Analyzing Human Robotic Interaction in the Food Industry

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Abstract: The food chain from farmer to fork has grown into a very complex sector. Industrial robots are being integrated in every part of the food chain in order to increase production, create a higher quality product to exceed customer expectations. As the bar on quality standards raises higher year on year, food safety and hygiene becomes an even greater priority and customer’s demands value for money. Food manufacturing robots are used all aspects of the food chain. Although the food sector is slow to adapt robots, the Food sector is the fourth most automatable sector. Robots are used for farming, transport, food production, packaging and delivering. [1] Robots are especially convenient for packaging of food items, where speed, consistency or high levels of repetition are needed. Robots usually win over humans in terms of efficiency and accuracy. The latest robots are equipped with intelligent vision, can multi-task and understand verbal commands. More businesses see the value in automation especially robotics which plays a vital role in process improvement. A smaller minority is still hesitant, sees it as a threat to their business, and is reluctant to implement robots. They argue that it will reduce jobs and employees will lose their valuable skills. The purpose of this paper is to identify, analyze and understand robotics in one of the largest sectors, the food chain.

1. Introduction

Agriculture supply food security and health to the human race and is one of the biggest sources of income for governments in many countries.[29] Like many other sectors in the food chain, hard-to-get laborers[15] and the increase in cost to hire laborers create many issues for farmers especially in labor-intensive farming. To attend to 1 acre (4046.86m) of vineyard for example, will require 32 laborers. [1].

Fig. 1 illustrates the decrease in laborers on farms over the past 10 years in the highest population countries, China, India and Brazil [2]. Several reasons stated under could justify the decreasing trend, for example an increase in automation on farms, or the continuous struggle to get enough laborers to work on farms. It could also be the lack of interest from the younger generation, which is opting these days for degrees and more positions that are academic. [30][33]
If humanity can take a leap into the future, farming will no longer be under solely human management but would find robots running most of the show. They are the redefinition of food production, packaging, and delivery. [31] Industry 4.0, with the advancement of artificial intelligence (AI), deep learning and the internet of things (IoT), has driven the rapid advancement in robotics especially collaborative robotics. [23] In addition, the evolution of peripheral components, such as sensors that enhance the robot’s ability to feel, touch, grip, and “see,” has change completely what robots are able to do. No longer do you find clumsy robots but rather artificial humans that can assist you in your work environment. [24] [50] [51]

Not that long ago, no one thought it was possible to have people working next to a robot. As we changed the technology to allow robots to work fenceless, people now can perform added-value tasks and robots can do the repetitive tasks. Robots can assist to create acceptable flavor profiles of customers, create new recipes built on the data collected from customers over a period. It contributes to the overall well-being of the human being in a working environment, jobs that are ergonomically difficult for example heavy lifting and repetitive cutting of fruit and vegetables. It can contribute to a significant reduction in muscular skeletal disorders, which is often associated with the food industry. The food industry has been slow to adopt robotics in their operation. [54] [55] Experts agree that food industry robots are changing at a rapid pace. Companies that are refusing to look at the possibilities of robot implementation might risk falling behind if new technology is not deployed. With over 7.5 billion of the world’s population, the food demand continues to rise.

2.0 Literature Review

Human has always been fascinated with robotic either it has due to its efficient and accurate calculations or the appreciation of precise approach of human made technology. However, the term interaction is has evolved after unleashing of the robots from its fence. The communication (remote interaction) has transformed into interaction with human due to close proximity of human, robotic, and opened new doors of development.

2.1 The Future of Robots in the Food Chain

The future of robotics and humans working together (HRI or Human Robotic Interaction) in a working environment seems promising. [35] Not very long ago, nobody thought it would be possible that humans and robots work together as a team. Robot used to be barricaded completing a single task at a time, and kept far away from humans to protect them from any harm caused by robots. [45] Industry 4.0 and the advancement of artificial intelligence (AI) and the internet of things (IoT), has driven the
rapid advancement in collaborative robotics. Cobots do not have the same footprint then a standard industrial robot, is less costly, light in weight and much easier to program before implement them. Cobots are designed to work next to humans in confined spaces, to enhance human capabilities and to optimize processes. Cobots are built to assist human beings in their daily task and not to replace them. Cobots have built-in sensors that make them safer and far more reliable than any robot out of the past. Cobots are completely mobile and can from one place to another without any effort. In Fig 2, indicates the use of robots in the past two years in different sectors. It is clearly shown that the implementation of robots in the food industry is far behind other industries.

![Fig. 2: An illustration of some industries and robot implementation.](https://example.com/fig2.png)

Cobots are able to handle multiple tasks at once, which makes them suitable for the food industry in many ways. Today not only Cobots but also different types of robots are used in farming, food manufacturing, packaging, cookery and deliveries. Cobots are ideal when humans and robots have to share the same working space.

