❐ 1

The Effect of Automated Swab Robot: New Technology Drives New Behavior

Jasper Rae Zeus A. Antonio[1], Jonalyn Mae E. Aranda[2]
[1]Simworks IT Solutions, Pangasinan, Philippines
[2]Electrical Engineering and Allied Department, Technological University of the Philippines Taguig, Philippines

Article Info	ABSTRACT

The world is now faced with a devastating pandemic outbreak, COVID-19. The latest coronavirus infected almost all continents and witnessed sharp rises in cases diagnosed. The engineers tend to eliminate the matter and have solutions, one in every utilizing technical innovation. Researchers from Singapore, Taiwan, and Denmark have developed a fully automated robot that may take coronavirus swabs in order for health care professionals don't seem to be exposed to the chance of infection. The objective of this study is to present the potential effects of robotics to help healthcare professionals on getting specimens and testing for COVID-19. These possible consequences include positive and negative outcomes and as a result, the overall impact on the profit or loss to society is far from obvious. The paper discusses two theoretical examples, distinguished fundamentally by the different behavioral responses of the automated swab robot and the selection of results in line with policy interventions. Researchers have opted to use the system dynamics approach to consider the potential widespread implementation of automated swabbing, which is increasingly regarded as unavoidable.

This is an open access article under the [CC BY-SA](#) license.

Corresponding Author:

Jonalyn Mae E. Aranda,
Electrical Engineering and Allied Department,
Technological University of the Philippines Taguig, Philippines,
Km, 14 East Service Rd. Western Bicutan, Taguig City, Philippines.
Email: jonalynmae_aranda@tup.edu.ph

1. INTRODUCTION

In the 2015 outbreak of Ebola, the United States White House Science and Technology Policy Office distinguished three (3) expansive areas in which robotics could make a great contribution: health care, logistics, and the detection or control of voluntary quarantine compliance [1]. Health care professionals can also be exposed to the virus by direct patient interaction when using their personal protective equipment.

According to the World Health Organization (WHO), as of November 2020 the COVID-19 has spread to 218 countries and territories, of which 251 have been recognized by the United Nations worldwide. [2-3]. This signifies the necessity of research into remote activity for a wide variety of applications involving dexterous utilization. Anticipate a growing number of cases, including robotic intervention in the medical field, such as an automated swab test, and other automated technology used to prevent the spread of disease.

1.1. Rise of Automation Caused by Coronavirus

The first major implementation of robotics has been in manufacturing applications. Similarly, the war on infectious diseases requires an atmosphere that is uncomfortable for human workers, but suitable for robots

[1, 4-6]. Remote temperature measurement robots in public areas and ports of entry show the application of modern diagnostic and screening technologies [7].

The coronavirus disease transmits not only through interpersonal contact with the respiratory tract, but also through exposed surfaces. The ultraviolet (UV) illumination systems such as pulsed xenon ultraviolet (PX-UV) are used as an alternative disinfectant to reduce contamination of contact surfaces in the healthcare setting [4, 8]. Instead of manual disinfection, requiring the mobilization of the workforce and posing a risk of exposure to cleaners, a stand-alone or disinfection robot can contribute to the remote process of disinfection [1,8]. Increasing the use and development of automated technology is catalyzing the pandemic. This study has a potential positive and negative effect on the use of technology and information in robotics. It seems perfect as a robot for repetitive work, making it great for swabbing [6]. The presence of "automated or robotic-assisted nasopharyngeal and/or oropharyngeal swabbing" can accelerate operation, lessen the risk of infection and reduce the number of workers involved in other tasks.

