Contribution of Industry 4.0 Technologies to Mitigating Pandemic Contagion and Proliferation

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Abstract

The novel coronavirus has caused a global pandemic of over 10 million infected cases which lead to over 500,000 deaths. The rapid transmission rate of this virus forced countries to impose nationwide lockdowns with the aim of decelerating infection rate and warding off the inevitable overloading of their healthcare systems. A few months after the lockdown, the countries are now looking into lifting lockdown measures and reopening economies. While some nations are able to exercise precautions and safety measures to reopen securely, other countries still face many challenges. In particular, developing nations can no longer be closed for business and must reopen to sustain their economy. Inevitably, this reopening, if not done securely will lead to rapid rise in the infection rates which cannot be absorbed by their healthcare systems due to shortage of medical equipment. Under these challenges, industrial, retail, logistics as well as healthcare sectors require alternate solutions that can fulfill the dual purpose of: (i) ensuring business productivity and profitability during the pandemic (ii) reducing risk of spread of contagion in their facilities by limiting human workforce. One way of ensuring production at minimal human resources is by adoption of automation and emerging technologies available under the industry 4.0 umbrella. In many ways, the pandemic has served as a catalyst to the implementation of these technologies in many sectors. To this end, this paper investigates the scope and competitive advantages of automation and robotics in controlling and mitigating contagions while ensuring that the economy remains open for business. For results, this paper provides a statistical analysis of areas where robotics have already been implemented pre-pandemic, and the advantages they have proven to bring.

1. Introduction

The COVID-19 virus has snowballed into a pandemic that is bringing unprecedented challenges to global economy and healthcare systems. Within the period of late 2019 to July 2020, there have been nearly 10 million cases worldwide and over 500,000 deaths due to the spread of the contagion (Global News 2020). In an attempt to curb the spread of the virus, governments worldwide have enforced physical distancing measures and lockdowns.

By imposing restrictions on physical interactions and maintaining at least a 2-meter distance with others, the health officials aim to stabilize the rate of infection and reduce the spread so that the number of cases does not exceed the capacity of the healthcare systems. As seen in countries such as China, Italy and Iran, when the rate of infection becomes higher than the healthcare capacity and resources, medical professionals are left with making the difficult choice of who receives care and supplies on a priority basis, and this shortage of resources has caused many fatalities. This makes the decision of social distancing very crucial in the control of the virus and prevention of overburdening the healthcare system.

While the social distancing measures keep the common public safe within the comfort of their homes, many essential jobs require workers to come out and do physical work to keep food supply chains and healthcare systems running. This exposes these essential workers to a very high risk for contracting the virus. These workers include jobs for truck drivers, nurses, grocery store employees, manufacturing workforce, among several others. In some of these sectors such as hospitals, maintaining a 2-meter distance becomes difficult due to the nature of the work. This in turn increases the probability of contagion and thus, makes the entire group of workers highly vulnerable. Statistics show that in Italy, 9% of the COVID-19 cases were in healthcare workers (International Council of Nurses). In the USA, COVID-19 cases in healthcare workers are as high as 16% in the state of Ohio (NBC News, 2020).

Risk of virus spread is high in healthcare staff due to:

- High risk of contamination from patients while testing and treating them
- Low opportunity for physical distancing from patients and other coworkers
- Running low on personal protective equipment (PPE)

In an already overburdened healthcare system, with limited personnel and high rate of incoming patients, it is not only important to keep the workers safe, but also to optimize the available workforce.

Industry 4.0 is an industrial revolution that offers several automation and digitization solutions for many industries (Wikipedia 2020). By relying on automation and reducing human intervention in manufacturing and supply chain, among many other industries, the Industry 4.0 technologies enable an economy with highly reduced risk of contagions by reducing frequency of human interactions.

2. Objective

The objective of this paper is to outline emerging technologies under the Industry 4.0 umbrella that are relevant to the challenges being faced by the food and medical industry during the COVID-19 pandemic. This paper aims to provide a strategic guide for management that is looking to improve the efficiencies of their business while also complying with the physical distancing measures to ensure the safety of their workers. Particularly, this study aims to identify address COVID-19 challenges faced by the workforce in:

- Healthcare
- Grocery stores and Food Sector
- Logistics and Delivery Services

The structure of the paper is divided in the following way. Section 3 analyzes the problems that are being faced in the three main industries (healthcare, Groceries and Food Sector, and Logistics and deliveries. Based on the analysis of the problems in these sectors, Section 4 recommends solutions that can be implemented using the technologies of industry 4.0.