Cobots can identify obstacles around them with the help of sensors and in this way avoid collisions accordingly, which is of a high importance in food production facilities. The rise of cobots is already visible in several industry sectors including precision agriculture and food services. In addition, the evolution of peripheral components, such as sensors that enhance the robot’s ability to feel, touch, grip, and “see,” bring more to what cobots can do. Cobots add the most value in situations where a human needs to be in close proximity to the robots. This includes human-robot collaborations where a human guide the robots makes the decisions or judgment for the best possible outcome and monitors the process. [28]

The latest development (Table-1) like robotic seeding through autonomous precision seeding or Robot assisted precise irrigation and usage of drones and vision guided robots have significantly contributed to the growth of HRI in the Food chain. The description of each is stated as under.

| Description | Important Features | Most Suitable Industry |
|-------------|--------------------|------------------------|
| Robotic seeding attachment attached to a tractor | **Autonomous precision seeding:** A geo map is created to identify the soil properties to see where the seed will grow the best. | Crop Fields (Food Industry) |
| Ground Based | **Robot-Assisted Precision Irrigation:** Ground robots for | Farming |
Robots (Wireless Robots) example can navigate between rows of crop and pour water directly at the base of each plant or can be utilized for weeding and fertilizing. It is equipped with a down load looking camera detection.

Drones Drones provide farmers with an overall picture of their farmland and help to make informed decisions that maximize crop production by using advanced sensors and imaging technologies, hyper spectral and thermal imaging.

Collaborative robots (Cobots) The Cobot can disinfect cows’ udders without being a risk to humans or animal, milk the cow successfully and been utilized in fetching eggs from the hen pen.

Vision Guided Robots (Machine vision) Vision Guided Robots are utilized in sorting by color, shape or size and the improved gripper technology can assist in delicate products for example pizza production and biscuits.

Contemporary robotics Packaging robots can carry out the following tasks: open, fill, pack, seal, and correctly label the package to be sent to the end-user.

Bella-Bot Delivery Robot Four shelves for placing items can deliver items automatically and collaborate with other robots thanks to integration with the Pudu Scheduler system.

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| Drones                   | Drones provide farmers with an overall picture of their farmland and help to make informed decisions that maximize crop production by using advanced sensors and imaging technologies, hyper spectral and thermal imaging. |
| Collaborative robots (Cobots) | The Cobot can disinfect cows’ udders without being a risk to humans or animal, milk the cow successfully and been utilized in fetching eggs from the hen pen. |
| Vision Guided Robots (Machine vision) | Vision Guided Robots are utilized in sorting by color, shape or size and the improved gripper technology can assist in delicate products for example pizza production and biscuits. |
| Contemporary robotics | Packaging robots can carry out the following tasks: open, fill, pack, seal, and correctly label the package to be sent to the end-user. |
| Bella-Bot Delivery Robot | Four shelves for placing items can deliver items automatically and collaborate with other robots thanks to integration with the Pudu Scheduler system. |

2.2 Collaborative Robots

Collaborative robots or Cobots need to be seen in a working environment as our teammates. Cobots are designed to work with people and create a better environment for the humans. A research study conducted by the University of Gottingen, Klumpp and his team has already observed that the co-operation between humans and machines can work much better together in teams than separately.[35]Humans will be in more supervisory rolls, and robots will be helping with the more repetitive, straining jobs that might be harmful in the long term to the human body. No comparisons or very little research has been completed in the food industry on what the effect of a robot will be on the on the chef that works next to a robot at work. Will it contribute to his well-being in a positive way? It is of vital importance that employees need to see the robot as a teammate that works right next to us in close collaboration. It will also improve the skillset of operators. Employees illiterate on technology terms are now promoted and have to learn a brand new skillset. [43][44][46]New job descriptions are created in companies for example a Chief Robotic Officer (CRO). The result is an improved work environment where humans are freed up to focus on more rewarding tasks for example creativity and critical thinking. Bringing cobots to food chain is exactly the same experience as hiring a human worker. Therefore, from a company’s point of view. The same rules and regulations should be applied and followed for them as for the human worker.[49][52] Cobot hiring is already a part of the recruitment process and will cost more or less the same as a laborer per day.

2.3 Latest development in robots suitable for food chain

In the past, the food industry was very difficult to automate. However, with the latest technology it has become simple in the past few years. Cobots are fascinating and will contribute to the progress of the
food chain in many different ways, which will also be a positive enhancement for human beings. The soft touch in their gripping ability for example, is an excellent asset to the food chain such that harvesting delicate fruits from trees will no longer be an issue because of labor shortages. Not only are they able to softly harvest the fruits, but also find different angles to harvest the fruits in the best possible way. “Another technological advancement is self-healing polymers that can be used for grippers to handle fruit. Being gentle and soft, enough to avoid damaging fruit means they are prone to damage. To solve this challenge, researchers have already successfully developed polymers that can heal themselves by creating new bonds after about 40 minutes.” [13] Cobots can shift from one department to another effortlessly. Instead of hiring humans to cover the routine tasks, robotics can fulfill this requirement. Robots do not get tired, don’t need vacation and are able do monotonous work for many hours.

