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Comprehensive Study of Industry 4.0 in Robotics for Policy Development

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Abstract

Robotics has advanced greatly in the past years. Modern robots can do complex tasks and are the central components of Industry 4.0. These improvements make robots applicable in a variety of fields like security, exploration, entertainment, agriculture, healthcare and industry. While advancements in robotics come with many advantages, it still faces roadblocks that hinder its development or implementation. To aid in the public acceptance and adoption of robotics in the industry, policy development is critical to minimize the social and economic effects. Several policy recommendations were made such as improved government support, wage insurance, upskilling programs, information dissemination, and robot tax, which would accelerate robotics development, bolster job security, publicize key information, and stabilize taxation.

Keywords: robotics, service robots, industry 4.0

1.0 Introduction

In Industry 4.0, the industrial robots are the central components of digital and networked production. Hence, the need for them to be able to communicate with each other regardless of manufacturer. The standardization of a generic interface for industrial robots allows them to connect to the Industrial Internet of Things. The use of digital sensors combined with smart software allows for direct teaching methods like hand guiding the robot arm through the moment then using machine learning tools that can optimize the movement. They are working better with humans where they are incorporated into shared workspace applications and they complete tasks sequentially. Research and development is being focused on methods that enable robots to respond in real-time to allow them to function like how two human workers would collaborate. The digital connectivity of robots is also an enabler for new business models. Could technology robot leasing could be attractive to small and medium sized enterprises as they require no committed capital, have a fixed cost, automatic upgrades and no need for high-qualified robot operators (International Federation of Robotics [IFR], n.d.). This paper aims to cover the current trends in robotics and the roadblocks that could hinder its further advancement. It also covers how it is being adopted and impacts and the different policies that are used when it is being implemented.

Trends

Global Trends

With more advancements made in artificial intelligence technology, the trends in robotics will also be ever-changing to meet the demand to improve the way products are produced. The International Federation of Robotics (IFR, 2021a) reported the top trends in robotics for 2021. The

first trend was the use of vision-based technology combined with other sensing techniques to carry out difficult assignments. The second trend is their implementation in smart factories where they are placed in assembly lines. It allows more human-robot collaboration as the improved sensors and awareness can avoid potential harm. The third trend is the introduction of robotics in new manufacturing sectors like textile, food, beverage as well as plastic and wooden products. Lastly, they are used to secure supply chains as the automation allows flexibility, productivity and security.

Another trend is the surge of service robots. These are robots that carries out tasks instead of other equipment or people outside of industrial automation applications. According to Gonzalez-Aguirre et al. (2021), the IFR recorded a market share on service robots of 27 billion USD. Moreover, in the United States alone 29% of all robotic companies that have a denomination of service robots in the new startups. Figure 1 shows the potential for service robot use to increase in the next few years.

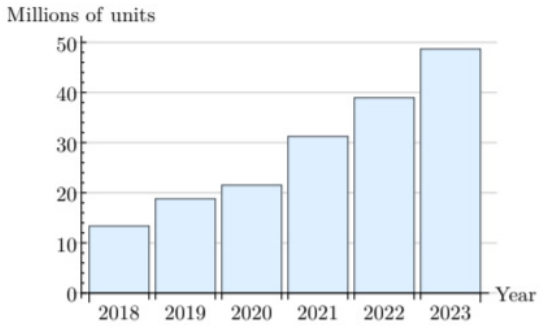

Figure 1. *Projection of the Potential Development of Service Robots*

The fields where service robots are diversifying cover multi-purpose indoor environments, home service and heatlhcare. This intertwines robotics with various types, including unmanned autonomous systems, autonomous navigation, imitation learning systems, and mobile robots. The top applications during the pandemic according to the IFR are Autonomous Mobile Robots (AMRs) and delivery robots, cleaning and disinfection, medical rehabilitation, social robots, and automated restaurants. Professional cleaning robots boomed by 92% during the pandemic using disinfectants or ultraviolet light for sanitation (International Federation of Robotics [IFR], 2021b).

Aside from Espace, a popular online digital platform for patent searching and applications, one study serves to graphically analyze the number of patent applications for both Cooperative Patent Applications (CPC) and the new set of robotic patents (K10) on labor-saving (LS) robotic technology each year. Their research found the following results in Figure 2 where by 2018 there were over 3000 K10 patent applications on robotics and roughly 2,500 CPC patents (Montobbio et al., 2022). While in Figure 3, what percentage of the total number of patents was for LS purposes.

