how and when it needs to be changed is crucial for the quality of the food. More than half of burning accidents in the food service industry are related to hot grease and the food service industry pays more than 2 billion US dollars every year for such slip-and-fall injuries (Ojha, 2018). Smart Oil Management System attacks this challenge in an intellectual way such that it improves employee safety, and restaurant cleanliness and reduces costs for the business (Frontline, n.d.). This system comes in the form of Portable Restaurant Cooking Oil Shuttle Systems and Fryer Oil Filtration Systems (Figure 15).

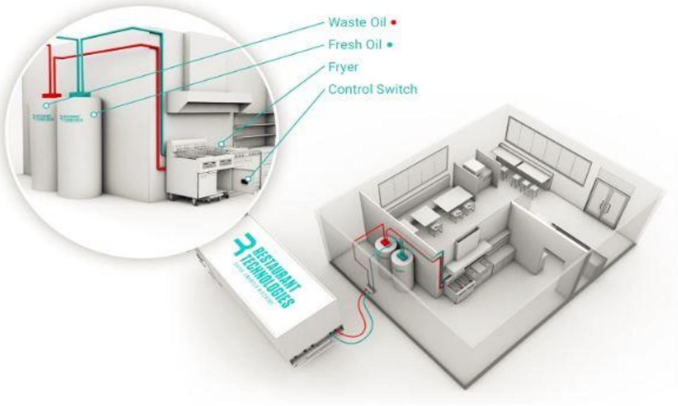

Figure 15. Typical Smart Oil Management System
Source: (Beach, 2015)

Smart Oil Management System allows employees to empty the oil tank of the fryer with just a touch of a button. The waste oil travels from the fryer to the containment tank, which is hands-free and fully automatic (Beach, 2015). Such a smart solution operates in an integrated platform where special designed sensors and equipment are interconnected by the Iot, allowing full control for restaurant oil management. Some of the companies that provide such technological solutions for restaurants also offer unique features such as web-based software that allows managers a dashboard for tracking oil usage, standardizing filtration, scheduling pickups, and measuring diagnostics from anywhere (Frontline, n.d.)

Customer Relationship Management (CRM) Systems

Attracting a new customer for a restaurant costs much more than retaining the existing customer. Moreover, there is a 60% higher chance that a customer who has already made a purchase will repurchase in the same business. These two facts alone should bring the attention of food service business owners/managers for making customer retention one of their valuable investments for long-term strategies (McCormick, 2018). CRM can appear in various forms and versions, but the main objective is to create and maintain customer loyalty while increasing the business's revenue (Demicco et al., 2013: 136).

Customer relationship management is not a new concept for restaurants and cafes. Frequent dining programs, loyalty programs, and gift cards are typical examples of CRM. However, the capacity to integrate and combine all components to provide an effective CRM system is a recent phenomenon. Modern restaurant operators can approach to customer's database thought in so many innovative ways. As a result, operators can provide an effective CRM system that best suit the business and also create a bond with customers for the long run (Walker, 2010: 411). Integrated CRM system solutions with POS system of the restaurant can save the contact information of customers such as email addresses, phone numbers, important dates (e.g., birthdays, anniversaries), and preferences. With the help of such valuable information, CRM can provide unique and specially designed loyalty programs for each individual according to their preferences and the history of their activities in the restaurants. For example, there are integrated CRMs that can produce slips based on customer information and previous activities in the restaurant. With the help of these slips, servants can welcome guest by their name and greet them with their favorite drink or appetizer. Moreover, the servant can suggest dishes according to recorded past preferences, dietary restrictions and historical data. Such interaction with customers creates a home-friendly environment for people who visit the place more often. (Demicco et al., 2013: 135).

Front of the House (FOH)

Any operation related to customers in the dining areas such as taking orders, delivering food and completing payment, belongs to the front of the house (Walker, 2010). The main technology that relates to the front of the house is Self-Service Technologies (SST). In this section, various form of SST such as tabletop technology, digital display menu and, kiosks will be discussed in the following sections.

Self-Service Technology (SST)

The concept of Self-Service Technology (SST) is not a new idea and has existed for a long period of time in different sectors such as banking (ATMs) or check-in and check-outs at hotels (Torabi Farsani et al., 2016).