2.4 The anatomy of a robotic arm

In Fig. 3, the basic anatomy of a robotic arm is explained. A robotic arm works very similar as a human arm and is based on the same principles.

![Fig 3: The basic anatomy of a robotic arm](image)

The digital controller controls the robot, similar to a human brain. Finally, the sensors are very similar to the sensors in the human body, which will send information to the brain. Sensors play an important role in robot operation, as it will measure for example position, temperature and velocity in different quantities. Cobots sensing are able to detect external contact. Embedded vision systems form an important part of collaborative robots and are one of the main reasons why collaborative robots are able to operate so efficiently and safely in a confined environment. Robots that were used in the past did not require this type of vision as they were barricaded from humans by metal cage.[45] Embedded vision systems allow cobots to identify the presence of human in near vicinity and insure safe operation.
The more humans and collaborative robots begin to work on tasks that are more complex together, the more effective communication becomes necessary between humans and robotics. Collaborative robots are building to recognize certain voice commands and hand signs by his human teammate. No longer will it be a necessity to re-program robots for different tasks then what they are already doing. Interactivity will be playing an important part of robotics in future. Imagine an expert barista preparing coffee and a mixologist all in one, ready to make a perfect beverage. There is no need to redesign the workers environment.

3.0 The role of the Cobots in the food chain

The collaborative robots in food industry have its imperative importance due to the nature of delicacies its production service and supply chain with a specific requirement from farm to fork. The Cobots are increasing its reach day by day in the industry.

3.1 Agriculture Precision farming

The world needs more food as the world’s population increases. The average increase in intervals of four years for the past decade was 4.6%. However, for the past four years the increase in population was slightly higher. It can be expected that the percentage will be even higher in the next four years when studying Maslow’s hierarchy of needs. The lower needs in the hierarchy must first be satisfied before the needs higher up can be meet. As illustrated in the Table-2, it is an indication of the increase of the world population over the past ten to twelve years.

| Description                  | 2020 | 2016  | 2012  | 2008  |
|------------------------------|------|-------|-------|-------|
| Total Population (Billions)  | 7.8  | 7.426 | 7.087 | 6.758 |
| Increase in %                |      | 4.8%  | 4.56% | 4.64% |

There is a decreasing trend of interest from the young generation who do not want to work on farms today and this is creating labor shortages on farms around the globe. Robotics can solve labor shortages for example in milking and feeding the dairy animals and collecting eggs from the same farm. Robots can be the permanent solution to end this food crisis. Additionally, it will provide youngster a chance to plan business rather being engaged in the repetitive tasks.

One of Japanese company named (Fig. 4), practice agriculture precision farming since the early 2000’s. Weather conditions do not influence the success of crops and only 10 liters is required to grow one lettuce head. Robots run the whole farm [3] produces 21000 lettuce heads per day. [3].
Fig. 4: The production of a crop of lettuce through Agriculture Precision Farming. [3]

Sensors between the plants provide data about how specific type of crops grows. These sensors alert human workers when a crop are not reaching maximum growth, allowing humans to adjust techniques as necessary on time before it is affecting the end result.[3]

### 3.2 Fruit and Vegetable Pick and Place

The correct timing and handling of fruits are everything in the fruit picking business. Fruits and vegetables are challenging to handle with a robot due to their variable sizes and shapes. They also require delicate handling to avoid damage. For these reasons, human workers have traditionally handled them. However, recent developments in gripping technologies look to change all that.[13]

Soft Robotics has introduced a flexible gripper that can handle very delicate foods for example raspberries or strawberries. Fig. 5 illustrates the farm to fork concept. It includes all the steps from where food is grown, right through production until it is ready to be consumed.[13]

Fig. 5: Farm to Fork Concept

### 3.3 Manufacturing

The demands of the customers are forever changing due to increased information in the 20th century. Cobots can improve flexibility in manufacturing due to the ability to be easy reprogrammed and restriction free movement ability. Cobots can be reprogrammed in a matter of minutes, which creates a lot of flexibility when for example a food product needs to be customized.
3.4 Robotic Butchery

Industrial butcheries have widely enhanced their slaughtering capacity by the usage of right technology starting from stunning scanning and packaging. Due to the nature of work in this industry, robotics will work separately from human beings to lower employee risk. Robots can cut up carcasses much faster and more accurately and remove the most dangerous parts in these operations from humans. Carcasses are very different from each other and vary in size, shape and even the number of ribs. Some butchery tasks are simpler to automate than others are. Rib cutting involves operating a high-speed circular saw for several hours and is a very dangerous repetitive work in a standard butchery. When the worker becomes tired or is distracted by, personal issues the risk of the worker increases and can easily lose an arm or hand.

3.5 Robotic Cutting and Slicing

For basic cutting skills, robots are not needed for these simple tasks but rather just a simply vegetable cutter. Even kitchen food processors can slice vegetables into different shapes. Robots are not needed for this type of simple automation but rather for processes that are more complex. Chefs mostly do advanced cutting and slicing skills. A very good example will be fish cutting. Fish cutting is a more complex action think about the different sizes bone structure and shapes. To clean fish involves detecting bones, without damaging the tender meat. Fish Fillets needs to be cut in uniformed shapes and sizes especially for commercial use. It is even more difficult to replace humans in the crab cleaning process. Some research has already been conducted where robots will replace humans in this industry. Crab cleaning is a time consuming job and young people today are no longer interested in doing this following this path as a career, therefore the average age of a worker in this industry is 55 years and above.

