Localized Automation Solutions in Response to the First Wave of COVID-19: A Story from Vietnam

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Abstract

Purpose – COVID-19 hits every country's healthcare system and economy. There is a trend toward using automation technology in response to the COVID-19 crisis not only in developed countries but also in those with lower levels of technology development. However, current studies mainly focus on the world level and only a few ones report deployments at the country level. In this work, we investigate the use of automation solutions in Vietnam with locally available materials mainly in the first wave from January to July 2020.

Design/methodology/approach – We collect COVID-related automation solutions during the first wave of COVID-19 in Vietnam from January to July 2020 through a search process. Our analysis and insights of a panel consisting of various disciplines (i.e. academia, healthcare, government, entrepreneur, media) aim at providing a clear picture of how and to what extent these solutions have been deployed.

Findings – We found seven groups of solutions from low to high research and development levels (R&D) deployed across the country with various funding sources. Low R&D solutions were widely spread due to simplicity and affordability. High R&D solutions were mainly deployed in big cities. Most of the solutions were deployed during the first phases when international supply chains were limited with a significant contribution of the media. Higher R&D solutions have opportunities to be deployed in the reopening phase. However, challenges can be listed as limited interdisciplinary research teams, market demand, the local supporting industry, end-user validation, and social-ethical issues.

Originality/value – To our best knowledge, this is the first study analyzing the use of automation technology in response to COVID-19 in Vietnam and also a country in Southeast Asia. Lessons learned from these current deployments are useful for future emerging infectious diseases. The reality of Vietnam's automation solutions in response to COVID-19 might be a reference for other developing countries with similar social-economic circumstances and contributes to the global picture of how different countries adopt technology to combat COVID-19.

Keywords – automation; healthcare; localized solutions; Vietnam; COVID-19

1 Introduction

1.1 Automation Solutions in Response to COVID-19 Worldwide

In response to the rapid spread of the COVID-19 pandemic, governments worldwide have applied various strategies to curb the transmission e.g. social distancing, contact tracing, lockdown, face mask-wearing. Automation has been chosen as one of the tangible solutions to enhance their effectiveness of the strategies (Bogue 2020, Javaid et al. 2020, Murphy, Gandudi & Adams 2020). For example, drones have been used for surveillance in outdoor public places (Couch et al. 2020). Mobile robot platforms have been deployed in the high risk of infection e.g. those operating in the areas of food and medicine delivery, temperature screening, family socialization, etc. (Yang et al. 2020, Murphy, Gandudi & Adams 2020). Other kinds of companion robots have helped people with loneliness during isolation (Odekerken-Schröder et al. 2020).

To our best knowledge, although there are a large number of published articles surveying the technical solutions during the COVID-19 pandemic, most of the studies mainly focus on the world level e.g. Murphy, Gandudi & Adams (2020), Bogue (2020), Vafea et al. (2020), Couch et al. (2020), Javaid et al. (2020), Fagherazzi et al. (2020). Only a few reported deployments at the country level (e.g. Italy (Bicchi 2020), China (Chen et al. 2020), Rwanda (Clarisse et al. 2020)) especially in those with low levels of technology.

1.2 Localized Automation Solutions in Response to COVID-19 in Vietnam

Vietnam was one of the first countries with COVID-19 cases imported from Wuhan (China) in late January 2020 (Giang et al. 2020). With the experience from the SARS outbreak in 2003 (Ha et al. 2004), the Vietnamese government has taken strict quarantine policies, contact tracking, and social distancing measures (lockdown) (Ha et al. 2020, La et al. 2020). This restrictive approach has shown an epidemiological accomplishment with only over 400 officially reported cases to the end of the first wave of COVID-19 (July 2020) and over 1000 in the second wave (October 2020) (Lim 2020, World Health Organization 2020*a*,*b*) in a country of nearly 100 million people. The implementation of this approach however requires a significant amount of human workload.

Besides relying on human effort and available imported technology, there have been efforts using localized automation solutions in disease prevention and impact mitigation of COVID-19 in Vietnam (see Fig. 1). In the 2020 Bloomberg Innovation Index, Vietnam ranks 57^{th} among more than 200 economies in the world (Jamrisko & Lu 2020). Countries with similar ranks can be listed as India, Qatar, Ukraine, Egypt, and Kazakhstan. Despite having a high growth rate, Vietnam is still a lower-middle-income country which ranks 44^{th} in nominal GDP and

Figure 1: Localized automation solutions being deployed in Vietnam during the COVID-19 pandemic have been well-covered by the media. (1) Automatic hand sanitizer dispensers; (2) "Rice ATMs" (automatic rice dispensers); (3) Mobile disinfection chambers; (4) Mobile robots for disinfection, safe distribution, and communication; (5) Localized ventilators; (6) Automatic body temperature measurement system; (7) Others: a robot for safe takeaway services, a patrol robot. Credits: Solution developers, VOV, VTV, Thanhnien.