In general, SST enables customers to consume different benefits and services on their own, independent of the involvement of an employee at a company. In the case of restaurants, SST can be explained as involving the customer as a participant in the production of the guest experience (Ford et al., 2001).

Self-service technology can appear in a variety of forms, such as assisting in producing a product (i.e., salad bars and self-service beverage stations), marketing (i.e., sharing stories of positive experience), and supplying the organization with beneficial information (i.e., purchase records and feedbacks) (Kincaid & Baloglu, 2008). Allowing the customer to participate in the service experience can be substantial. The greatest benefit of it is cost reduction since customers replace labor that the organization would have to pay to perform otherwise (Meuter et al., 2000).

Even if the financial benefit of SST is ignored, there are still some important advantages of using SST for businesses. First, more involvement of the customers in providing service for themselves means the more likely that the experience is more pleasant for them and will meet their expectations. Second, if customers do anything for themselves, the organization does not have to do it for them, which means less cost and effort for the organization. A third and most important one is that organizations may achieve the loyalty of their customers since they are participating somehow in a task and may see themselves as part of the “family/team” (Ford et al., 2001)

Digital Display Menu

The recent self-service technology for restaurants that has gained so much attention is replacing their printed menu with a digital display menu. This SST solution comes in various forms and versions (Figure 19). They may be installed as a part of the table itself or just provided as a mobile tablet for customers (Saeid & Macanovic, 2017). Moreover, the spread of smartphones pushed companies to develop a mobile application for business so that customers can access to their menu through their personal phones and even order from there. Studies show that usage of such SST in a restaurant has a significant impact on customer experience and satisfaction (Hsu et al., 2013; Kincaid & Baloglu, 2008). The finding indicates that SST's most frequently liked features were convenience, ease to use, and fast service (Kincaid & Baloglu, 2008). Moreover, at least one study suggests that using iPad for a menu in a restaurant significantly affected the perceived value for customers in both functional factors (i.e., better control, ease of use, and usefulness) and emotional factors(i.e., perceived enjoyment and novelty) (Wang & Wu, 2014).

Figure 16. Various versions of E-Menu
Source: (Saeid & Macanovic, 2017)

Using a digital display menu allows customers to order food and drinks along with providing enormous amounts of information in an easy way for the customer without interaction with employees. For example, menu descriptions may include nutritional information, preparation specifications, zoomable HD pictures with taste notes, and preparation video of the product (Wang, 2012). Moreover, customers can also search through the menu for what they have in their mind by typing the name of a specific dish/drink or their favorite ingredient and see available options. In addition to that, such a menu can suggest the best food pairing drinks, such as wine options, according to selected items. This technology can also monitor the stock level of the business and remove items that are sold out from the menu automatically (Wang & Wu, 2014). Finally, servers will be able to provide better service to a greater number of tables when they are no longer busy with the responsibility of taking order and handling it to the kitchen (Kincaid & Baloglu, 2008).

Tabletop Technology

Tabletop technology is another form of SST that makes ordering a unique experience for the customer in a restaurant. Like e-menu, they come in a variety of forms. They can appear as a multitouch interface that allows the customer to access services that the business provides for them (Chen, 2012). In the more advanced version, they appear as a holographic interface that detects the user's asked action by hand motion (Figure 16). The use of such an SST solution not only makes boring task such as ordering and waiting as a fun experience for customers but also can significantly affect dining time, table turnover and labor for a restaurant (Wang, 2012). Just as an example, a restaurant that used proper tabletop devices in their environment and allowed customers to just order or order and pay through their SST solutions dropped the dining time of their guest by 17% and 31%, respectively (Susskind & Curry, 2018).

For example, a restaurant in London by the name of Inamo applies this idea by using tabletop technology. Customers in this futuristic restaurant can access to the menu and order without a waiter just by their hand motion and the use of a mouse trackpad (Figure 17 and Figure 18). Extra details of food and drink with the holographic illustration of the selected item appear on the plate of diners and after placing the order, they may watch the preparation procedure live from the installed camera in the kitchen or bar. In addition, diners may select the desired theme of their holographic tablecloth and play some board games such as battleships (Sergioatinamo, 2009; Spence & Piqueras-Fiszman, 2014).