3.6 Bakery

One impressive application is robotic cake decoration. This involves using a robotic arm much like a 3D printer to pipe icing onto a cake. The Deco-Bot can pipe hand-drawn decorations onto cakes on a moving conveyor however; it lacks creativity and is depended on human creativity. Deco-Bot can create beautiful patterns as programmed by a human but is misses the artistic flair.

3.7 Artisan Food

“Artisan food describe a product that is made by an artisan and is most properly used to indicate something that is handmade, unique, and high quality – often the very opposite of mass-produced.” [26] When thinking about artisan food Artisan food producers have a valid point when asking the question if by that adding robots in their processes that the tradition through the ages and the skillset carried over from generation to generation will be lost and it will become another mass manufacturing product. The secrets and the love going into a product made from scratch by hand will be lost and it will become a heartless product.

3.8 Food Packaging

Less and less workers are to be found which are willing to do food packaging and palletizing as a permanent job. The outbreak of the pandemic has increased this shortage, as many workers don’t want to work less than two meters from each other. Fig. 6 illustrates a possible solution to minimize the laborers and increase the responsibility of them by implementing robots in a food production facility.
More and more food production facilities are using robots for packaging and palletizing. It decreases the boring repetitive tasks from humans as well as the overall health of the workers. No longer do humans have to shift heavy crates or boxes. It is estimated that more than 90% of food manufacturers are using already robots to assist with this task. For the ones that did not invest in this option is indicating that they will follow soon and are already investigating different options most suitable for this task.

Fig. 6: Implementation of robots in a food production facility

Food packaging can be divided into three steps:

- **Primary packaging** — Cookie bags are filled with individual cookies.
- **Secondary packaging** — all the cookie bags are placed in a box.
- **Tertiary packaging** — the boxes filled with cookies is placed on a pallet, ready for shipment.

Robots can be implemented in all three steps, which will add a profits and benefit to the company’s financial statements. Companies have not to fork out a lot of money for injuries associated with heavy lifting and related injuries and accidents.

### 3.9 Food Delivery Service

Driverless trucks are here to stay, but what about food deliveries. Delivery bots are light in weight and can deliver orders up to 10 kg. It is equipped with 360-degree cameras and can navigate through sidewalk traffic and through uneven territory. It is ideal for short distances, the orders that delivery staff not normally wants to do.

Drones for deliveries used to be only a far fetch dream, however COVID 19 has accelerated how medical supplies to be delivered to rural areas and has been tested with positive results. In some countries for example Ireland some food deliveries has been tested with mixed results. The benefits of drones delivering food and critical medicine to different areas have outweighed the possible danger in
aviation. More research and testing must still be completed before this will become a regular occurrence, and a part of our daily lives.

3.10 Food Production

Preparing food to an edible stage is one of the final stages in the food chain. In a recent comment made by a professor from a UK university during a webinar, it was mentioned that she would not like the idea that her food she is paying for in a restaurant is been prepared by robotics. Looking from a consumer point of view, there could be many reasons which can include but not limited to the following: Lack of knowledge on the latest development of cobots which forms excellent teammates in back of house operations, personal choice based on the principle that artisan food is has more value because this is prepared with love by a chefs hand which well-known that a robot cannot put into food or purely maybe stubbornness, think about the luddites in the beginning of the 19th century when automation was introduced in textile manufacturing in the UK. Mass production is associated with inflexibility, which means in the consumer's knowledge that a product cannot be customized. An example will be when a customer has an allergy for a certain product, in a normal food production area; the specific food item that is causing an allergy could be replaced immediately in the preparation. Not only will the food ingredient be used but also a clean set of utensils can be used to minimize the risk.

When cobot is preparing the food, maybe the time to clean the end effector will take time and create a slowdown in preparation. In this part of the food chain, more research needs to be completed to be on par with the rest of the food chain. Often the questions arises amongst youngsters that want to follow a career as a chef, will cobots replace chefs in the industry? Up to today, robots cannot create creativity and passion or love for food. Robots will rather be utilized in the monotonous, repetitive work leaving aspiring chefs to be creative and come up with the latest food trends. Spyce Robotic Kitchen (Fig. 7) in New York uses robots to prepare healthy plates of food at an average price. Customers are not always looking for an experience but rather a healthy quick meal that will not cost an arm and a leg. Spyce Kitchen uses pre-cut ingredients to create these nutritional meals.