130^{th} in GDP per capita (International Monetary Fund 2019). Some might raise the question that how and to what extent a developing country with a low level of technology can deploy such localized solutions over a period of uncertainty. This article aims at answering this question.

The rest of this work is organized as follows. First, we collect COVID-related automation solutions deployed during the first wave of COVID-19 in Vietnam through a search process in Section 2. In Section 3, different aspects of these deployments are analyzed i.e. purposes, levels of research and developments (R&D), technology readiness levels (TRLs), funding sources, guidelines and regulations compliance, distribution, and time of deployment. Second, in Section 4, we endeavor to provide insights from different perspectives, i.e. academics, government officials, tech developers, entrepreneurs, and journalists, on how much Vietnam can convert their limited resources and technology into practical solutions. The panel also draws limitations and proposes resolutions that might help improve the existing and upcoming solutions in the future. Finally, a conclusion is given in Section 5.

2 Current COVID-related Automation Solutions in Vietnam

2.1 Search Methodology

Most of the localized automation solutions deployed in Vietnam in response to COVID-19 are well-covered by local, national, and international media. Intending to list all solutions in Vietnam, we rely on the following sources.

- *Web-search:* We obtained most of the solutions by searching on the Internet with the combination of the following keywords: *robot*, *solution* (*vi.* giải pháp), *technology* (*vi.* công nghệ), *machine* (*vi.* máy), *device*

(*vi.* thiết bị), *automation* (*vi.* tự động), *COVID*, *coronavirus* (*vi.* virut/virus corona), *support* (*vi.* hỗ trợ), *response to the pandemic* (*vi.* chống dịch), and the names of 58 *provinces* and five *municipalities* in Vietnam.

- *Surveys:* An online survey (Qualtrics) was sent to research institutes in Vietnam to collect solutions that have not been covered by the media especially those with medium and high R&D.
- *Networks:* Authors are from a wide range of backgrounds. This ensures that missing important solutions from the other sources can be added and solution developers can be contacted for extra information.

2.2 Inclusion Criteria

With a focus on automation solutions, we only consider solutions that meet the following criteria.

- Being related to automation technology i.e. systems integrated with sensors and actuators. Purely smartphone apps or mechanical systems are excluded.
- Being a complete product or prototype. Ideas, plans, and proposed solutions are excluded.
- Being deployed during the first wave of COVID-19 in Vietnam from 23 January 2020 (Giang et al. 2020) to 27 July 2020 (Vuong et al. 2020).
- Being in response to COVID-19 as the primary function.

2.3 Search Result

The search process results in a list of *1323* devices including robotics, automation, Internet of Things (IoT) that fell into the scope of this overview. Among the included devices, *1221* were from the web-search process, *95* from the online survey, and *7* were added thanks to the authors' networks. After removing duplicates, a total of *1292* devices can be categorized into seven groups of solutions. The majority of solutions belong to six main groups (1–6). Two solutions are categorized as "Others".

1. Automatic hand sanitizer dispensers *(1032)*
2. "Rice ATMs": Automatic rice dispensers providing free rice for low-income people *(157)*
3. Mobile disinfection chambers *(72)*
4. Robots for disinfection, safe distribution and communication *(12)*
5. Localized ventilators *(10)*
6. Automatic physiological measurement systems (mainly body temperature) *(11)*
7. Others e.g. a robot for safe takeaway services, a patrol robot for checking mask-wearing and public-gatherings *(2)*

Table 1 presents in detail motivations, functionalities and operational areas of the six main groups of solutions.

Table 1: Six main groups of automation solutions in response to COVID-19 in Vietnam.