3. Problem Analysis

During the pandemic, legislative physical distancing has directly lead to a deceleration of businesses and the economy at large due to lowered staffing and human resources available. In order to comply with physical distancing measures, industrial facilities face the challenge of allowing only a limited number of workers to work at the facility in each shift. This has lead to lowered production rates. For many products, this lowered throughput is directly leading to shortages along the supply chain and consequently, a loss of profitability for many businesses. In this section, a summary is presented on some of the major problems governing the healthcare, food and logistics sectors in the Covid-19 pandemic.

Healthcare

The first point of potential virus spread to a healthcare worker begins at the point of diagnostic testing. The testing procedure involves nasopharyngeal test in which a swab is inserted by the healthcare worker in the patient's nose or mouth and sample is collected. During this testing procedure, not only is the physical distance between the patient and worker very less, but there is also physical contact. Thus, there is high risk of virus transmission through airborne method as well as physical contact. In addition to that, in the event that a patient coughs or sneezes unexpectedly, that risk of infection is drastically heightened, considering the fact that the mask is removed by the patient during the testing procedure. A second part of the diagnostic testing is checking the body temperature of the patient, which involves holding a thermometer to their forehead, which again requires close proximity. Temperature reading is also repeatedly carried out during the patient monitoring phase, which requires healthcare staff to physically conduct the procedure. Thus, the probability of infection is very high for healthcare workers during diagnostic testing and monitoring.

Table 1 Problem Analysis of Issues Caused by Covid-19 Across Sectors

Healthcare	Grocery Stores and Food Sector	Logistics and Delivery
• Risk of infection among healthcare workers • Understaffing due to higher than normal volume of patients • Long wait times and queues for Covid-19 tests and processing of results • Shortage of PPE for staff	• Essential workers in stores and along supply chain at high risk for exposure due to work • Through the grocery store staff, the stores can become a center for spread of contagion from one customer to another • High risk of spread of virus through surfaces such as carts, checkout counters and shelf items • Risk is amplified through air borne droplets from one person to another • Home deliveries are a viable option to maintain physical distancing but can put delivery staff as well as customer at risk	Delayed deliveries across the supply chain Risk of infection among truck drivers

Food Sector

Groceries stores across the world are open as essential businesses even during the Covid-19 pandemic. In fact, there is a growing demand for workers at grocery stores during the COVID-19 pandemic in Canada (Bloomberg 2020 and The Globe and Mail 2020). Being open for business, puts the grocery store workers at high risk for not only contracting the disease but also spreading the virus without knowing they are being a carrier.

Logistics

Due to physical distancing measures to curb the spread of the coronavirus, logistics services have been greatly affected globally. Truck drivers face a great risk of infection spread as they commute long distances between shipper and receiver and often take pit stops at locations that may not have adequate hygienic procedures, such as hand sanitizers, during the COVID-19 pandemic. A major cause of concern in North America is the transportation of supplies from the hotspot New York state where the number of new cases per day are consistently high, across the border into Canada. In addition to the truck drivers that face a high risk, there are many last mile deliveries within cities that require human resources which can ultimately propagate the spread of the virus. Since the drivers are handling packages from various customers all over the region all day long, they could potentially be coming in contact with the virus through surfaces. This endangers not only the driver, but other receivers as well (Mike Antich 2020).

The issues discussed in this section are mainly caused by the physical distancing measures in place to curb the virus by limiting human interactions. However, this is causing a heavy loss in revenue for small and large businesses. In order to bring the businesses back in operation without compromise health and safety of both- staff and customers, robotics and automation can provide a viable situation under the Covid-19 circumstances. The next section discusses some of the solutions that are being implemented or can potentially be used in the future.

4. Solution Methodology: Industry 4.0 Technologies

Industry 4.0 is essentially an industrial revolution which is a cross breed between traditional manufacturing practices, with the advent of latest technologies in automation, smart devices and machine-based learning. Synonymous with terms such as "smart manufacturing", "smart factory" and "manufacturing 4.0", this revolution leverages the Internet of Things (IoT) and other technologies in human-machine communication to enable enhanced automation, self-monitoring and smart machines that can greatly reduce the need for human intervention (Wikipedia 2020).