2.   METHODOLOGY

As a tool to examine the effects of automated swab on safer COVID-19 testing, researchers have opted to use the system dynamics method used to evaluate the complex conditions that would emerge from the two theoretical scenarios. The causal loop diagram (CLD) approach method and the Ishikawa diagram describe the primary variables and the causal relationship between them. The ease of seeing the interrelationship of variables is expressed in the causality that is created and the actions that will occur with the application of the scenario. CLDs include variables that are indicated by their names and causal connections, arrows that point from the independent variable to the dependent variable [9].
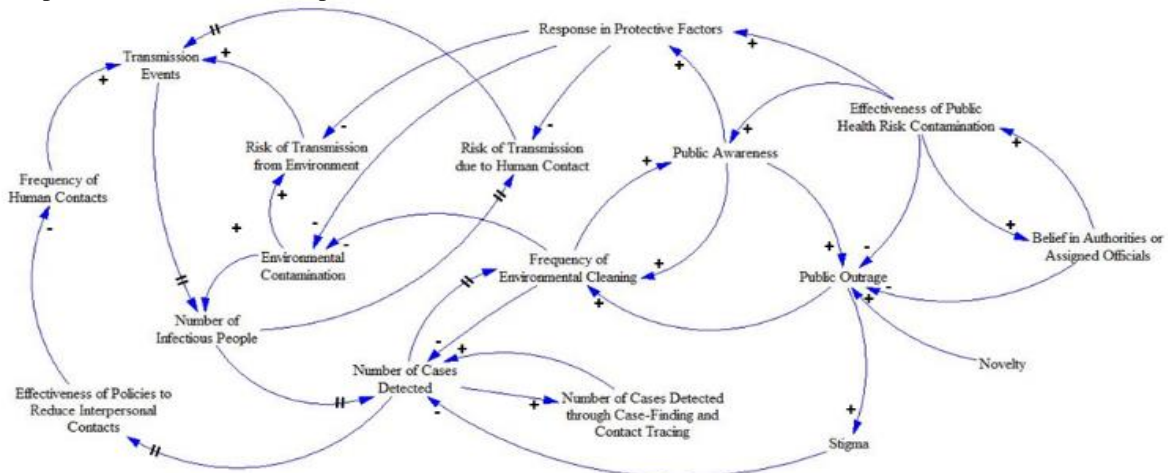

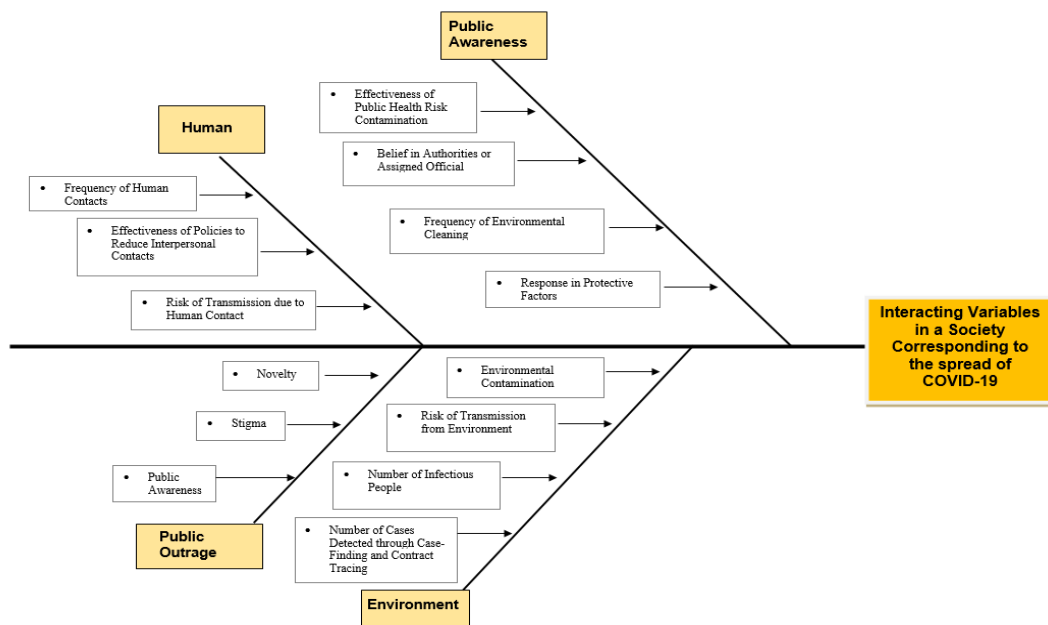Figure 1. CLD showing the interacting variables in a society corresponding to the spread of COVID-19

Figure 2. Ishikawa Diagram for the Society's Response in the spread of COVID-19

Figure 1 provides an illustrated CLD for the interaction of different variables in a society that responds to the spread of COVID-19 [10]. The increase in the probability of infection due to human interaction is consistent with an increase in transmission events. It also inhibits the rate of increase in the number of infectious people. The perceived number of infectious people is due to preventive measures or capacity to test and identify new cases. The factors established in Ishikawa diagram was based on the conducted open-ended questionnaire survey to a random sample of 100 medical technologists. Figure 2 presents the possible contributing causes (public awareness, human, public outrage, and environment) or interacting variables, listed on the smaller "bones" under various cause categories, resulting in the society's response to the spread of COVID-19.

2.1. Scenario Development
In view of the degree of uncertainty regarding the possible effects of Automated Swab Robot on safer COVID-19 Testing, the researchers have chosen to apply scenario-analysis methods. The goal of this approach is to gain valuable perspectives by exploring a number of different futures.