Solutions	Motivations	Functionalities	Operational Areas
Automatic hand sanitizer dispensers *R&D Effort:* Low *Localization Rate:* Medium	Hand disinfection. Efforts were originally from individuals (e.g. students, teachers, doctors) as DIY touch-free dispensers with customization for internal use only. These solutions expanded due to support from local governments and private sector organizations.	Commercial hand sanitizer liquid or gel is dispensed automatically when hands are detected by affordable proximity or infrared sensors. Most of the solutions followed the recommended sanitizer volume and timing by public health offices. Devices need to be disinfected regularly.	Many schools, universities, offices, factories, and hospitals across the country due to affordability (**TRL 6-9**).
"Rice ATMs" (Automatic rice dispensers) *R&D Effort:* Low-Medium *Localization Rate:* High	Humanitarian purpose. Free rice is given to low-income people who lost jobs due to the pandemic. Rice is donated by individuals and private and public sector organizations. Locations are sometimes provided by local governments.	Rice is (semi-)automatically dispensed when a person is detected by motion sensors, buttons, or cameras. Genuine low-income status is manually accessed by responsible people.	Public areas. Originally from an individual in Ho Chi Minh City and later in many public areas across many provinces and cities (**TRL 8-9**).
Mobile disinfection chambers *R&D Effort:* High *Localization Rate:* Medium-High	Full body disinfection. Efforts from hospitals for internal use and research laboratories for commercial purposes using localized resources.	Sanitizing liquid or clean air is sprayed when a person enters the disinfection chamber – detected by several types of sensors. Several solutions have passed technical quality control and/or infection control. There are however concerns on the negative effects of the used sanitizing liquid in some solutions on health.	Designed to be used in public areas such as hospitals and offices. Solutions were developed in major cities (e.g. Ha Noi, Hai Phong, Ho Chi Minh City, Can Tho) and several provinces. The Vietnamese Ministry of Health however does not recommend the use of such devices. Most of the solutions rely on third parties for commercialization (**TRL 7-9**).
Robots and drones for disinfection, safe distribution, and communication *R&D Effort:* Medium-High *Localization Rate:* Medium-High	Disinfection and safe distribution. Collaborative efforts are mainly between research laboratories, the government, and hospitals for practical use and can be widely applied. Sole efforts from a single hospital or university are for internal use only. Solutions are also proven to be cost-efficient compared to the human workforce.	Robots or drones are equipped with disinfecting, carrying, and manipulating functions (e.g. disinfectant, UV light, boxes, arms). The robot autonomy varies from teleoperation (with camera and speakers), line-following, and full autonomy with pre-defined route and LiDAR for obstacle avoidance. Many solutions especially those in collaboration with the government have passed infection control.	Demonstrated, tested, and/or used in hospitals with COVID patients and centralized isolation centers in major cities e.g. Ha Noi, Da Nang, Hue, Da Nang, Ho Chi Minh City, Can Tho (**TRL 5-7**).
Localized ventilators *R&D Effort:* Medium-High *Localization Rate:* Medium-High	In preparation for ventilator shortage (did not happen in the first wave). Efforts are mainly from research laboratories based on MIT's open-source design with locally available materials and adapted to local hospitals' needs. One private-sector organization produces ventilators based on Medtronic's design.	Designs vary from proof-of-concept to commercial products. Materials (PCB, actuators, sensors) are localized to save costs and adapt to the limited international supply chain during the pandemic. Some are only prototypes while others are under quality control process.	Solutions are only from major cities with high levels of technology development e.g. Ha Noi, Da Nang, Ho Chi Minh City. None have been applied in healthcare facilities during the first wave(**TRL 4-7**) but later in the second wave.
Automatic physiological measurement systems *R&D Effort:* Medium-High *Localization Rate:* Medium-High	Automatic and non-contact physiological measurements, mainly body temperature. Efforts mainly from research laboratories for internal use only. One private-sector organization produces a complete commercial solution.	Solutions are IoT systems using commercially available physiological sensors. Most of the solutions are proof-of-concept prototypes. Only one product from a private sector organization obtained quality control.	Most of the solutions are demonstrated within colleges and universities in several major cities e.g. Ha Noi, Da Nang, Binh Dinh, Ho Chi Minh City, Can Tho (**TRL 7**). One product was commercialized (**TRL 9**).

3 Analysis of the Current Deployments

3.1 Purposes

Solutions have been deployed for various purposes but mainly for *disease prevention*. Five out of seven groups of solutions focus on preventing cross-contamination (except "rice ATMs" and localized ventilators). Most of the solutions focus on adding non-contact features to ordinary tasks (e.g. sanitizer dispensing, temperature measuring, decontaminating) to avoid direct human contact. This is in light of Vietnam's approach which focuses on prevention rather than cure (Ha et al. 2020, La et al. 2020). Although having a non-contact feature, the main purpose of "rice ATMs" is *impact mitigation* (Duong 2020). These solutions help low-income people whose jobs were affected by COVID-19. Less popular solutions are localized ventilators based on open-source designs which purpose is *disease treatment* (Pearce 2020). None were deployed in practice during the first wave since no ventilator shortage happened in Vietnam. Afterward, two of them were used in the second wave (VOV World 2020).

3.2 Levels of R&D

The majority of deployments in Vietnam are low R&D solutions i.e. "rice ATMs" and automatic hand sanitizer dispensers. They are simple, portable, affordable, and customizable; and do not require intensive R&D effort. Medium and high R&D solutions are primarily mobile robot platforms and IoTs. Only two solutions are integrated with manipulating functions to grasp objects in the high-risk area and deliver takeaway products.

Compared to solutions in other countries, some important medium and high R&D applications have not been deployed in Vietnam. For example, there are currently no solutions to support older adults due to no demand. Unlike many countries, COVID-19 cases of Vietnam in the first wave are primarily young (mainly from 20 to 49) and imported from abroad (Nguyen & Vu 2020). Other sectors seem not to be ready for automation solutions. In the service sector, there is only one proof-of-concept robot arm for safe takeaway delivery. In the manufacturing sector, only one firm repurposes its factory to produce ventilators.

3.3 Technology Readiness Levels (TRLs)

Vietnam did not deploy automation solutions in the previous epidemics e.g. SARS. Therefore, all solutions deployed in the current pandemic are newly developed. TRLs (Mankins 1995) of the deployed solutions range from *validation in laboratory environment* (**TRL 4**) to *actual system proven through successful mission operations* (**TRL 9**). Most of the solutions have been demonstrated and/or operated in a relevant environment from schools, offices, to hospitals and other public places (**TRL 7-8**).