Figure 17. Holographic types of tabletop technology
Source: (Sergioatinamo, 2009)

Figure 18. Tabletop Technology at Inamo restaurant in London, U. K
Source: (Sergioatinamo, 2009)

Self-Service Kiosks

Kiosks are one of the most widely used SSTs in the food service industry, especially among quick-service restaurants (Rastegar, 2018). These self-service machines have a big touch screen that allows customers to interact with them (Figure 19). Kiosks started out as simple display machines and they developed over time and with advancements in digital technology. Nowadays, self-service kiosks are capable of providing sophisticated services for customers. Check-in and out processes, purchasing, market research, and ordering are just a few examples of these processes.

Figure 19. McDonald's Self-service Ordering Kiosk
Source: (Rastegar, 2018)

Restaurants use these machines for customers to place and pay for their food and drinks while they have the ability to customize their order. Using such SST can bring many advantages to the business. Reducing labor cost (Ford et al., 2001), improving the speed of service (Kincaid & Baloglu, 2008), and increasing the accuracy of orders (Kincaid & Baloglu, 2008) are the most important values that can be achieved by adopting such technology. In addition to those, self-service kiosks can increase sales due to upselling by always asking customers for additional items on their orders, which can be forgotten by a normal employee when taking orders. For example, the president of Wow Bao franchise (Quick service Asian restaurant) reported that self-service kiosks increased the average check amount of the business from 90 cents to 1.5 $ just due to the upsell feature of kiosks (National Restaurant Association [NRA], 2016b). Moreover, studies show that people are avoiding purchasing complex menu items and items that have higher calories than others (Strauss, 2015). Meanwhile, adopting self-service kiosks can attract millennial customers and their younger counterparts to the business (Cross, 2017).

SUMMARY

This book tried to discuss the transformative impact of Industry 4.0 technologies on the restaurant industry, exploring the convergence of digitalization, automation, and artificial intelligence (AI) within the context of restaurant management. The research work examines how new technologies transform the traditional models of operation, the experience of customers, and strategic decision-making processes in food service. By providing a comprehensive analysis of the current state and future potential of these technologies, the book aims to equip restaurant owners, managers, and researchers with the knowledge necessary to navigate this rapidly evolving landscape.

The core focus of this work lies in understanding the practical applications of key Industry 4.0 components within restaurant environments. It includes the discussions on the implementation of advanced automation systems for food preparation, order processing, and inventory management. The book also discusses how digitalization can create new customer experiences through online ordering platforms, recommendations, and digital interactive interfaces. These technologies are not only being adopted as an upgrade but also as a cultural shift in how restaurants function and relate to their customers. The book also covers how AI can be applied to improve customer service through chatbots, virtual assistants, and targeted marketing campaigns. The book critically evaluates the opportunities and challenges created by the adoption of AI with respect to data privacy, algorithmic bias, and the ethical implications of automated decision-making.

This book goes beyond the technical aspects of Industry 4.0 to address strategic implications for restaurant businesses: how these technologies can be used to achieve competitive advantage, improve operational efficiency, and enhance profitability. Second, it discusses adapting organizational structures, workforce skills, and management strategies to the new technologies. A holistic approach has to be designed, considering interactions among technology, human capital, and business strategy.

The aim of this book is to extend the challenges and opportunities that the adoption of Industry 4.0 technologies has raised in the restaurant sector. It admits that such an implementation may be associated with some challenges, such as high investment costs at initial stages, expertise for technical operations, and raising issues related to data security. It highlights, however, the huge opportunities these technologies offer regarding innovation, growth, and the increase in customer satisfaction. It provides a balance between the possible risks and the great rewards that come with embracing Industry 4.0.

The book concludes by giving an insightful and balanced view of the transformational effect of the discussed technologies on the restaurant industry. The book will consequently dwell on the practical implications, strategic implications, challenges, and opportunities created by digitalization, automation, and AI. It is supposed to serve as a helpful roadmap for those interested in further understanding and better handling the future of food service, emphasizing the importance of embracing new technologies as the main drivers of operational efficiency, customer experience, and sustainable growth within the dynamic, competitive restaurant landscape.

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