2.1.1. Scenario 1: Behavioral Responses of Automated Swab Robot
The given scenario presupposes major changes in behavior related to operation and use of automated swab robots. Researchers discover the possible impact of automation technologies on medical applications. Figure 3 illustrates an Ishikawa diagram for a variant of factors related to 'community and health congestion' in response to the use of automated swab robots. This new technology serves as a replacement to the conventional swabbing process. An efficient, safe, reliable automated swab robot could, in fact, enhance the human quality of patient and healthcare professional interactions by preventing their interpersonal contacts.
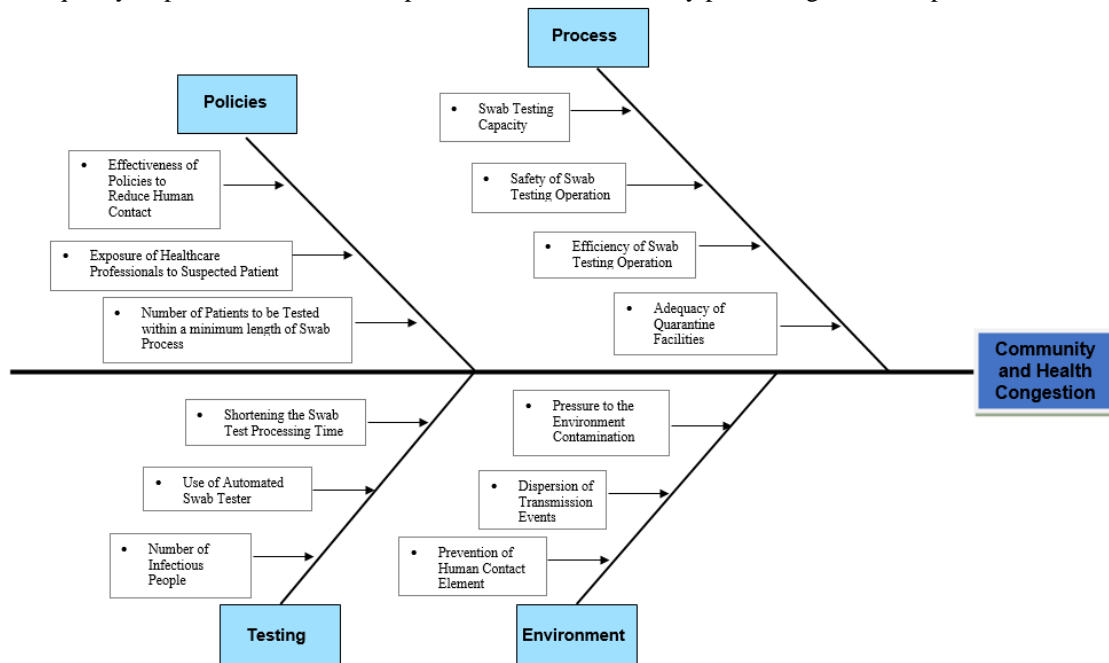

Figure 3. Ishikawa Diagram of the Behavioral Response of Using Automated Swab Robot

Two categories underpin the behavioral responses for the adoption of Automation in safer and more efficient COVID-19 testing. These categories are: (1) consumer preference changing to favor automation; and (2) increasing familiarity of automation technologies.

(1) Consumer preferences in favor of Automation Technologies
As part of the urgent need to respond to the COVID-19 pandemic, governments, health care providers and businesses have looked at the Artificial Intelligence (AI) applications to compensate for human workers' unavailability [11-13]. Human element meanings of people will begin to alter consumer desires and see emerging technology as helping them to protect their health and enhance their well-being. These positive events show Automation Developments in a new light on the medical sector as helping assistants rather than intimidating overlords.

(2) Increasing familiarity of Automation Technologies
By removing repetitive manual labor from these research practices, physicians, and health specialists

could fully-concentrate on patient care and critical medical decisions. Creating and introducing new technology to speed up research and to report results rapidly, while at the same time protecting patients' privacy [14-15]. This illustrates the familiarity and change to automation technology in the battle against COVID-19.