3.4 Funding Sources

Solutions are financially supported by various sources. Low R&D solutions for public places were originally self-funded but later sponsored by many individuals, private and public sector organizations. Higher R&D solutions for high-risk areas were mainly funded by research institutes. Several solutions were funded by the government. However, the commercialization of these high-tech solutions is either unplanned or dependent on third parties (moving from **TRL 7-8** to **TRL 9**).

3.5 Guidelines and Regulations Compliance

Each solution is subjected to specific guidelines and regulations depending on its classified device type. The classification might be different among countries. Since all solutions presented in this work are deployed only in Vietnam, publicly applied solutions have followed the national guidelines and regulations. Proof-of-concept solutions with no quality control are either used internally within organizations or still under development.

Non-medical devices such as automatic hand sanitizer dispensers and "rice ATMs" are not subjected to any specific regulation. They however still follow guidelines from public health offices (e.g. regular disinfection, sanitizer volume, and timing). Mobile robots and drones for disinfection, safe distribution, and communication are healthcare support devices. These solutions have been obtained permissions from hospitals e.g. allowed operational areas and tasks. Those equipped with UV disinfection light have passed infection control. A few solutions are equipped with cameras but no serious concern on privacy protection issues has been raised.

Other types of solutions require specific regulations. Mobile disinfection chambers are invasive devices. Many have obtained quality and infection control certificates issued by the authorities. However, they are not recommended by public health offices since many types of sanitizing liquid used in these devices might have negative effects on health. Localized ventilators and automatic physiological measurement systems are medical devices. To our knowledge, two commercial ventilators were in production during the first wave and start to be used in

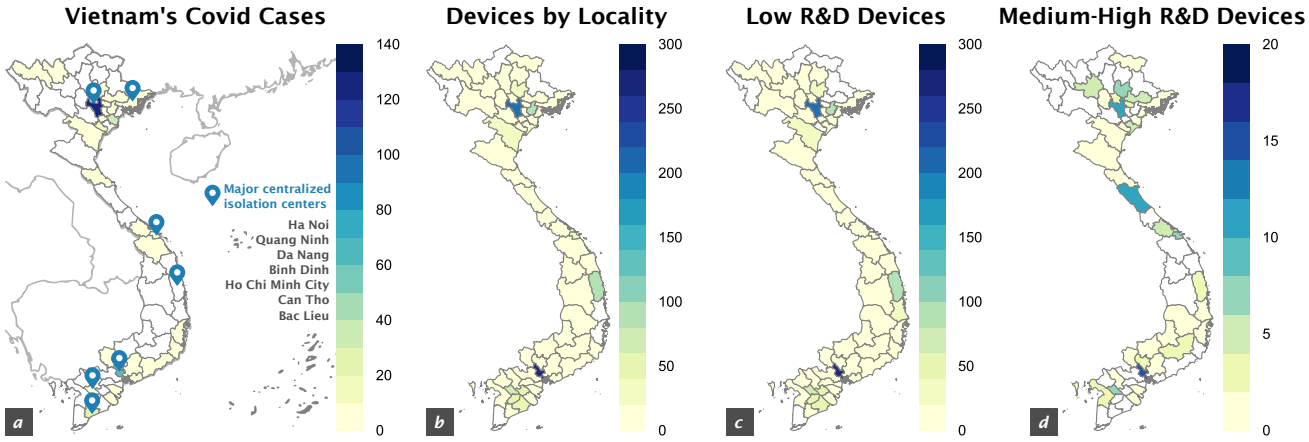

Figure 2: Automation solutions in response to COVID-19 across regions in Vietnam are mainly with low R&D efforts (until 25 July 2020). Medium and High R&D solutions have been deployed only in major cities.

the second wave, several ventilators have been under quality control process, and one commercial temperature measurement system has passed quality control.

3.6 Distribution of Solutions

Despite big economic and technological gaps among regions in Vietnam, there exist solutions in most areas across the country with different R&D levels. The gaps are however reflected on numbers of solutions by locality and by R&D level (see Fig. 2).

Low R&D solutions, such as automatic hand sanitizer dispensers or "rice ATMs", appear across the countries including lower developed regions due to simplicity and affordability (Fig. 2c). Media also plays an important role in promoting these solutions especially the "rice ATMs". Although automatic rice dispensers are technically not novel, their humanitarian purpose caught the attention of local and international media (Duong 2020). This brought many individuals, private, and public sector organizations to replicating these solutions. It is worthwhile to mention that there are many more low R&D devices in reality that have not been covered by the media.