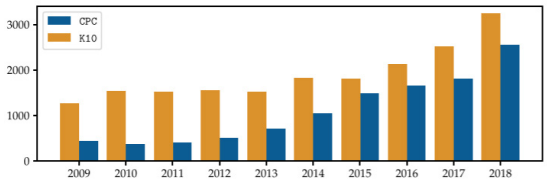

Figure 2. *Projection of the Potential Development of Service Robots*

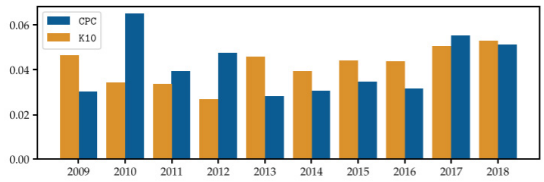

Figure 3. *Percent of total patents under robotics that were considered labor-saving (LS)*

Philippine Trends

In the Philippines, there were only 11 patent applications recorded in Espacenet (https://worldwide.espacenet.com/) for 2008 to 2020

while only 3 of them were published. The most recent application was in 2021 where a portable air purifier was proposed in hopes of tackling air pollution in the country, such as any particulate matter, nitrogen oxides, and carbon monoxides. Another patent in 2020 proposed the use of a robotic hand for simulation and analysis use in the medical field. Lastly, a mobile robotic platform for school utilization was also published in 2020.

In Google Patents (https://patents.google.com/) there were only 15 results from the PH patent office under "robotics" between 2019 to 2021. The top assignee, Our Lady of Fatima University, makes up 2 of the patents, with one being the robotic hand mentioned in the previous paragraph and the other, an automated robot for ocean rescue and garbage collection. Many of the other patents focus on utilizing mobile robots for industrial and personal service use. One that stands out in particular is a patent on an expanded mobile workstation for collaborative robots, which was filed by the Department of Science and Tech Metals Industry Research and Development Center in March of 2021 Rescue or retrieval-type robots may also be a trend under the scope of mobile robots. Retribot is a "smart surveillance and retrieval robot" that can maneuver in hazardous, deserted areas. It can be used in places with high radiation or volatile gases, like one engulfed in fire. Finally, the "Rescuebot" focuses on search and rescue for Earthquake victims. It has the potential to find people under collapsed structures and other debris, making use of a thermal camera that has a max range of 7 meters.

Globally, the Philippines ranked 48th in terms of robot density in 2014. In fact, the density shows that there is only one if not fewer units of industrial robots for every 10,000 employees in the country. Furthermore, the same study plotted the vulnerability each country's economy to robot-based automation in manufacturing from 2010 to 2014. The plot shows that though in the Philippines the exposure to automation in manufacturing in total employment is less than 10%, automation exposure reaches roughly 40% of the automotive, electronics and rubber, and plastic and chemical product sectors (Kituyi, 2017).

Innovation Roadblock in a Global Scale

Global Roadblocks

Some common roadblocks are ethics, utilitarian values, autonomy, battery estimation and modeling, lack of formalism and generalization in taxonomy and classifications and the design problems of gender biases (Gonzalez-Aguirre et al., 2021). The ethical issues of social assistive robots were investigated by Boada et al. (2021), where they focused on three main categories: well-being, care and justice. Out of the 56 journal articles that they reviewed, 60% of ethical issues are in well-being, 22% in care, and 18% in justice. The ethical issues that the authors' noted for well-being are privacy or data control, deception, autonomy, safety, dignity, emotional attachment, unauthentic intersubjectivity, freedom, objectification, human-human relationships, human moral skills, and identity. Loss of human contact being present as an ethical issue in both well-being and care, and recognition being present in both well-being and justice. They also noted that in care, the ethical issues present are the following: legitimacy of the introduction of social assistive robots (SAR), quality of practice, human moral practices, trust, impact on the concept of care, and role disruption. Lastly, they noted that the ethical issues present in justice are distributive justice, politics of SAR technology. responsibility, social equality, robot's decision making, and ecological sustainability (Boada et al., 2021). The paper written by Kozak et al. (2020), looks into the automation insecurity in the EU. They asked workers how they perceive employment changes based on technology and if they experience automation insecurity. The results showed that European workers are

greatly concerned that technologies would substitute labor, which showed their exposure and vulnerability to objective automation risk. The trust between humans and robots in human-robot interactions is another related issue. This is due to workers having a lack of trust in its functionality or safety, or even fear of job loss. After all, if regions such as the EU have 72% of its citizens viewing robots as beneficial, yet at the same time 70% see them as job-killers, it is quite clear that incorporating them in workplaces will be difficult