![Fig. 7: Demonstrates how to food is prepared by robots in Spyce Kitchen, Boston.][4][16]

The menu was developed and tested by a professional chef. Spyce Kitchen lacks tools to handle allergens and will have to increase their scope of culinary techniques so that a wider menu can be prepared. [4][16]

3.11 Fast Food Services

Labor issues and higher wages in the fast food industry make it much more attractive for fast food companies to invest in robotics. The latest development of robotics is able to differentiate between
shapes and colors have brought the fast food industry even closer to be fully automated in future. Rensi a former CEO of McDonald’s USA mentioned to a local newspaper, “It’s cheaper to buy a $35,000 robotic arm than it is to hire an employee who’s inefficient making $15 an hour bagging french fries. In more simplified tasks, robots can greet the customers and guide them to the correct station or table. [5]The only technology that will be required for this application will be a standard machine vision technology that forms a part of the robot. Robots will speed up and reduce cost of food for loyal customers in the fast food industry. It will reduce the interaction of human beings with customers. Most fast food companies try to increase the traffic to their online orders through apps and chat bots.

Automated Kiosks (Fig. 8) are on the rise in big fast food chains. Automated kiosks can be a pleasant experience for customers as they do not have to stand in long queues, they can change their mind a few times before pressing the button for the final order and it gives the customer time to look at all the offers available on the menu.

It is already proven through different case studies the average spends per customer increases when they use self-service kiosks. Companies can also monitor which products sells out first and reorganize the digital menu that the lease popular items are displaying first at a certain point during the day. In this way wastage is minimize and the company is in control of his inventory. Staff members can be skilled in different sectors and no longer only to serve in Front of House Operations.

The issue with this type of technology might be found in the safety standards of the touch screens. These touch screens is germ collectors, which can contribute to a serious outbreak foodborne illnesses if not, sanitized in an acceptable way.

4.0 Benefits of latest technology in the food industry

4.1 Food Safety and Quality Control

Food safety risks can cost a reputable food company its name and it can take years to recover and win the trust again of its loyal customers. With the increase in automation and technology in the food industry, food safety becomes even more important to minimize any risk.

The most important factors in food safety that plays a vital role in clean safe food are:

- Cleanliness in food production
- Raw and cooked food should be separated
- Food should be cooked till the minimum temperature (60 C)
- Hot food must be kept hot and cold food should be kept cold.
In the past robots was mostly limited to secondary and tertiary packaging, however this changing. Robots are implemented from the primary stage of packing which highlights once again the importance of food safety seeing that robots is in direct contact with the individual or raw food product. When robots pack food, the risk of food contamination is minimized by the limited touch of a human being. It is important to make sure that the guidelines for food safety and hygiene is followed for robots as well.

One of the most challenging aspects in automation is that HACCP standards should be followed in every step of production. Therefore robots should be manufactured in such way that it is easy to clean, no loose wires associated with the robots and the material of what the robot is made of especially for example the grippers must be food grade. There should be regular deep cleaning sessions scheduled and it should be cleaned with the correct sanitizer. In some applications, it is possible that the robots can be utilized to wash down the workstation with the correct sanitizer, high-pressured water, and even was down each other. Imagine the robot is handling raw meat on a daily basis, but is never sterilized or cleaned in the correct way. Robots also assist in other CCP according to HACCP standards. It monitors refrigerator and freezer temperatures and can get the staff know when the oil in the deep fryer should be changed. From a food safety point of view the room temperatures where the robots operate from should be the correct temperature for the food product associated with this operation. A good example will be a dairy plant, it is very important that dairy products are kept and packed at the correct temperature to avoid spoilage and increase the risk of food contamination.

4.2 Traceability of Raw Food Items and Identification of Contamination

Food sensor technology can help food manufacturers identifying critical issues as early as in the farming stage which will minimize the possibility of a major food safety risk outbreak for example the Salmonella outbreak amongst onions recently in Canada and USA.[21][36][48]

4.3 Worker safety and Robotics

Although the number of deaths caused by robots is very low, data varies on the amount of deaths or injuries caused by robots over the past few decades. In 1942 Asimov[45] created the Three Laws of Robotics, or also known Asimov’s Laws, a set of principles robots should follow in the future towards human beings.

- A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws. [45]

Through proper implementation of Robots in a manufacturing or production area, it can decrease musculoskeletal disorders, injuries associated with falls from higher places and other hazards that can cause harm to human beings. Robots can also reduce overexertion and repetitive, monotonous or tasks which is often associated with the food chain for example bulk vegetable cutting. Robotics is ideal to work in harsh environments for example in freezers where temperatures reach -18 C or below. Robots can also assist with heavy lifting, for example in a bakery lifting heavy bread tins, or arranging heavy food items in a dry store.
4.4 Increased productivity

Labor shortages can be solved by “employing” more robotics. Robots can work for hours the same product without getting tired or lose focus. They do not go on strike or demand a higher salary. There are no additional costs for visas, and can normally work in confined spaces.[33][42] In some food production plants robots can provide an end-to-end experience with very little human intervention. Machine vision technology can identify and remove foreign objects and defects. It can also sort food items based on color and shape. Laser illumination can help to determine the degree of Chlorophyll, which can indicate if the product is fresh, or not. Automated sorting, washing and peeling can improve the quality of the products. Not only is robotics improving the process flow in the sorting area, but also reduce costs significantly without any human intervention.