Medium and high R&D solutions are mainly from major cities, e.g. Ha Noi, Ho Chi Minh City, Hue, Da Nang, Can Tho, with higher densities of research institutes and tech firms (see Fig. 2a and Fig. 2d). These cities are also in higher need of high-tech solutions because of greater numbers of infected cases, larger populations (higher risk of cross-infection), and more international airports and centralized isolation centers. Tech firms from these major cities also contribute to the deployment of solutions in other areas.

3.7 Time of Deployment

Most of the solutions were deployed during the early phase and social distancing measures (lockdown) periods (see Fig. 3). Most of the solutions (except the "Rice ATM") have been available in the world with similar functionalities during the COVID-19 crisis (Bogue 2020, Javaid et al. 2020, Murphy, Gandudi & Adams 2020, Yang et al. 2020, Zeng et al. 2020) e.g. Italy, Belgium, China, India, Thailand, Singapore. Nevertheless, localizing those solutions were necessary to overcome limited international supply and/or to reduce costs. No new type of solutions has appeared since early May 2020 when the country reopened and switched into the Reopening phase (new normal).

"Rice ATMs" appeared right after the social distancing measures period (lockdown) in April 2020 and have supported thousands of low-income people whose jobs were lost or heavily influenced. It is worth mentioning that automatic rice dispensers have already existed in other countries for several years e.g. China, Malaysia. However, repurposing this solution from vending machines into "free rice dispensers" with a non-contact feature for humanitarian purposes during the COVID-19 crisis has made an impact. When the economy reopened, "rice ATMs" gradually finished their missions.

Similar to the "rice ATMs", other solutions were also deployed early and ended during the reopening phase. Automatic hand sanitizer dispensers were quickly replicated with locally available materials with low R&D efforts. When international supply was resumed, the demand for localizing this solution was reduced. Mobile disinfection chambers caught attention at the beginning of the outbreak. However, they were not recommended by the authorities because of the negative effects of the used sanitizing liquid on health. Mobile platforms for disinfection, delivery, and communication in high-risk areas cut costs and consumption of personal protection equipment (PPE) during its shortage period ($20-$30/PPE). They are expensive and difficult to be implemented

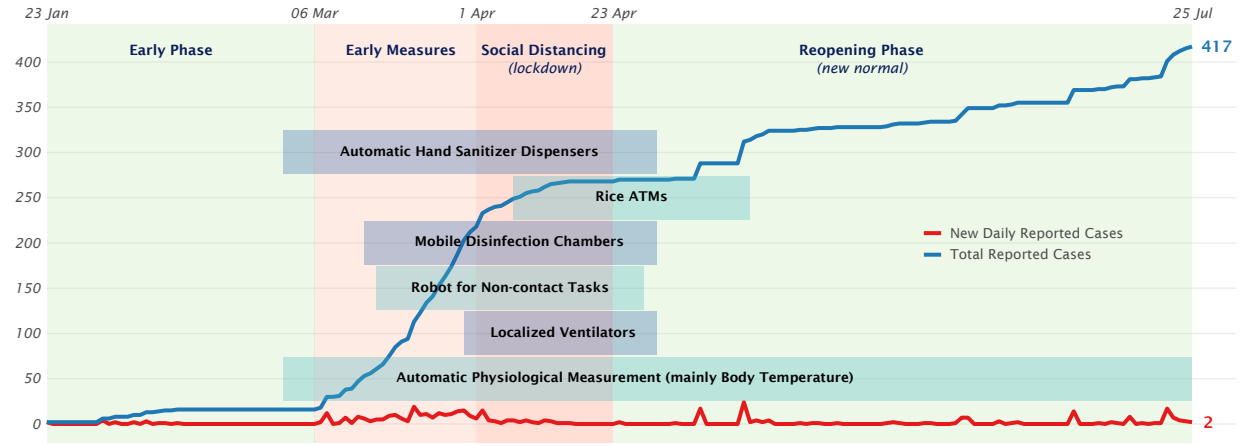

Figure 3: Most of the solutions were deployed in the Early phase and Social distancing measures (lockdown) periods. Very few new solutions have been deployed in the Reopening phase (new normal).

widely. Localized ventilators followed the trend of producing open-source ventilators (Pearce 2020). Since a company started to mass-produce its localized ventilators, other efforts diminished.

Only automatic physiological measurement systems continue to be deployed until the second wave. The service industry in Vietnam is among the hardest hit and trying to attract customers back in the reopening phase (Nicola et al. 2020). Despite no clear scientific evidence that monitoring body temperature has a positive effect on COVID-19 control, there is a common practice of having automatic body temperature measurement systems in shops, offices, and other public places. Localized solutions are more affordable in many cases.

4 Insights from a Multidisciplinary Panel

4.1 Panel Members

We established a multidisciplinary panel to collect opinions from different disciplines about automation solutions deployed during the first wave of COVID-19 in Vietnam and future perspectives. Panel members consist of university staff, entrepreneurs, journalists, healthcare workers, and government officials. The panel discussions were held online taking into account the current COVID-19 measures and locations of panel members. Opinions of panel members are summarized as follows.