Utilitarian values are a challenge in the implementation of social robots (Gonzalez-Aguirre et al., 2021). The perceived value of the utilitarian values is referred to as the person's overall evaluation of the benefits of the robot's function and utility based on the experience they had. With this, depending on the general perceived value of the robot will be able to determine if it will become a gimmick or service improvement (Hu, 2021).

Another challenge mentioned is autonomy and battery estimation and modelling. In autonomy estimation and modelling, research titled "A reference architecture for Social Robots", notes that in the software design the social robots were modelled to have autonomy that would allow them to be able to interact, collaborate and communicate with humans with the robots following the behavioral norms present. The journal notes that the social robot should have a software that considers the common vocabulary, standard software components, easing customizability and extensibility of the social skills used, and predictability of the decision-making processes used (Asprino et al., 2022). For battery estimation and modelling, a paper titled "Pro-active positioning of a social robot intervening upon behavioral disturbances of persons with dementia in a smart nursing home", aims to be able to design a social robot to be used in a smart nursing home. One of the aspects that is considered for the design of the robot is Energy Management as the social robot is created to be able to support the caregivers present in the nursing home. They designed the robot to autonomously move itself to the charger to charge the batteries, ideally when fewer behavioral disturbances (BD) are expected to occur (Nauta et al., 2019).

Philippine Roadblocks

When it comes to the early stages of development, the availability and access to equipment for Research and Development (R&D) is very important. One of the greatest obstacles the Philippines has as a developing country is the lack of these resources and if they are within reach, they are either very expensive or low in quality (Philippine Council for Industry, Energy and Emerging Technology Research and Development [PCIEERD], 2020). This significantly increases the lead time of any experiments being conducted and reduces the experience and exposure researchers have during production. Other barriers can be seen in Figure 4 where they are categorized as resources and infrastructure, policy, ecosystem, and culture.

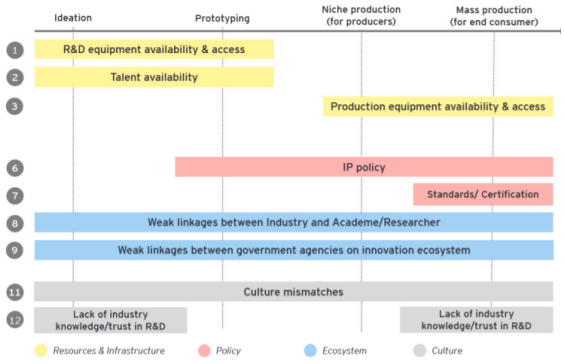

Figure 4. *Project Projection of the Potential Development of Service Robots*

Facilitating Factors

With many existing challenges in the Philippines, and especially under the problems caused by the COVID-19 Pandemic, the Science, Technology, and Innovation (STI) sector serves to contribute to

achieving the goals of the Philippine Development Plan; A plan from 2017-2022 that further reinforces the Philippines Competition Act (PCA) with the mission to create a competitive field to simulate innovation and investments (Barroga et al., 2021). The Philippine Development plan has since been updated and it aims to enable the Philippines to thrive through nurturing a supportive environment for research and development. Aside from that, they aim to strengthen and expand the investigation, detection, and prosecution of anticompetitive conducts and agreements and the like (National Economic and Development Authority, n.d.-a). The main approach being, to 'scale-up' technological adoption, as well as accelerating innovation to further address these problems and applying STI to the Industrial, service, agricultural, and health sectors of the country. Furthermore, investing in STI-based enterprises, spin-offs, and start-ups.

Government Programs

In terms of how the Philippine government may facilitate robotic technology, the Department of Science and Technology-Science Education Institute, (DOST-SEI) had adapted to continuing its yearly robotics and engineering projects online despite the on-going pandemic (Science Education Institute, 2020). Competitions such as "i make. we make" the Tagisang Robotics 2.0 have the potential for new, innovative designs.