In order to reduce these losses, robotics and automation that reduces the need for human workers can be a profitably investment to overcome the constraints of physical distances. The automation solutions developed by Industry 4.0 can allow businesses to continue to run efficiently without allowing 'work from home" or physical distancing restrictions to adversely affect efficiency or profitability.

This section gathers resources on automation and industry 4.0 technologies that can be useful in times of a pandemic to ensure that business profitability is sustained when human resources are limited either by pandemic or other factors.

4.1 Automation in COVID-19 Diagnostic Testing and Patient Monitoring

To reduce the patient proximity during testing, in the current state many hospitals have introduced concepts like drive-through testing (blogTO, 2020). However, this infrastructure is not possible for all clinics and hospitals to develop and manage in terms of the space required as well as the costs. Moreover, patients who do not have cars are still required to be tested inside the facility. An additional disadvantage is that healthcare personnel are still required at the drive-through booths to perform the testing and they need to be wearing PPE, which uses up human resources as well as essential supplies.

Implementation of automation solutions for the testing and monitoring phase can be achieved by using robots to perform the swab testing and temperature reading of the patients. This concept has been developed in a study by Hunt et al. at Wayne State University in 2008 (Hunt et al. 2020). Their study explores how robots can be used for swab testing given all the medical parameters such as depth of insertion and textures of different surfaces along with simulation results. The implications can be used to enhance existing robots and program them for rapid deployment for COVID-19 testing. Small scale commercial examples of robots already being used in the pandemic can be seen in China where they are not only being used for swab testing (The Star 2020, CNA 2020) but also for spraying antiseptic in public areas and monitoring public for wearing masks (Business Insider 2020). According to a Lifeline Robotics, a company that began experimenting with robots for COVID-19 testing, the entire automated swabbing process, which includes automated data entry of patient information, takes about seven minutes. The process of collecting the swab sample from the throat with a robot only takes 25 seconds (Steve Crowe 2020). According to another report from Spain, a robot can perform up to 20,000 tests a day (The Next Web 2020).

The main advantages of introducing this automation in medical procedures during any pandemic are:

1. Robots can mitigate the effects of current shortages in medical staff. By employing robots to do the tasks that can be automated, hospitals can reserve their human resources for other complex tasks such and performing the lab tests. More staff will be available in the lab which could expedite the delivery of test results to patients. Other complex tasks involve assisting and monitoring critical patients who are in ICUs or on ventilators. Thus, robots in this scenario can allow for more efficient human resource deployment.
2. Another consequence of shortage of human resources during the COVID-19 crisis is that nurses and doctors are being pulled out of other departments, which is leading to cancellation of appointments for other medical procedures not related to COVID-19, such as elective surgeries for cancer. By using robots, these doctors can go back to serving patients in other departments which are just as critical.
3. Reducing the number of workers on the testing stage will directly mean that the amount of PPE required will also reduce, as robots do not need masks, gloves and face shields to perform their functions. This means that more PPE be available to perform critical functions.
4. Reduced risk of infection for healthcare workers and transmission of disease from one patient to another by reducing frequency and proximity of close contact with patients.

4.2 Automated Guided Vehicle (AGVs) in Healthcare

Automated Guided Vehicles are robotic carriers that travel along marked paths on the floor. Some AGVs are also programmable to be navigated by means of wireless technology, magnets or even lasers (Lee and Yang 2012; Ida et al 1993). In industries, AGVs are currently used in warehouses for order picking or material handling to move parts from one area to another without human intervention (Banker 2020).

In the pandemic crisis, AGVs in hospitals can be used for movement of either supplies or hospital beds within the facility. For example, when patients are first admitted into the hospital or arrive in the hospital in an emergency, the healthcare team is usually wearing their PPE and waiting at a special entry door for COVID-19 patients. It usually takes two or more people to push the hospital bed from the ambulance to the room. However, based on the AGV technology developed by Wewo Techmotion, using an AGV for the hospital bed can reduce the number of workers required to one (Wewo Inc. 2020). This allows the other staff to be deployed for tasks that are more essential. Moreover, it reduces the number of healthcare workers exposed to the patient while pushing the hospital bed, which can be at a very close distance. In a similar fashion, AGVs can be used to transport food, medical supplies to patient wards, thereby eliminating the need for persons coming in close contact with the patients.