2.1.2. Scenario 2: Selection of Effects in Accordance to Manual Swab Test Policy and Automated Swab Procedure

Without good policies and standardized processes, it will be difficult to direct research and innovation programs. However, policies and procedures must be adopted and enforced in order to have the desired result.
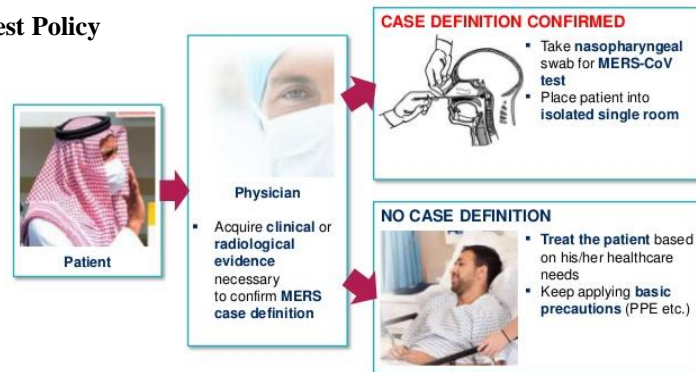
A. Manual Swab Test Policy

Figure 4. Assessing the Patient Conditions prior MERS-CoV Testing

Testing protocol is the general concept that a medical practitioner should obey the exams. The initial diagnostic tests for COVID-19 are based on the Provisional Guidelines provided by the WHO for the MERSCov Laboratory Testing in which countries suggest the collection and testing of nasopharyngeal and oropharyngeal swabs. The decision to test should support clinical and epidemiological factors (refer to Figure 4), and there are a handful of rules listed [16].
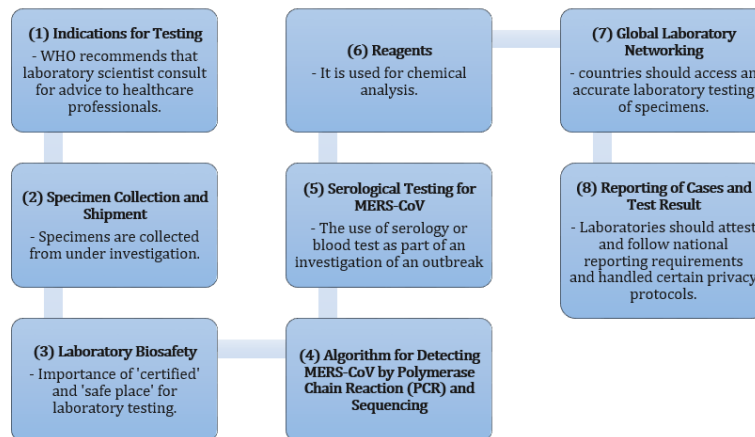
MERS-CoV Testing Policy:

Figure 5. Manual Swab Testing Policy based on Interim Guidance issued by WHO

B. Automated Swab Test Procedure

Automated 'Throat Swab' Robot Procedure:

The team of ten (10) researchers at the University of Denmark, Europe, has developed a fully automated oropharyngeal swab robot (Figure 6) capable of performing COVID-19 throat swabs [17-18].
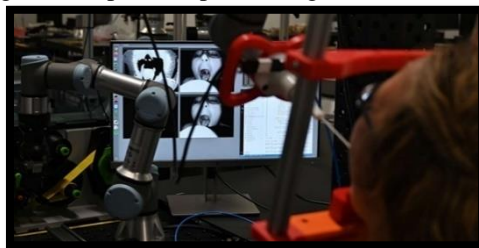

Figure 6. Throat Swabbing Actual Operation of Denmark's Automated Swab Robot
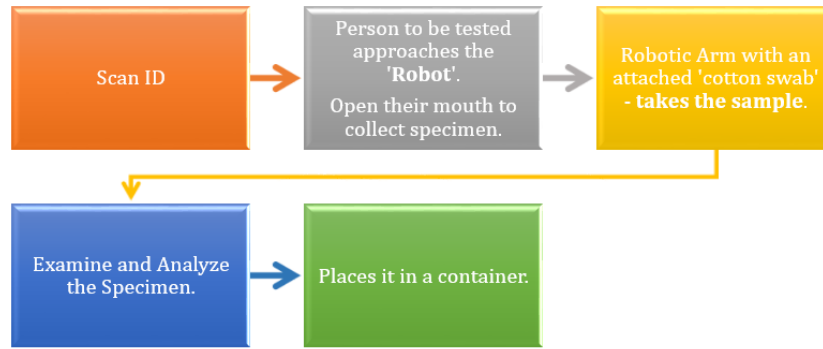
Figure 7. Procedures followed by "Automated Throat Swab Robot"

Figure 7 shows the process on how the patient and the robot gather the specimen for testing. The person who will be tested will approach the robot then opens their mouth to accumulate specimens from their throat. The robotic arm has an attachment of cotton swab to take the specimen from the person that is being tested and then it will be placed in a safe container. After getting the sample, a medical technologist will examine the specimen to assess the patient if positive or negative from the virus [17].