By 2018, the National Economic and Development Authority (NEDA, n.d.-b) recorded that up to 45 innovation hubs were instituted by the government, providing services, facilities, and networking for tech start-ups, spin-offs, and enterprises in the country. In the same year, it was also reported that research and development had focused more on improving the designs of existing technology in comparison to developing new inventions that included 962 newly registered industrial designs and 1,044 utility models. Additionally, the Department of Science and Technology (2020) has programs that further improve technological innovation in the country like Science for Change Program (S4CP, n.d.) that was made to accelerate Science, Technology, and Innovation (STI) in the Philippines in order to keep up with any developments.

Companies or Institutions

Advancements in robotic technology in the Industry are facilitated by those that make use of it as well as those who provide the services to implement them in the workplace. In the eyes of many companies, especially those in the field of manufacturing, robotics has been an important part of automation. Allowing for the assembly and production of various products, and eliminating the need for manual labor. Auroratech Corporation (n.d.) is one example of a business that provides services for companies, including the installation of automation and electrical systems. In their site, they include new innovations such as smart factory implementation, connecting factory machinery and systems and enabling them to be aware of their current status.

International corporations have worked to expand their business in the Philippines as well. Universal Robots, a Danish Firm, partnered with Asia Integrated Machine Inc. (AIM) in 2018. It was mentioned that the Philippines had a strong adoption for the collaborative robots that they offered to the automotive, food and beverage, and electronics industries. With their partnership with AIM, Universal robots want to offer customized accessories and automation solutions for collaborative robots in the market (Arayata, 2018).

Robotics has also found itself in the healthcare sector. In terms of how such technology has been stimulated in recent years, one reason is due to the current threat of the pandemic. One application can be read from a government article that addresses the use of a robot to care for COVID-19 patients in Kalibo. The robot in Figure 5, Logistics

Indoor Service Assistant (LISA) transports medicine to the patients, making up for the lack of manpower in overcrowded hospitals and minimizing contact risks. Another feat can be said about the government deployed robot "nurses" in Taguig City. These robots serve the same purpose as LISA, deployed in 2019 as a safeguard for medical staff members against COVID-19 (Caliwan, 2020).

Figure 5. *LISA at the Center of the Group*

In 2021, the Manila Medical Center launched a program for robotics rehabilitation for patients that need physical therapy. The government worked with Robocare Solutions Inc., to obtain three Hybrid Assistive Limbs (HAL) ("Tingnan: Inilunsad Ng Ospital Ng Maynila", 2021). Figure 6 shows HAL, a cyborg-type robot that supports the user to help them stand or walk (Montemayor, 2019).

Figure 6. *HAL Robot Assisting a Patient*

Aside from remote medical assistance and rehabilitation purposes, robotics has also found itself as the next step in improving surgical procedures. Philippine hospitals have taken this step forward. A few examples include the Medical City Department of Surgery (n.d.), a private hospital which claims to be a pioneer in the country with the most number of annual laparoscopic surgeries. In 2017, another private hospital, St. Luke's Medical Center (2017), saw success in performing the first transoral robotic surgery in the country. By utilizing a "third generation da Vinci Si robotic system", this type of surgery can be used on patients with tumors located in the oral cavity. Figure 7 shows the image of the doctors who performed the first transoral robotic surgery in the country.

Figure 7. *The Da Vinci Robot*

Universities Facilitating Robotics Education

According to the Global Innovation Index Report, the Philippine University-Industry collaboration

ranked 48th in 2018 (National Economic and Development Authority, 2017). In addition, there were a total of 78 STI-related cooperation that Higher Education Institutions (HEI) had internationally which was 30 percent more than their goal for that year. Education wise, there were 1.02 million recorded students that enrolled in HEI STEM classes in the academic year of 2017-2018; STEM being education under the field of science, technology, engineering, and mathematics. As a way to maintain the numbers and encourage these fields, various scholarship programs were implemented by DOST-SEI (National Economic and Development Authority, n.d.-b).

Learning about advanced robotic technology is further facilitated by Universities that have courses in or relating to the field. A few examples are De La Salle University (n.d.) and its Manufacturing Engineering and Management specialization in Mechatronics and Robotics Engineering course, as well as Ateneo De Davao University offering its Robotics Engineering course (School of Engineering and Architecture, n.d.).