In the literature, a relevant study by Pedan et al. (2017) outlines the design and specification criteria needed for AGVs for hospital standards. The study provides simulation results of potential application in a hospital and what benefits can be achieved from the implementation.

Bringing the AGV's into healthcare may have the following advantages:

1. Reducing workload for healthcare workers
2. Minimizing their interaction in close proximity of patients
3. Allowing more optimized resource allocation of the workforce
4. Reducing number of interactions between healthcare workers and patients
5. Minimizing PPE usage.

4.3 Solutions for Food Retail Stores

In order to reduce the risk of contagion spread at retail stores through contact and respiratory droplets, many stores have adopted a limit on the number of people that can be inside the store at any given time. At peak shopping hours of the day, is a hindrance which can drive down the retail revenue as it can cause shoppers to divert to other shopping centers that better suit their timings. Additionally, grocery stores provide essential items to senior citizens who are at a higher risk of the virus. For this reason, many stores have reserved early shopping hours exclusively for senior citizens to reduce the traffic inside the store and reduce the probability of contagion.

In order to sustain the revenue at these essential stores and preventing a closure of the businesses due to possible spread of the virus, it is necessary to devise solutions that can enhance physical distancing to the maximum degree while reducing, or even eliminating, any risk to staff and customers through contact and air. This solution is possible by using automation and robotics inside the stores to build fully automated grocery stores that promote pick up and deliveries rather than in-person shopping.

To begin with, the concept of AGVs can strategically be applied to grocery (or retail) stores in much the same fashion currently used in warehouses. Grocery stores can be stocked using AGV robots, and order picking and packaging can also be done using automation for customers that place orders through online apps. Moreover, grocery checkouts can either be automated (Advantage2Retail, 2020) or rebuilt for self-checkout, a phenomenon picking up pace during the pandemic (NCR 2020). Automating the cash counter directly reduces the number of employees required at grocery stores and thus helps to flatten the infection rate among essential workers.

4.4 Logistics and Delivery Technologies in Industry 4.0

Due to physical distancing measures, there is a heightened demand for home deliveries of food, groceries and medicine. All of these activities leave essential workers at high risks for infection. Some of the emerging technologies that can enable the reduction of labor required in the logistics industry are discussed below.

4.4.1 Drone Deliveries

Drone deliveries are basically parcel deliveries made by remote-controlled or automated drones. Drones can reduce delivery times by up to 50% (GPS 2020). They have been previously tested out by Amazon (Amazon Inc. 2020). However, wide scale adoption of drone deliveries was limited because of limited testing, governmental constraints, and limitations on the weight that the drones can carry efficiently (about 5-10kgs). In the COVID-19 scenario, many pharmacies and essential goods stores are forced to remain open for business. In the USA, home kits for testing will soon be made available (U.S. Food and Drug Administration 2020) and high influx of buyers are expected to visit pharmacies for purchases. This influx may increase the risk of potential spread of the virus from the stores itself. These businesses must consider drone-based technologies for delivery of medicines so that the direct influx of potential customers who come to buy testing kits or other supplies, or asymptomatic carriers is reduced. Since medical packages are generally lighter in weight, the pharmacies would be a feasible starting point for drone based deliveries Due to the state of emergencies, governments must look into relaxing the laws related with flying drones and consider allocating budget for testing and implementation of drone based deliveries. A great source of motivation lies in that fact that this method can greatly facilitate the physical distancing measures by directly reducing the number of customer interactions at pharmacies.

In some countries such as China and Japan, rapid deployment of drone deliveries has been adapted during the pandemic. Antwork, a drone delivery company in China applied for clearance for drone based deliveries as early as October 2019 for the transport of medical supplies. Terradrone is a Japanese company that began drone deliveries for medical supplies in China as early as February 2020, before the pandemic grappled countries worldwide (GPS 2020).