Automated 'Nasal Swab" Robot Procedure:

The nasopharyngeal or nasal swab testing is another method of collecting the specimen and offers highest yield for laboratory analysis. Biobot Surgical Pte Ltd has partnered with a group of clinicians from Singapore NCCS-SGH and Duke-NUS MedSchool to set up a robot to automate the nasal swabbing required in diagnosing COVID-19. [19-21].
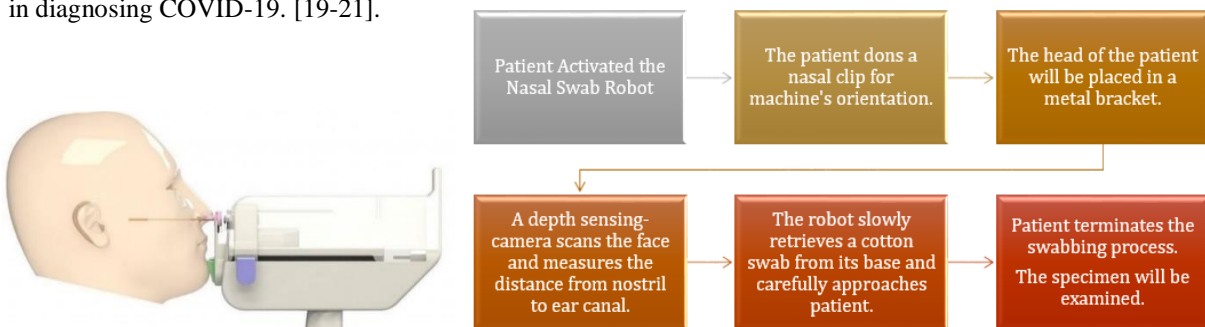

Figure 8. First-fully patient controlled 'Nasal Swab Robot' (Left picture), and Nasal Swab Robot –Swabbing Procedure (Right picture)

An automated nasal swab robot, known as the "SwabBot," as shown in Figure 8, is a self-managed robot that enables individuals to initiate and terminate the swab process. The robotic swabbing process is said to have been completed in just 20 seconds from start to finish [20].

In order to protect the patient, the robot has an integrated feature that withdraws the swab stick if there is resistance as it goes deeper into the nasal cavity. In the improbable event that the individual can't endure the operation, they can terminate the operation by turning their heads away from the robot [19-22].

3. RESULTS AND DISCUSSION
3.1. Modeling Simulation

The world is capable of adapting and developing certain circumstances and technologies. One of the greatest achievements and inventions that man created is technology. Robotics could be a big step towards advancement, and very helpful particularly in the field of medical technology. Amidst this pandemic, robotics and automation are some solutions to protect the welfare of people and eradicate the virus.

One invention that is very capable to perform the task of medical personnel and at the same time protects the person and the patient when testing for COVID-19 is the "*automated swab robot*". Every research there will always be positive and negative effects.

A.   Positive Effect of Automated Swab Robot

We are living in a world where technology and automation are starting to develop, and some of them are implemented. Medical automation will revolutionize the way we experience medical care [23-24].

Medical Automation
- A technologically enhanced workplace to reduce the burden of health workers and a solution to the health care cost crisis [23].

Economic Uprising
- This invention will surely hit the economic uprising amidst the pandemic.

Engineering Innovation
- This technology leads to new products and services for inventors, engineers, and scientists

Cost Effectiveness
- The increase in swab testing throughput produces an increased in productivity.

B.   Negative Effect of Automated Swab Robot

Here are the following *negative effect of automated swab robot*:

Potential Job Losses
- Human may not be needed at all if the robot can perform at a faster but efficient and more consistent rate.

Initial Investment Cost
- Not all countries have the capability of funding research and innovation.
- This is one of the obstacles on investing medical robotic technology.

Mechanical Error
- The most critical flaws of robotics and it can be joint errors, kinematic errors, and non-kinematic errors.
- Mostly, these errors are due to mechanical or parts of the robot that can cause a false-postive result [25].
- Always check the machine and perform periodic maintenance.

Technical Problems

The RT-PCR tests have established a defined standard for the detection of COVID-19 in clinical practice [26]. Technical problems being encountered including contamination during sampling (e.g. accidental contact with contaminated gloves or surfaces), contamination with PCR amplifiers, contamination with reagents, cross-contamination of samples and cross-reaction with other viruses or genetic material may also lead to false-positive results. [25].

False negative is a test result that is incorrect, since it means that a person is not infected when they are actually infected, and a false positive result shows that a person is infected when they are not infected [25, 27-28]. The impact of COVID-19 could lead to more research in the field of robotics, however, without continued development in research, robotics will not, on their own, be prepared for the ensuing scenario. By encouraging the group of engineers, and healthcare specialists, we can be prepared when the subsequent pandemic arrives.