First in Educational Learning Trends Always (FELTA) Multi-Media Inc. (n.d.) works alongside the Philippine Cultural Center, Philippine Information Agency, and Ayala Museum with the mission to give access to the materials and quality education for students in the country. One of their programs is the Philippine Robotics Academy Digital Program and they partner with many schools all around the country.

Impacts of the Technology

Economy

There is a potential for Artificial Intelligence to dramatically change the economy (Furman & Seamans, 2019). AI and robotics do boost productivity growth but the effects on labor are mixed. The journal also cited a paper by Graetz and Michaels (2015) where robotics added an estimated 0.4 percentage points of annual gross domestic product growth between 1993 and 2007 [32]. This is similar to the magnitude of the impact of the steam engines to the growth in the United Kingdom [31].

Companies that adopt robotics show that they have better evolution overtime in their business for firm performance and labour productivity. This investment into research and development in the form of robotisation is present for SMEs and large firms. The adoption enables companies to evolve into a more efficient model of productivity. Companies that use robotics have an increased productivity and labour share per employee compared to if they did not use robotics in the US. The productivity per employee chained index reached 1.54 for large firms and 1.33 for SMEs in robotics companies which is higher than 1.20 and 1.21 for companies that don't use robotics (Ballestar et al., 2021).

Industry, Manufacturing and Labour

Willcocks (2020) cited that the World Economic Forum (2018a) surveyed 313 companies representing 15 million workers in 20 economies for the period of 2018-2022. They found that automation is replacing 0.98 million jobs while creating 1.74 million new ones. Willcocks suggested that the later the study, the lower the job loss estimates because of automation. When job creation is added in the reports suggest that the net job loss over the next 12 years is going to be negligible at least. Advanced technologies are likely to create a considerable number of jobs and restructure most of the existing ones. It is suggested that automation readiness and early adoption may lead to frontrunner countries and companies getting stronger. most of the existing ones.

Figure 8 compares the calculated job creation and job destruction averaged across firms and years, among manufacturing industries in Japan. In most cases, job destruction was on average greater than job creation, accompanied by a negative growth rate of net employment. This follows the trend where the total number of employees in manufacturing is shrinking with exceptions to automotive and

pharmaceutical industries where continuing and increasing needs of labor persist (Ni & Obashi, 2021).

The distribution of the number of industrial robots by-industry is seen in Figure 9. The automotive industry adopted the largest number of robots indicating the need for automation as it requires lots of assembly work and is demanding in precision. Generally, industries that adopted the most robotics like automotive experienced large job creation and destruction (Ni & Obashi, 2021).

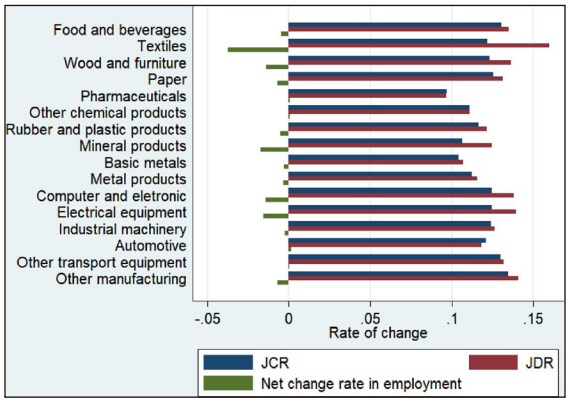

Figure 8. *Job Creation and Destruction Rates, Averaged across Firms and Years 1996-2017, by Industry*