Major advantages of drone deliveries during the pandemic are

1. Shorter delivery times for essential supplies including medicines and COVID-19 test kits

2. Lesser public visiting stores for purchases

3. Lesser human resources required for home deliveries, and 100% contactless deliveries

4. A major advantage for senior citizens who are at maximum risk of the virus.

In addition to home deliveries of food and other items, robots have found other uses during the pandemic. These have been listed in Table 2

Table 2

Drones Functionality	Advantage	References
Crowd patrolling: Ensuring physical distancing in public places and face masks usage	The drones can detect people in a crowd not wearing a face mask and they can be instructed to disperse and comply with physical distancing	MicroMultiCopter Aero Technology Ltd. (PR Newswire 2020)
News broadcasting in public areas	Rapid updates during COVID-19 were provided over speakers on drones with the advantage that remote areas or areas without coverage through traditional broadcasting speakers can also receive the news in a timely manner	
Temperature sensing	Thermal sensors installed on drones patrolling crowds can detect any person with higher than normal body temperatures to identify potential coronavirus case in the crowd and disperse them in a timely manner.	
Traffic control	Monitoring of road conditions in larger areas is possible in lesser time with drones.	
Disinfectant spraying	Drones can used to spray disinfectant in small public areas such as shops, bus stops and gas stations	

4.4.2 Self -Driving Trucks

A major segment of workers under risk are the truck drivers, on whom the entire supply chain and logistics is dependent. Currently, under the COVID-19 protocol for the US-Canada borders there are many long waits and procedures to ensure the health and safety of the truck drivers while crossing over. These procedures increase lead time of the supply chain. Moreover, the rate of infection can be high for truck drivers. One way to reduce the number of truck drivers is by the implementation of autonomous vehicles for the transportation of goods.

Autonomous, or self-driving, trucks are vehicles that can operate with little or no human involvement (Wikipedia 2020). They have been developed by many companies including Tesla, Volvo and Walmart. However testing of these vehicles has been slow and at least pre-pandemic, the implantation of self-driving trucks was far off. However, the pandemic is accelerating the adoption of Industry 4.0 technologies, and there are many advantages for industries to rapidly test and implement autonomous vehicles in their supply chain during the pandemic. This will not only provide efficiencies for the company during the pandemic, but will also prove to be economically beneficial after the pandemic is over.

The main advantages of adopting autonomous trucks in supply chain during the COVID-19 crisis include:

1. Reduction of risk of infections among workforce required to drive truck: Since self-driving trucks require minimal human involvement, long distance trucks might require only one driver to be present, whereas traditionally, trucks have at least 2 drivers to alternate the driving shifts. This automation solution reduces the number of drivers required, thereby reducing the probability of infection. This in turn helps flatten the curve.
2. Border crossing can be facilitated as no temperature and swab testing would be required for the drivers for unmanned vehicles
3. Testing of the autonomous truck technology is now feasible more than ever. This is because, due to physical distancing, provincial restraints and lockdown measures, the traffic flow on highways is greatly reduced. This enhances the feasibility of companies wishing to run pilot tests for self-driving trucks. With lesser cars on the highway, there is reduced risk of collision with manned vehicles, an issue that has previously created a lot of debate for the adoption of autonomous vehicles (West 2020 and Koopman et al. 2020). This idea of reduced risks should serve as a motivation for governments to encourage the testing and implementation of both self-driving cars and trucks. It is highly unlikely, that wide geographical areas will have the same kind of reduced traffic flow for testing purposes post-pandemic. The same benefits extend to reducing the number of drivers required for restaurant deliveries by testing out self-driving cars, a concept being vehemently developed by (Uber 2020).
4. Lead time for deliveries can be reduced since unmanned vehicles will require lesser stop overs at on-routes.
5. As businesses struggle for economic viability during the pandemic crisis, reducing the number of drivers can reduce the number of paid workers for companies. These benefits can continue for the company even after the pandemic is over, as they would have already established a working model of their supply chain with self-driving trucks to use indefinitely.

5. Conclusion

Industry 4.0 emphasizes on automation of all industries. While it was developed conceptually in 2011, its adoption is still in the early stages. This paper fulfills its objective of illustrating how the COVID-19 pandemic can be mitigated through the acceleration of the adoption of Industry 4.0 solutions, which help reducing the spread of the virus in the communities. The paper successfully discusses, with depth, relevant emerging technologies and their advantages for the medical, food and logistics industries not only during the pandemic, but after the return of businesses to normalcy as well. The paper also provides intuitive insights on why governments and industries can use the pandemic as an opportunity to overcome previous barriers, which hindered testing and implementation of many of these emerging technologies like drones and self-driving vehicles, which are perceived as risks for human in the testing phase.

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