C.   Automated Swab Test *versus* Manual Swab Process

To investigate the effects of automated swab testing over manual swabbing process, a causality relationship of 'Ishikawa diagram' was established as shown in Figure 9. As for the design of two different swab testing operations, the given diagram considers their corresponding system and process.

The model makes an appropriate framework for discussion in the consumer preferences to be in favor of automation technologies as part of the investment in medical applications, and to provide an increase of significant advances in patient care. The newly-developed automated swab testing is theoretically designed to increase the swab testing capacity while shortening the turnaround time of the testing process.

On the other hand, the results of the traditional or manual swabbing process in this context present the trust acquired during the swab operation and the processing of specimens due to the existence of interpersonal interactions and/or the perspective of the human element reliability. Both of these factors help to offset the impact of the swab operation and suggest that the method can settle in a new balance state.
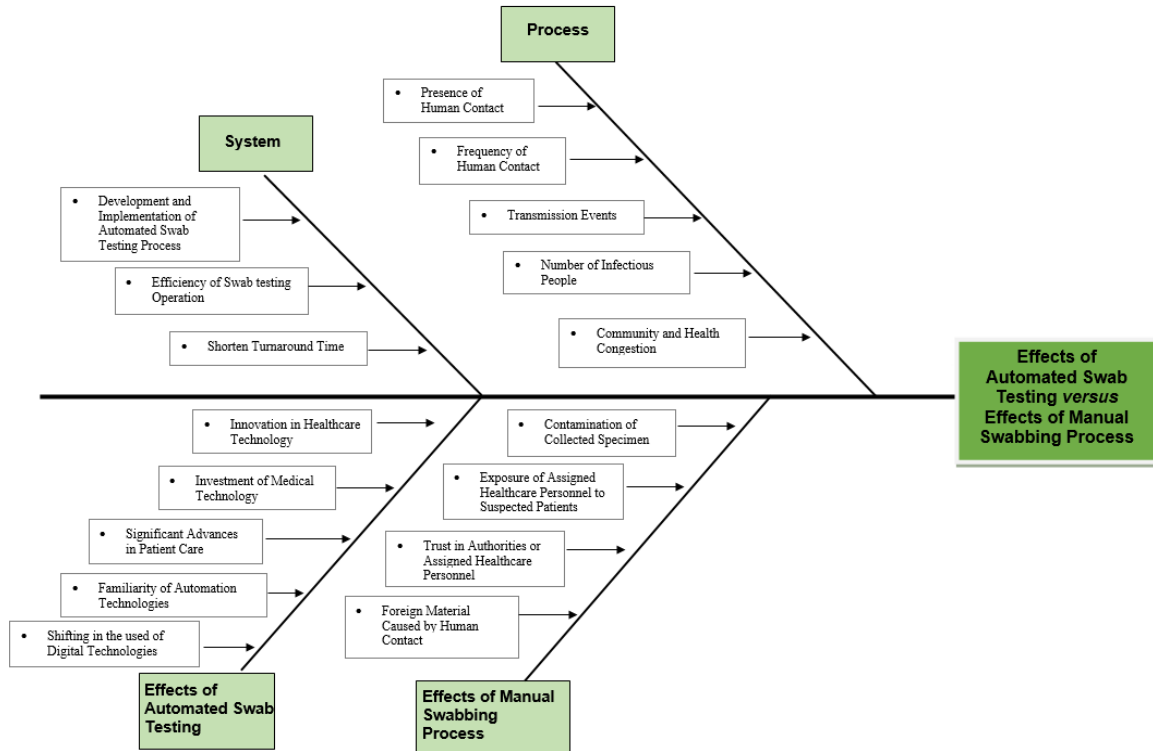
Figure 9. Ishikawa Diagram for the Effects of Automated Swab Testing versus
Effects of Manual Swabbing Process

C. Implementation Capability

The expeditious migration to automated technologies driven by the pandemic, and acceleration of the community's automated capabilities to keep pace are the requirements to its implementation capability. Many companies that consider robotic swab testing are engaged in developing and marketing this technology. The goal is to make the job limit the virus contamination with the patient and the medical staff. This pandemic has presented many of us with a chance to develop new capabilities and perspective using the field of engineering and specialization.

The First Associated Hospital of Guangzhou Medical University used an automated swab robot to collect oropharyngeal (OP) samples [29]. Sampling parameters, safety, and efficacy of OP swab robot have been observed in 20 healthy individuals and 20 suspected COVID-19 patients from a fever clinic [30]. The efficiency was determined on the basis of the success rate of the sampling procedure (completion in first attempt). Success sampling rates were both 95 percent for healthy individuals and pathogenic consistency for suspected COVID-19 patients [29].