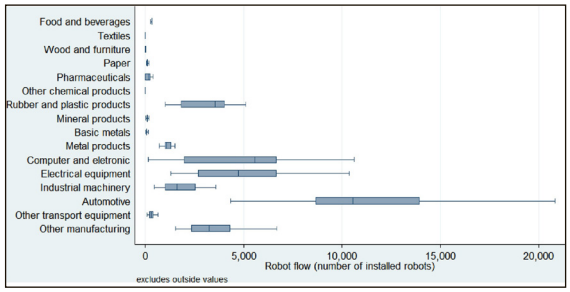

Figure 9. *Number of Robots Delivered, Years 1996-2017 by Industry*

Society

The long-term decline in labor force participation rate is a significant societal impact. The labor force participation rate in the US reached its peak at 67.3 during the 2000s. However it started decreasing at stayed around 66 percent until 2008. Subsequently, the rate experienced another drop, reaching 62.7 percent by mid-2016 (Hipple, 2016). The decline is concentrated among those with a high school degree or less and suggests that the individuals are experiencing a difficulty in learning new skills and transitioning from one occupation to another. Since AI innovations lead to changes in occupations, it will be important for the workforce to learn new skills so continued employment is possible or the possibility to transition to new employment. One concern with the technology is that the changes might happen so suddenly that there will be sustained periods where a large segment of the population is not working so it is important that policies are in place to support workers (Furman & Seamans, 2019).

A study done by Sheetz et al. (2020) in 73 hospitals found that the use of robotic surgery for all general surgery procedures increased from 1.8% to 15.1% from 2012 to 2018. Hospitals that started robotics programs had an increase in the use of robotic surgery and is associated with a decrease in traditional laparoscopic minimally invasive surgery.

Policy Recommendations

Universal Basic Income and Restructuring Welfare and Entitlement Programs

Due to the expected job loss that would be brought by automation, there are certain calls and debates that there is a need of universal basic income or negative income tax. Entitlements such as healthcare and pension other welfare programs should also be reviewed in order for such programs to be sustainable in the long run.

By definition, Universal Basic Income (UBI) is a form government support program where every citizen of certain criteria (such as age) would receive a certain amount of money on a regular basis. Its main goal is to alleviate poverty and replace other need-based social programs (Ward, 2021). The UBI program aims to reduce the bureaucratic involvement of the government, thereby, lessening the cost of administering other traditional welfare programs. However, the problem of putting in

place a universal basic income is first the price tag. An American US president candidate back in 2016 proposed a 1,000 USD monthly "freedom dividends" to alleviate poverty that would cost the federal government 3.24 Trillion USD for it to be implemented. UBI might also trigger imbalances on supply and demand for goods that could lead to higher inflation rates. A similar program to America's UBI program in the Philippines is the "Pantawid Pamilyang Pilipino Program" or "4P's". The 4P's is a conditional cash grant program to the poorest of the poor to improve health, nutrition, and education. For 2021, a total of P106 billion have been distributed (Cervantes, 2020).

If these programs are to be implemented or modification of already in placed programs to a wider scope (increased coverage either both by the entitlements it would cover and social classification), policy and law makers should also rethink and reorganize all other welfare programs and entitlements given to the citizens such as age of retirement, medical insurance, and education. UBI as well for the working class might also make job offers more competitive.

Wage Insurance

Wage insurance is a form of protection to workers against the consequences of earning loss due to uncontrolled circumstances causing job loss. Implementing certain form of Wage Insurance targeted at retraining and job seeking can be implemented in order to encourage adjustment of the labor force into doing a shift in work (National Bureau of Economic Research, n.d.). In the US, the Re-Employment Trade Adjustment Assistance Program stipulates that for those over 50 who have lost their jobs due to import competition, can receive up to half of the difference in their pre and post displacement earnings. This specific program can alleviate and help transition the labor force. If a certain restructuring of the entitlements, which might include pensions and age of retirement, and affected with job loss. In terms of specific implementation, certain more specific policies can be in placed such as the cap to which it can cover, the max period which the person can receive such insurance, age, retraining requirement etc.

Broadening of Career shifts/ Job to Job Transitions and Adjustment Program for Worker Protection and Social Safety Net

In a report prepared by Bessen et al. (2020), it was found that with the current state of companies adopting automation and robotics has resulted to an increase in job to job transitions and career shifts among the labor force. A similar program can be adopted in the Philippines with the American Trade Adjustment Assistance Program to reduce friction from the transition. A current program being implemented in the Philippines, the Adjustment Measures Program by the Department of Labor (n.d.) which aimed at providing an assistance package with the means to help workers in coping with economic and social disruptions. As mentioned in the same paper, Robotics and by extent, automation are forms of disruption in the labor market, this a broadening of such programs that cover the effects of advancing technology (Bessen et al., 2020). This policy aims to help employees adapt to the changes by providing them with the necessary training and skills to find a new job or career.