4.2 Panel Opinions

4.2.1 The Media Significantly Contributed to the Spread of Solutions

Mainstream and social media have a significant contribution to the spread of solutions. A wide coverage has also been given to these solutions, especially low R&D ones i.e. “rice ATMs” and automatic hand sanitizer dispensers. Consequently, more people are benefited from these solutions. Major news agencies like CNN, Reuters, Strait Times have given the novel creation rave reviews. Although not novel, it is believed to somewhat influence the deployment plans of “rice ATMs” in Indonesia and Malaysia.

A secondary effect of promoting technology solutions is raising awareness and strengthening social solidarity during the COVID-19 period. Most of the solutions are novel to the general public and therefore attract their attention. For example, automatic hand sanitizer dispensers help convey the importance of keeping hygiene. “Rice ATMs” strengthen the message that no one is left behind. Other solutions with a variety of stakeholders help create an image that everyone in the society is together against the coronavirus. However, overselling these solutions on the media will create an incorrect perception of the country’s technology development. This illusion might result in unrealistic expectations and consequently disappointment toward the current and upcoming solutions.

4.2.2 Opportunities for Higher R&D Solutions but Challenging

Most of the solutions were deployed in a short period mainly for disease prevention and impact mitigation purpose during the COVID-19 outbreak. Nevertheless, the COVID-19 crisis still influences the healthcare system, society, and economy in the long term (Nicola et al. 2020). Since the country reopened and faces economic influences, there are certain demands for some current solutions and opportunities for new ones especially with high R&D levels in the post-COVID period.

High-risk areas are still in need of solutions. There will be patients and suspected cases in further COVID-19 waves and healthcare workers need to be better-protected (Chirico et al. 2020). Current solutions in these areas in Vietnam are mainly mobile robot platforms with low autonomy and lack manipulation. This requires more R&D efforts and also end-user training.

Services such as non-contact food preparation, autonomous delivery robots, and social robots for reception currently do not have any robotics and automation solutions. Only one proof-of-concept robot arm was deployed for safe takeaway service. Having these robots delivering non-contact services is not practical for most services due to the low labor cost in Vietnam at the moment. The high-end services might consider these solutions for both practical purposes and customer attraction.

Developing high R&D solutions entirely requires interdisciplinary research teams and Vietnam seems to be not ready for all of these examples. Localized solutions can be either infeasible or can compete with the imported ones. However, developing software for imported robot platforms with the advantage of local social and cultural knowledge can be the initial step.

4.2.3 Government Keeps Sponsoring High R&D Solutions but More Efforts from the Private Sector are Needed

In light of the early reaction of the healthcare system, in early March 2020, the Vietnamese Ministry of Science and Technology and the Ministry of Health consulted scientists and specialists from different disciplines for automation solutions for infectious prevention to protect healthcare workers and service staff in hospitals and centralized isolation centers. Orders were given to several robotics and automation laboratories and resulted in several mobile robot platforms for disinfection, safe delivery, and communication in high-risk areas with COVID-19 patients and suspected cases.

The contribution of automation technology in Vietnam's COVID-19 prevention and control is still minor compared to other disciplines e.g. biotechnology, ICT. Although the government keeps sponsoring COVID-19 related solutions, this source is currently inadequate for a high number of research laboratories with knowledge, ideas, and proof-of-concept that are beneficial for combating this crisis. Robotics and automation laboratories in Vietnam are generally under-equipped. Collaborations between research, industry, and healthcare facilities are still weak. Dialogue channels among these stakeholders currently lack both quantity and quality. These reasons limit the possibilities of converting research outputs into commercial applications.

More efforts from the private sector are needed especially in manufacturing and commercializing solutions. The market demand for these solutions is the biggest obstacle. Taking into account the low labor cost in Vietnam, only affordable solutions can be deployed on large scales. Other solutions can go to niche markets such as hospitals and high-end services. Even so, it is still a challenge for tech firms especially small and medium-sized enterprises (SMEs) to approach potential end-users. Government policies seem to be still at macroscopic levels with limited visible benefits to SMEs. Although the local workforce is not yet an issue for the current solutions, the local supporting industry is an issue that influences quality and speed solution deployments.

4.2.4 More Awareness toward Social-ethical Issues and Validation

Although solutions included in this overview currently do not face very serious problems directly social-ethical issues, they become more important when the R&D levels of solutions increase. More awareness of these issues is crucial since it is believed that the majority of Vietnamese people do not prioritize or are not aware of standards and privacy protection among other issues (Sharbaugh 2013, Sriratanaviriyakul et al. 2014). A relevant incident happened at a "rice ATM" when the low-income status of visitors is personally judged by a human operator behind a camera. The "wizard" mainly judged visitors based on their appearance and consequently mistakenly rated a female visitor as "not genuinely poor" based on her "proper clothes". When higher R&D solutions will be deployed in the long term, e.g. with AI-based facial recognition, this bias should be considered during the development process.