The conventional process of OP swab includes proper delivery of the swab to the target tissue, adequate strength and contact-avoidance of surrounding tissue, and confirmed an improvement in the positive detection rate [30-31]. The automated OP swab robot enables medical personnel to have clear vision through remote camera during sampling without close proximity to patients, resulting in a consistent collection of swab specimens [30]. This would make the work more competitive and make it easier to do more tests compared to medical personnel. This would be of great benefit not only to medical professionals, but also to hospitals that perform swab testing.

4. CONCLUSION AND FUTURE WORK

One of the positive effects of automated swab robots is the increase in swab testing capacity that could shorten the turnaround time of the testing process. The theoretical scenarios given examined at a number of possible outcomes from the adoption of automated swab testing. They are not intended to describe a precise picture of the future, but rather to display a variety of potential futures. Within the two scenarios, changing the conventional approach to the use of automation systems would become safer, time spent, and the burden on environmental contamination will be minimized as it decreases the presence of interpersonal contact respiratory droplet transfer.

REFERENCES

[1] G.Z. Yang, B. J. Nelson, R. R. Murphy, H. Choset, S. H. Collins, P. Darlo, et al. "Combatting COVID-19 – The role of robotics in managing public health and infectious diseases", in Science Robotics (ISSN 2470-9476)American Association for the Advancement of Science, New York Avenue, Washington, 2020, pp. 1-3.

[2] World Health Organization. (2020, November 23). WHO Coronavirus Disease (COVID-19) Dashboard. Retrieved from https://covid19.who.int/

[3] S.A. McFadden, A.A. Malik, O.G. Agoulou, K.S. Willebrand, and S.B. Omer. "Perceptions of the adult US population regarding the novel coronavirus outbreak", Cold Spring Harbor Laboratory, 17 April 2020. doi: 10.1371/journal.pone.0231808.

[4] E. Dombre, P. Poignet, and F. Pierrot. Design of Medical Robots. Online Library, Wiley 2013. 05: 281. doi:10.1002/9781118562147.ch5

[5] M. M. Nerandzic, P. Thota, T. Sankar, and A. Jencson. Evaluation of a Pulsed Xenon Ultraviolet Disinfection System for Reduction of Healthcare-Associated Pathogens in Hospital Rooms, in Research Gate, Infection Control and Hospital Epidemiology, 2015, pp. 192-197

[6] M. Chui, J. Manyika, and M. Miremadi. Where machines could replace humans-and where they can't (yet),in Mckinsey Quarterly, McKinsey.com, 2016

[7] Bucher Emhart Glass (2020). Integrated Swab Robot. Retrieved from https://emhartglass.com/FlexRobot

[8] H. Kitagawa, K. Tadera, T. Hara, S. Kashiyama, M. Mori, H. Ohge. "Efficacy of Pulsed Xenon Ultraviolet Disinfection of Multidrug Resistant Bacteria and Clostrdiodes difficile spores", Infection, Disease and Health, 11 April 2020. doi; 10.1016/j.idh.2020.03.001

[9] L.B. Littlejohns, F. Baum, A. Lawless, and T. Freeman. "The value of a causal loop diagram in exploring the complex interplay of factors that influence health promotion in a multisectoral health system in Australia", BMC Part of Springer Nature, 29 December 2018. [Online] Available: https://health-policy-systems.biomedcentral.com/articles/10.1186/s12961-018-0394-x

[10] D. T. Bradley, M. A. Mansouri, and F. Kee. A systems approach to preventing and responding to COVID-19, in Elsevier, EClinical Medicine, 2020, pp. 1-2

[11] C. Coombs. Will COVID-19 be the tipping point for the Intelligent Automation of work? A review of the debate and implications for research. Elsevier Public Health Emergency Collection, 2020 Jul 16. doi: 10.1016/j.ijinfomgt.2020.102182

[12] K. LaGrandeur, and J.J. Hughes. "Surviving the Machine Age – Intelligent Technology and the Transformation of Human Work.", London: Palgrave Macmillan, 2017.

[13] A. Granulo, C. Fuchs, and S. Puntoni. "Preference for human (vs. robotic) labor is stronger in symbolic consumption contexts.", Online, Wiley Library, 18 July 2020. [Online] Available: https://onlinelibrary.wiley.com/doi/full/10.1002/jcpy.1181

[14] R. Vilanova. How is intelligent automation speeding up COVID-19 testing? Retrieved from https://www.ey.com/en_gl/consulting/how-automation-is-enabling-covid-19-test-result-reporting-atspeed.html

[15] K. Warwick. "Artificial Intelligence: The basics". Oxon: Routledge, 2012.