Robotics in the Curriculum and Increased investment to educational materials and tools

In order to build the necessary local expertise and enough trained and educated students in the technology, including Robotics in the curriculum of students is a must. Current implementations of robotics education include being an elective in the K-12 Program and Special Science high schools (Montemayor, 2018). There are also some private schools and universities partnering with organizations to provide the necessary

requirement to teach efficiently robotics (Anagaran, 2018). Broadening the scope and increasing the accessibility to advanced education materials related to the field could further foster and prepare the young students as the future of the workforce. In addition, to grow further the interest of students, there could be competitions in robotics across different schools, be it private or public. This could increase their engagement with the technology and eventually grow their interests.

In the Philippines, there are high schools that provide robotics education. One such school is Camarin High School, the school aims to provide STEM education through robotics education [46]. Aside from this, there are some universities already in the Philippines which specialize or specifically teach robotics. One of the well-known is in De La Salle University in which it offers BS in Manufacturing Engineering with Specialization in Mechatronics and Robotics Engineering. In order to further ease the adoption of similar courses to MEM, standard procedures and curriculum can be developed by CHED or other organizations that govern and regulate tertiary institutions.

Upskilling and Reskilling Programs and Incentivization

Upskilling is defined as training of employees in order to gain new knowledge while reskilling is training an employee to do a new job (TalentGuard, n.d.). In order to adapt to the changing nature of work and the active labour market, upskilling and reskilling programs would be a key component to prepare the future workforce or help adapt the current workforce.

Apprentice-based training programs can help synchronize both the curriculum and the job. It can help close the gap between the skillset graduates have and what is required for future employment. Through this kind of programs, it can help ensure the training being received by the students is applicable to the job. The government could implement a subsidy program for these apprenticeship programs to help start the university-industry partnerships (Meyers & Besanko, n.d.).

In Germany, the standards of training have been infused not only in robotics but with newer knowledge in AI with its program Industrie 4.0. If applied in the Philippines, it can utilize Technical Education and Skills Development Authority to direct more programs focusing on robotics. Currently, there is a Robotics Technology Course online by TESDA (Meyers & Besanko, n.d.). Further improvement and expanding the knowledge in the field could elevate the knowledge of the trainees under TESDA.

Broadening of Capacity building Programs of necessary Competencies

The Philippines still lacks certain competencies, so that it needs to tap assistance coming from social sectors in order to stimulate the field of robotics. As a result, some scholarships and programs abroad on select and priority programs are launched and the scholars are provided sufficient support upon their return. Similarly, increased incentivization can also make the industry more acceptable and would prevent brain drain.

Taxation

Due to possible effects of automation to the labor force, South Korea (2017) has imposed a "robot tax". The income from these taxes would then be used to fund welfare programs. The core idea of the robot tax is that income from this tax policy helps fund retraining programs for displaced workers. By implication, it disincentivizes firms adopting and maintaining human workers (Seamans, 2021).

Standardization, and Regulations

For proper implementation in the Philippines, government regulation standards should be set to ensure safety and quality is sustained. Examples

for this can be OSHA Standards and ISO standards adapted or required in the Philippines such ISO 10218-1 for robots for industrial environments (Occupational Safety and Health Administration, n.d.).

Sadly, in terms of medical robotics and approval of its use in the Philippines, the FDA has yet to set standards and regulations in using, manufacturing, and distributing them (Chioson et al., 2020). It also affects how startups and university spin-offs establish a laboratory to market products in medical robotics. The FDA can pattern or adjust the standards of US Food and Drug Administration to fit in the Philippines context.

Information Dissemination

The majority of people still sees robotics as generally beneficial while similarly seeing it as a threat to job security. In order to keep people informed of the benefits in having robotics and automation in everyday life and in industries, a proper dissemination program should be developed using traditional and new forms of media.

Infrastructure Development

Back in the 20th century, infrastructure project involved improved roads, bridges, railways and airports helped workers access to work and power the economy. Now, in the 21st century, we shift into a digital economy which requires investment on digital infrastructure such as the internet bandwidth and connectivity (Meyers & Besanko, n.d.). As of 2020, there are 73% of the Philippines was connected in the Internet. Easier and greater access to digital infrastructure will help stimulate the integration of automation in companies and industries, including robotics. One application of Robotics is in surgery where the internet connection has been a bottleneck. Having a reliable internet is a must to effectively and efficiently conduct surgery. Note that infrastructure for robotics ranges from IT Infrastructure to the capability to manufacture and develop devices locally.