4.5 Cost-Cutting

Yearly food production companies spend millions on injuries related to this industry. The most common injuries in the food industry are thermal burns, repetitive stress, cuts, and bruises. The cost of injuries can be divided into two groups: direct and indirect cost. Direct cost includes medical assistance, workers compensation and legal services. Indirect cost can include loss of production, loss of current and future earnings, replacement costs and training cost. Companies can reduce injury compensation n cost by training staff members on safety and improve safety procedures. By implementing robotics in food, production will reduce injury related claims.

Automation can save on operations and maintenance costs in the food manufacturing industry. [42].When new standards are introduced, manufacturers can simply update the existing hardware and software to be compliant and save the trouble of maintaining everything else. Preventive maintenance can be applied through automation, which reduces the long-term cost.

4.6 Staff-related Issues

Today one of the biggest challenges in the food industry is to retain staff. To employ staff in countries includes a high visa cost and training cost including a loss of opportunity cost. By replacing staff members with robotics in critical areas, can reduce the staff cost significantly.[42][49][52]

4.7 Equipment-related demands

Customers of today are very knowledgeable about life in general. Their requirements can change on a daily basis according to the latest research or fad as per the latest news article. It is not always so easy for human beings to keep up with the latest trends in food production facilities as a few changes needs to be done before changing to the next item. Production areas must be able to do quick changeovers to stay in ahead of customer demands.

Cobots can assist with these issues as they can effortlessly move from one section to another without any major interruptions. There is no need for additional time to learn how to produce to new item, or room for any mistakes. Software programs can be changed in a matter of a few seconds and the cobot can produce the new food item effortlessly.

4.8 Improving product consistency

When creating a “lean culture” behind house operations robots plays an important role to achieve this target. The implementation of “Lean Six Sigma”[37][38][39][53] principles can be the most successful when robots forms a part of this implementation. Robots or cobots reduces wastage according to the
eight wastages of “Lean Six Sigma” and improve efficiency and production flow overall. Consistency in food products attracts more repeated customers and reduces wastages, which can improve the net profit on financial statement.[41]

5.0 Pandemics and Disasters

Up to recently the part of customer experience was to have human element to their interactions with a company in the hospitality sector. Due to the latest pandemic, this important experience has changed rapidly and companies needs to be creative and find new ways to stimulate this interaction. Agriculture is especially affected during pandemics due to increased labor shortages. The fear of going out (FOGO) is holding seasonal farm workers back and many valuable crops might be lost if a continuity plan was not put in place. Further, down the line in the food sector, customers are now comfortable to technology for a similar experience and their minds it is much safer to deal with a robotic than a human that might carry the risk of contamination. Customers are now more open to robotic implementation than ever before and if you were planning to digitize your restaurant deliveries, this is the correct time. According to research studies, on it takes 66 days on average to change a habit, but it can vary according to the behavior the circumstances and the person involved. Most of humans are already living in the new normal for more than 66 days, and has got used to technology in their lives. Consumers had learned to put a lot of trust in technology and it seems it will not change soon. All generation groups have learned very quickly to purchase online.

The use of automated systems in different forms can ensure continued manufacturing and supply of food products on daily basis even during a lockdown period. Automated systems can be controlled and monitored remotely without visiting the area of production. This allows the factory to operate remotely, which benefits the current scenario as automated systems aid manufacturers in negating the risks of personnel loss or food contamination. Less human-to-human interaction give way to robots and the world is getting used to this type of interaction. Contact free payments are forming a part of the latest technology. Robots can take temperatures of guests or workers when entering a restaurant or a confined space. Robots can serve food and collect empty plates.

6.0 Applications of Robotics in the Food Chain

Eggs are a very delicate product and needs careful handling. Robots can have a continuous motion for 8 hours or longer, do not need breaks and do not reduce speed (Fig. 9). The question remains if workers will lose their jobs after an upgrading to robots. In a case study in the UK robots has increased production by 55%, no workers lost their jobs and in fact, thirty additional workers were hired to maintain stock.

![A robot is palletizing eggs](image)

Fig. 9: A robot is palletizing eggs [6]
Kraft Heinz Co. in Netherland invested in robotics and AI to strengthen their competitive position by increasing their efficiency in the production process and allowing the company to identify waste. They produce 1.8 million bottles of ketchup on a daily basis. One of the upgrading is automated forklifts, which can uplift pallets with a weight of 1300 kg up to 8.5 m height with a maximum variance of 16 mm. [10]. Flippy the robot is the world’s first kitchen assistant who helps with grilling and food preparation. It is able to monitor the temperature and to make sure the patty is perfectly cooked. According to staff working together with Flippy the robot, it cleans the griller better than what a human being does does can achieve. However when it comes to the final assembling of the burger it is still the best option to utilize human beings for this task.