As solutions were quickly deployed, there lack of rigorous validations on the end-user side and social-economic impacts, especially for long-term use. For example, we found no report on how healthcare workers learn new skills to operate unfamiliar devices, which is very important since they are busy and stressed during emergency (Murphy, Adams & Gandudi 2020). Social-economic impacts of solutions operating in public places should also be reported quantitatively and qualitatively. These validations provide lessons for upcoming solutions to avoid unnecessary mistakes.

Although every effort is appreciated, solutions that do not comply with social-ethical issues and/or lack validation should not be deployed widely. Law-makers should be prepared that new solutions might require new regulations. Developers, researchers, and end-users should be more aware and improve their knowledge toward these issues e.g. via training, workshops, courses.

5 Conclusion

Automation solutions have been used in many areas worldwide in response to the COVID-19 crisis. Vietnam shows that with limited resources and technology development, a developing country can also develop localized automation solutions to help people during the COVID-19 pandemic. These solutions, both sponsored and self-funded solutions, are encouraged and motivated by society.

With the current conditions of Vietnam, deploying simple and affordable solutions with locally available materials in a short time shows quick and noticeable effects during this pandemic. Experience gained from deploying and operating automation solutions during the first wave of COVID-19 will be useful for Vietnam in the waves or other infectious epidemics in the future (Murphy, Adams & Gandudi 2020). Higher R&D solutions require continuous development and maturity to be deployed on large scales. There are indeed challenges but Vietnam can take lessons from the deployments of high R&D solutions in other countries. Open hardware and software can also help a developing country to adopt new solutions more easily (Maia Chagas et al. 2020, Vanderborght 2020). New solutions will come with new regulations, privacy, and ethical issues. Relevant stakeholders need to be prepared for these issues to avoid possible negative effects.

From a technical perspective, Vietnam did not make outstanding automation solutions in response to COVID-19 since solutions deployed in other countries are technologically more admirable. In this work, we focus on the deployment perspective in which Vietnam is an example of making good use of locally available resources. The story from Vietnam contributes to the global picture of using technology to combat COVID-19 and can be a reference for countries with similar social-economic circumstances in Southeast Asia and other regions.

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References

Bicchi, A. (2020), 'Re: On combating covid-19: A "citizen robotics" approach from the italian community', *Science Robotics* .

Bogue, R. (2020), 'Robots in a contagious world', *Industrial Robot: the international journal of robotics research and application* **47**(5), 673–642.

Chen, B., Marvin, S. & While, A. (2020), 'Containing covid-19 in china: Ai and the robotic restructuring of future cities', *Dialogues in Human Geography* p. 2043820620934267.

Chirico, F., Nucera, G. & Magnavita, N. (2020), 'Covid-19: Protecting healthcare workers is a priority', *Infection Control & Hospital Epidemiology* pp. 1–1.

Clarisse, M., Muhamed, S., Baptiste, M. J., Jose, N., Aline, U., Malick, K., Francine, U., Paul, U. J., Andrew, M., Thierry, N. et al. (2020), 'Use of technologies in covid-19 containment in rwanda', *Rwanda Public Health Bulletin* **2**(2), 7–12.

Couch, D. L., Robinson, P. & Komesaroff, P. A. (2020), 'Covid-19—extending surveillance and the panopticon', *Journal of Bioethical Inquiry* .

Duong, Y. (2020), ''Rice ATM' feeds Vietnam's poor amid virus lockdown'.
URL: *https://www.reuters.com/article/us-health-coronavirus-vietnam-riceatm/rice-atmfeeds-vietnams-poor-amid-virus-lockdown-idUSKCN21V0GQ*

Fagherazzi, G., Goetzinger, C., Rashid, M. A., Aguayo, G. A. & Huiart, L. (2020), 'Digital health strategies to fight covid-19 worldwide: challenges, recommendations, and a call for papers', *Journal of Medical Internet Research* **22**(6), e19284.

Giang, H. T. N., Shah, J., Hung, T. H., Reda, A., Truong, L. N., Huy, N. T. et al. (2020), 'The first Vietnamese case of COVID-19 acquired from China', *The Lancet Infectious Diseases* **20**(4), 408–409.

Ha, B. T. T., La Quang, N., Mirzoev, T., Tai, N. T., Thai, P. Q., Dinh, P. C. et al. (2020), 'Combating the COVID-19 epidemic: Experiences from Vietnam', *International Journal of Environmental Research and Public Health* **17**(9), 3125.

Ha, L. D., Bloom, S. A., Hien, N. Q., Maloney, S. A., Mai, L. Q., Leitmeyer, K. C., Anh, B. H., Reynolds, M. G., Montgomery, J. M., Comer, J. A. et al. (2004), 'Lack of SARS transmission among public hospital workers, Vietnam', *Emerging infectious diseases* **10**(2), 265.