Improve Internal Policies and Increase Budget and Programs

According to Razo et al. (2019), some government processes and policies should be improved to make Research & Development (R & D) more efficient. On top of the list is the procurement process, especially with Science &Technology equipment. Due to the complicated and lengthy process of procurement, it has negatively impacted the efficiency of the implementation of Department of Science and Technology – Grants-In-Aid Programs (DOST-GIA) and Projects. Expectedly, it has resulted to less overall productivity of the research projects aside from taking too much time.

In terms of the budgetary support, the Philippine government has a lot to improve by investing more on R&D to be at par with other countries (PH at 0.2% GDP vs Singapore at 2.4% and Malaysia at 1.3%). In this regard, it is worth noting that it does not necessarily means pouring of money over R&D support. For it to be effective, infrastructure and human capital should also be present to create more innovations.

R&D programs should also encourage researchers to commercialize their projects. DOST TAPI is in place already in order to provide support, especially on the field of Technology Transfer and Intellectual Property (Mamauag, 2021). They also developed a roadmap from the DOST 500 project which projects and programs can follow from proof of concept to industry (Mamauag, 2021). There are also programs for academe and industry linkage such as CRADLE and i-CRADLE. It is recommended that together with the increased investment in human capital, R&D, and infrastructure, real efforts to further improve sustainable development of robotics in the country should also be implemented.

2.0 Conclusion

This paper has presented an extensive discussion on Robotics. It provides a systematic in-depth view of all the facets to which we can see robotics from its origins back in ancient times down to how it affects the future of our labor force. Its purpose is to raise awareness and to educate the readers on the current state of Robotics, benefits and consequences, and its implications on a wide range of different areas of government, industry, R&D, and even on our daily lives.

In global context, robotics has gotten smarter and getting bigger. The application of robotics has expanded and patent registration has also increased corollarily. Development in digital sensors and optimized smart software allows a much wider range of possibilities on how to train robot to conduct much more complicated tasks.

In the perspective of the Philippines, there is a great growth opportunity for the industry and application of the technology with many jobs fit for automation and robotics application. Despite a low robot density with only less than 1 unit per 10,000 and lower exposure to automation in general, the Philippines has great automation, especially with robotics in many of its industries which include logistics, agriculture, and manufacturing.

In terms of the facilitating factors of Robotics in the country, the Department of Science and Technology (DOST) and the entire Philippine government has been instrumental in facilitating the entry of the technology by investing on R&D through programs and providing avenue for capacity building such as scholarships to create a critical mass of experts in the country. Certain universities and educational institutes also contribute to building the robotics in the Philippines ranging from training programs to tertiary courses.

Despite the facilitating factors mentioned above, there has also been barriers and constraints of adoption which not only in the Philippines but on a global scale. For the Philippines, the weakest link between Industry and Academe has impeded the overall growth of the field. The informal channels produced between the two have prevented adoption of the R&D technologies to industry applications. There is also a lack of awareness among industries on the benefits of the technology, leading to hesitation. Other innovation roadblocks of the technology are ethical issues such as privacy, safety, freedom, and overall utilitarian perception of the technology. It has been found that the people view robotics as both a great benefit and of threat to their job security. Locally, the lack of infrastructure as well have impeded the overall growth of the technology.

Robotics has a great potential to greatly impact our lives in the aspects of economics, industries, and society. Economically, it has a great potential to change the overall labor market. More business evolves to a more efficient model, increasing productivity in the manufacturing. Automotive companies share the largest number of robots being adopted in the manufacturing sites resulting to large job creation and destruction.

The decline in labor force due to automation and robotics have mostly concentrated among those with a high school degree or less, and has experienced difficulty learning new skill and shifting into different career. With that, it is highly recommended that certain programs and policies should be in place to reduce friction in job-to-job transitions. This may come in the form of wage insurance or basic income benefits. In order to sustain growth and smooth adoption of robotics in the Philippines, policy development such as improved government support, wage insurance, and upskilling programs should also be implemented. Education will also play a crucial role in transitioning the labor market from a traditional to digital economy where robotics is one of the disruptive technologies. To help realize this, investment in education will equip everyone

the needed knowledge to prepare stakeholders in the academe and industries tackle the challenges of the future and control destiny as the world advances through innovation.

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