7.0 Case study of a Delivery Bot

A delicatessen shop situated in an office park employs three delivery staff to deliver food over lunchtime. It takes on average about 15-20 minutes for every delivery. The distances can be anything from 300 m to 900 m in a single direction. A delivery bot moves the same speed as an average human jogger, around 8.045 km an hour. [26]

Table 3 depicts the average walking speed of a human being at a certain age (Table-3). The average age of delivery staff is between 20-30 years old. [11]

| Age       | Meters/second | Miles/hour |
|-----------|---------------|------------|
| 20 to 29  | 1.34 to 1.36  | 3.0 to 3.04|
| 30 to 39  | 1.34 to 1.43  | 3.0 to 3.2 |
| 40 to 49  | 1.39 to 1.43  | 3.11 to 3.2|

It is also proven through research studies that males walk slightly faster than females. It was also observed that most delivery staff is male. When studying this comparison, the delivery bot at 8.045 km and the human staff member at 8.1 km per hour is almost the same.

The operational hours of the deli are between 8:00 am and 12:00am seven days a week. For the research purposes, it is assumed that the deli is busy at all times. To have three delivery staff at all times, the deli will have to employ seven staff members. This will cover both shifts and allow for one day per week off for every staff member.

During this case study, gender was not taken in consideration for the calculations. For the same cost of one month’s fixed salary to human delivery people, four Delivery Bots can be purchased. The average delivery time of a delivery bot is between 27 minutes to 30 minutes. The average battery life is two hours or six km of driving.

It will take around 45 minutes on average to charge a delivery bot. In an 18-hour workday, the delivery bot will be able to do deliveries for roughly about 12 hours and will be on a charger for 6 hours. The illustration in the below table-4 states the charging times and of the different delivery bots:
Table 4: Charging times and of the different delivery bots

| Delivery Bot | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|--------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|
| 1            |   | x | x | x | x | x | x | x | x |    |    |    |    |    |    |    |    |
| 2            | x |   | x | x | x | x | x | x | x |    |    |    |    |    |    |    |    |
| 3            | x | x | x | x | x | x | x | x | x |    |    |    |    |    |    |    |    |
| 4            | x | x | x | x | x | x | x | x | x |    |    |    |    |    |    |    |    |

Some extra time was allowed for the changeover at the charging stations, and the timing should increase slightly on the delivery times and should get almost 25 to 26 deliveries out of every delivery bot per day.

This conclude that the one delivery bot will be able to do 24 deliveries in an 18-hour workday. The total deliveries of four delivery bots will be 96 deliveries in total. A human delivery staff member must deliver at least 12 deliveries to be cost effective. [13]

The below pictorial presentation (Fig.10) of the delivery cycle for a restaurant or coffee shop illustrates the calculation of the deliveries and comparison of the deliveries by human and robots.

Price per delivery bot : $5500 x 4= $22000

Total deliveries =96

Total deliveries = 84

Fig. 10: The delivery cycle for a restaurant or coffee shop.

Salary delivery staff members (Based on a fixed salary)
$ 14.00 per hour x 9 = $ 126.00 x 7 staff = $ 882.00
882 x 7 = $ 6174.00 per week
6174 x 4 = $ 24696.00 per month

Except for the salary and visa cost the price of finding reliable delivery staff can be high. It is very seldom that you will find delivery staff that is on their own visa. The salary is not inclusive or medical insurance, uniform cost or efficiency cost. Delivery bots can normally handle all weather conditions, and do not waste time by talking to people along the road or stop to talk on their mobile phones.

8.0 Advantages & Disadvantages of Delivery Bots

8.1 Advantages

The Delivery bots[26] can work in different weather conditions and have unlimited possibilities of development. The average lifespan of a delivery bot is around 5 years in regular conditions. There is no continuous requirement of training, paid leaves, medical insurance or uniform. Less staff members can be employed, which can be up skilled in leadership or supervisory rolls. Delivery bots can do more deliveries per day then their human delivery staff.
8.2 Disadvantages

The disadvantages of these delivery bots are that the delivery bots cannot normally climb stairs but only certain curbs. Orders cannot be cancelled. Once the order is placed, the order must be delivered. The maximum delivery radius is around 4.5 km. However, this is for sure a way to keep the last minute cost down.

Another disadvantage is that it cannot operate in extreme weather conditions but can only handle temperature between -5 to 40 °C, which makes it unsuitable for countries with weather in summer or winter for example GCC countries were your average daily temperature can reach 50° C or far north countries were temperatures reach -30+ °C in winter.

9.0 Challenges faced by the implementation of Robotics in the Food Chain

The implementation of Robotics will initiate the unforeseen requirements of the policies and regulation related to the operation, usage and legalities of the business. However, the contemporary challenges of implementation of Robots in the food chain are as under.