International Monetary Fund (2019), 'World economic outlook database'.
URL: *https://www.imf.org/*

Jamrisko, M. & Lu, W. (2020), 'Bloomberg innovation index'.
URL: *https://www.bloomberg.com/news/articles/2020-01-18/germany-breaks-korea-s-six-year-streak-as-most-innovative-nation*

Javaid, M., Haleem, A., Vaishya, R., Bahl, S., Suman, R. & Vaish, A. (2020), 'Industry 4.0 technologies and their applications in fighting covid-19 pandemic', *Diabetes & Metabolic Syndrome: Clinical Research & Reviews* .

La, V.-P., Pham, T.-H., Ho, M.-T., Nguyen, M.-H., P Nguyen, K.-L., Vuong, T.-T., Tran, T., Khuc, Q., Ho, M.-T., Vuong, Q.-H. et al. (2020), 'Policy response, social media and science journalism for the sustainability of the public health system amid the COVID-19 outbreak: The Vietnam lessons', *Sustainability* **12**(7), 2931.

Lim, T. W. (2020), 'The global fight against covid-19: Sino-asean cooperation in mitigating the coronavirus pandemic along with other global actors', *China and the World* **3**(03), 2050011.

Maia Chagas, A., Molloy, J. C., Prieto-Godino, L. L. & Baden, T. (2020), 'Leveraging open hardware to alleviate the burden of covid-19 on global health systems', *Plos Biology* **18**(4), e3000730.

Mankins, J. C. (1995), 'Technology readiness levels', *White Paper, April* **6**, 1995.

Murphy, R. R., Adams, J. & Gandudi, V. B. M. (2020), 'Robots are playing many roles in the coronavirus crisis–and offering lessons for future disasters', *The Conversation* **22**.

Murphy, R. R., Gandudi, V. B. M. & Adams, J. (2020), 'Applications of robots for covid-19 response', *arXiv preprint arXiv:2008.06976* .

Nguyen, T. H. & Vu, D. C. (2020), 'Summary of the COVID-19 outbreak in Vietnam–lessons and suggestions', *Travel Medicine and Infectious Disease* .

Nicola, M., Alsafi, Z., Sohrabi, C., Kerwan, A., Al-Jabir, A., Iosifidis, C., Agha, M. & Agha, R. (2020), 'The socio-economic implications of the coronavirus and COVID-19 pandemic: a review', *International Journal of Surgery* .

Odekerken-Schröder, G., Mele, C., Russo-Spena, T., Mahr, D. & Ruggiero, A. (2020), 'Mitigating loneliness with companion robots in the covid-19 pandemic and beyond: an integrative framework and research agenda', *Journal of Service Management* .

Pearce, J. M. (2020), 'A review of open source ventilators for covid-19 and future pandemics', *F1000Research* **9**.

Sharbaugh, P. E. (2013), What is mine is yours: An exploratory study of online personal privacy in the socialist republic of vietnam, *in* 'CyberCulture Now: Social and Communication Behaviours on the Web', Brill, pp. 69–85.

Sriratanaviriyakul, N., Felipe, A. L., Shillabeer, A., Pui, O., Nkhoma, M., Tran, Q. H. & Cao, T. K. (2014), Awareness and impact of vietnamese security concerns in using online social networks, *in* 'Proceedings of the 18th World Multi-Conference on Systemics, Cybernetics and Informatics', pp. 1–5.

Vafea, M. T., Atalla, E., Georgakas, J., Shehadeh, F., Mylona, E. K., Kalligeros, M. & Mylonakis, E. (2020), 'Emerging technologies for use in the study, diagnosis, and treatment of patients with covid-19', *Cellular and molecular bioengineering* **13**(4), 249–257.

Vanderborght, B. (2020), 'Robotics' role in the coronavirus crisis [from the editor's desk]', *IEEE Robotics & Automation Magazine* **27**(3), 4–15.

VOV World (2020), 'Vingroup donates 3,200 ventilators to ministry of health'.
URL: *https://vovworld.vn/en-US/spotlight/vingroup-donates-3200-ventilators-to-ministry-of-health-889607.vov*

Vuong, N. M., Le Quyen, N. T., Tra, D. T., Do Van, T., Tuan, N. Q., Co, D. X., Trang, N. T. H. & Cuong, D. D. (2020), 'The second wave of covid-19 in a tourist hotspot in vietnam', *Journal of travel medicine* .

World Health Organization (2020*a*), 'Coronavirus disease 2019 (covid-19): situation report, 187'.

World Health Organization (2020*b*), 'Coronavirus disease (covid-19): weekly epidemiological update 8'.

Yang, G.-Z., J. Nelson, B., Murphy, R. R., Choset, H., Christensen, H., H. Collins, S., Dario, P., Goldberg, K., Ikuta, K., Jacobstein, N., Kragic, D., Taylor, R. H. & McNutt, M. (2020), 'Combating COVID-19—the role of robotics in managing public health and infectious diseases', *Science Robotics* **5**(40).

Zeng, Z., Chen, P.-J. & Lew, A. A. (2020), 'From high-touch to high-tech: Covid-19 drives robotics adoption', *Tourism Geographies* pp. 1–11.