[16] Anonymous (2019 March 9). Centers for Disease Control and Prevention, Interim Guidelines for Collecting, Handling, and Testing Clinical Specimens from Persons under Investigation (PUIs) for Coronavirus Disease 2019 (COVID-19). Retrieved from https://www.cdc.gov/coronavirus/2019-ncov/lab/guidelines-clinical-specimens.html.

[17] S. Hunt, G. Witus, and D. Ellis. "Computer Assisted Robotic Examination Swab Sampling", 2018 April. doi: 10.1117/12.783229.

[18] S.Q. Li, W.L. Guo, H. Liu, T. Wang, *et al.* "Clinical Application of Intelligent Oropharyngeal-swab Robot: Implication for COVID-19 Pandemice", European Respiratory Journal, 2020.

[19] Sing Health (2020 September 21). Made-in-Singapore Robot Features Faster and More Comfortable COVID-19 Swabbing. Retrieved from https://www.sgh.com.sg/news/covid19/made-in-singapore-robot-features-faster-and-more-comfortable-covid-19-swabbing

[20] S. Wang, K. Wang, H. Liu, and Z. Hou. "Design of a Low-Cost Miniature Robot to Assist the COVID-19 Nasopharyngeal Swab Sampling", in Cornell University, 26 May 2020. [Online] Available: https://arxiv.org/abs/2005.12679

[21] Anonymous. "Could this throat-swabbing robot speed up testing?" in Reuters, 5 June 2020. Retrieved from: https://www.reuters.com/video/watch/idOVCGYNP0B

[22] Anonymous. "Artificial Intelligence Technologies-Helping the Fight against COVID-19", (Vol. 24, No. 10, Full Issue). Asia-Pacific Biotech New, 2020.

[23] R. Felder, PhD. Medical Automation. Retrieved from https://www.thelancet.com/journals/lanres/article/PIIS2213-2600(20)30453-7/fulltextPPw?fbclid=IwAR2yBctOpWq2FGDsDf5vffRd_YTn5MbkSb

[24] D.T. Bradley, M.A. Mansouri, F. Kee, and L.M.T. Garcia. "A systems approach to preventing and responding to COVID-19", EClinical Medicine, 2020.

[25] C. Mayers, and K. Baker. Impact of false-positives and false negatives in the UK's COVID-19 RT-PCR Testing Programme, in Assets Publishing Service UK, 2020, pp. 1-5

[26] MIT Medical (2020, May 11). FAQ: Testing for COVID-19. Retrieved from https://medical.mit.edu/faqs/faq-testing-covid-19#faq-3

[27] E. Survoka, V. Nikolayevskyy, and F. Drobniewski. "False-positive COVID-19 results: hidden problems and costs." The LancetRespiratory Medicine, 2020.

[28] S. Brown. "A new study measures the actual impact of robots on jobs. It's significant." [Online] Available: https://mitsloan.mit.edu/ideas-made-to-matter/a-new-study-measures-actual-impact-robots-jobs-its-significant

[29] A. Radonic, S. Thulke, and I.M. Mackay. Guideline to reference gene selection for quantitative PCR. BiochemBiophys Res Commun, 2004; 313: 856-862

[30] E.L. van der Veen, E.A. Sanders, and W.J. Videler. Optimal site for throat culture: Tonsillar surface versus posterior pharyngeal wall. Eur Arch Otorhinolaryngol, 2006; 263:750-753

[31] C.Q.L Li, and Y.F. Wang. Comparison among nasopharyngeal swab, nasal was, and oropharyngeal swab for respiratory detection in adults with acute pharyngitis. BMC Infect Dis, 2013. 13: 281. doi:10.1186/1471-2334-13-281

BIOGRAPHIES OF AUTHORS

	Jasper Rae Zeus A. Antonio is a graduate of Bachelor of Science in Electronics and Communications Engineering at Adamson University, Philippines. He is currently the Project Engineer in Simworks IT Solution, Pangasinan. E-mail: engrzeusantonio@gmail.com
	Jonalyn Mae E. Aranda is a graduate of Bachelor of Science in Electronics and Communications Engineering at Adamson University and currently pursuing Master of Science in Engineering Major in Electronics Engineering at Polytechnic University of the Philippines, Sta. Mesa Manila. She is working as College Instructor in Electrical Engineering and Allied Department at Technological University of the Philippines - Taguig Campus. E-mail: jonalynmae_aranda@tup.edu.ph