9.1 Policies and regulations

Policies and regulations needs to be in place that will guide the collaboration between humans and robots successfully. In many implementations, the policies and regulations that will guide the collaboration between humans and robotics are not in place once the implementation is completed. In case of an event where it involved a robotic, it will create a new set of issues. The question arises should robots have rights. Humans built robots and program them. We are the creators of them. Living beings, deserves rights, robotics do not. However, this is not the final solution if an incident arises between a robotic and a human being, and it is debatable. “While OSHA (Occupational Safety and Health Administration USA) does not have regulations specific to robots in the workplace, employers would be wise to conduct job hazard analyses and evaluate any existing or potential robotic equipment installation, to abate any hazards posed by these machines.” [14]. Companies should have regulations in place for example regulations that protect their work force from a human error involving robotics. A proper analysis should be done of the hazards that could arise from working next to a robot in certain areas. Robots and automation is complex, which leaves the business owner with many questions associated with ‘human’ and moral values. An example will be a driverless forklift. Who will be responsible if the forklift causes an accident and a worker is injured?

9.2 Advancement in seed technology

Upcoming advancement in different seed technology bringing in Artificial Intelligence (AI), improved fertilizers with better properties and other crop inputs has led to higher yields of crops and created an oversupply. Famers are then often forced to destroy valuable crops due to a low or no demand for huge quantities. This contributes to wastage and influenced the sustainability of the food chain.

9.3 Return on investment

As any strategic decision, the Investment in the robotics for any company is a decision that should not be taken in the light of appreciation of technology. If the wrong technology is chosen, it is a costly affair for any company. Before making any final decisions, the company goals should be clear what should be achieved over a certain period. However, the growing need of production improvement, the constant need to complete tasks faster the many challenges of labor shortages and the ever-higher customer demands related to product consistency can make a large difference on your productivity.
The return of investment through Robotics can lead to the successful profitable business model only with the right implementation of technology with the pre calculated and well directed approach from the industry experts who understand the technology and industry business operation adequately. This has raised the demand of cross-collaborative studies in the field of Tourism and Hospitality.

9.4 Evolving Technologies and Robotics

Technologies are rapidly changing with every refined development and so the features of Robotics are changing almost on a daily basis. Everyday new features are created that could solve issues in the food chain. This can also be seen as the walkway to the success of Robotics. For an example, one of the challenging tasks is de-molding the cakes for which there is no skill is yet achieved by robotics.

9.5 Customer Service

A robot can achieve the warmth of a genuine smile welcoming your guests in a restaurant. Robots cannot create an exceptional customer experience. For some applications, depending on your environment and type of customer, it is not important how a person is for example greeted but rather how quick and efficient the food is prepared. The question still remains are customers ready to accept a high tech approach. Customers are still reluctant to trust robots completely and often wonder how robots follow strict food safety rules. Who monitor them? Up to today most food production companies do not have a set of approved rules how to make sure that the correct food safety rules are in place when using robotics for production. Learning from past has always indicated that the technology has been more reliable in many different industries like surgeries and medicine, where technological intervention has secured or increased the success rate.

9.6 Procurement and Malfunctioning

The biggest operation issues any industry may encounter is the malfunctioning of the machines and adopted technologies. What alternative plans are in place when your procurement system is fully automated and the system malfunction? A detailed trustworthy operation management plan with possible investigations on solutions of every malfunctioning possibility of equipment and their combinations must be looked to develop a contingency plan to ensure the confidence. As today, we find our documents secure and available with cloud and computers compared to physical copy.

10.0 Conclusions

Through the careful evaluation of the food chain industry, it is clear that trust plays an important role in establishing technologies in the business. The emergence of Robotics in the business is widely seen across the world however, the trust seems to be underdeveloped between Human Robotic Interaction (HRI). If we do not trust industrial robots or cobots, we would be reluctant to collaborate with them. This is one of the main challenges in cobot development.

While observing the different applications of robotics in the food sector it is clearly visible that what companies sacrifice in speed, can be gained in agility. By reducing the number of repetitive jobs by replacing them with robots is not replacing jobs, but paving the way for more intelligent jobs. When spotting the direction what professions in the future will be moving to, it is clear that hardcore skills for example cooking techniques will become less important as it will be done by robotics. Laborers or workers will have to be trained in skills far better than only doing monotonous jobs that could be harmful to the body on the long term. Vocational training centers will have to invest more time in skills of the future, for example customer service, problem solving skills and emotional intelligence. It will be more important for a company that has skilled workers to handle difficult customers and
workers that are able to bring creativity to a business. It will also be vital that food manufacturers will train their staff on critical thinking and problem-solving skills, and this must be planned before deploying automation into their facilities.

The shift to food producing robots offers substantial benefits for the industry. Lack of workforce in the food chain can be solved by the implementation of robotics. Not only will the labor shortages be addressed but it will also minimize the following issues in this ever-changing sector:

- Vacation and sick leave absences
- Duty Hours (24X7)
- Cultural differences
- Labor issues
- The cost of incorrect training by vocational training centers
- Less costly human errors
- Added layer of Safety, less human contact especially during pandemics
- Consistent cleaning procedures

The robots of today are much cheaper than their counterparts of the past. They are also much easier to install and operate. The construction and the material that is used to build robots is more user friendly today and it provides easier ways to clean the robot, especially in the food industry and the strict HACCP regulations.

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