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Total Automation: The Possibility of Lights-Out Manufacturing in the Near Future

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The Industrial Revolution, which began in the late 18th century, ushered in a new era of manufacturing. Fewer people were needed to produce more products at a higher rate, and this trend continues as technology improves more and more. Society is on the verge of another great leap in manufacturing technology, which is pushing the question of whether or not factories will soon be able to completely eliminate employees and run autonomously. This question has not come out of nowhere. In the 1980s, Roger Smith, the CEO of General Motors, envisioned a future of fully automated factories capable of working in the dark, a technique now referred to as lights-out manufacturing, or LOM (Null and Caulfield 2003). In 2001, a Japanese company called Fanuc built one of these factories (Null and Caulfield 2003). Specific manufacturing cases currently use lights-out factories, but a time when fully automated factories are the norm has yet to come. The purpose of this study is to determine whether or not LOM will become the norm within the next five to ten years.

This literature review has several components to help decide whether lights-out automation will become the norm soon. First, it analyzes current implementations of lights-out factories to find out how successful they are, what kind of benefits they have brought, and what sort of issues they experience. One issue of interest is how well these implementations work in different kinds of industries, in other words, for producing different types of products. Second, it analyzes the number of humans working in factories now, and in what ways they are working. This component determines how humans might be incorporated into factory designs in the future, as well as how integral they will be. The last major component is focused on historical trends. It considers how leaps in technology have changed employment in factories in the past and analyzes whether factories tend to opt for more human-based options or more mechanized options in the short run and the long run.

Certain restrictions were placed on the scope of research in this paper because of a large amount of activity in the field of automation and the political implications of this subject. The scope did include recent news stories of lights-out projects but excluded articles that heavily focus on the political and human impact of automation. The scope included research papers about the implementation of lights-out technologies, the interactions between humans and machines in the future, the development of Industry 4.0 (with a focus on automated machinery), and trends in manufacturing jobs. Considering the research that was reviewed under these conditions, I determined that although lights-out technology has become very advanced compared to its advent, total lights-out operations will not become the most common method of manufacturing in factories in the near future.

Analysis of Implementations of Lights-Out Technology

To understand what lights-out technology will be capable of in the future, the present state must be observed. The president of Gosiger Automation, Mark Eddy (2013), compiled a list of considerations for companies hoping to create lights-out factories. The list outlined the advantages and disadvantages of LOM as it exists now to better define what will be required for this technology to succeed. *Advantages of Lights-out systems*

A well-known benefit of lights-out technology, according to Eddy (2013), is the ability to manufacture at night. This allows more complicated processes to be focused on during the day, which increases efficiency, saves on energy use overnight, and reduces labor costs. Another advantage is the relative accessibility of lights-out technologies. Though this technology appears to be exclusively for large manufacturing firms, it is also accessible to mid-sized and smaller companies as well. Voodoo Manufacturing, a small 3D printing company, was able to create a lights-out production line "using technology Universal Robots, the UR10, for roughly $50,000.

This cost is scheduled to have paid for itself within six months of purchase" (Engelking 2017). The UR10 is used to harvest 3D printed objects, then set the printers to their next tasks. This device was cost-effective and allowed for manufacturing without constant human supervision, even within a small company. The more adoptable LOM is, the more likely it is to become widespread within manufacturing.

Another benefit of LOM is the safety it can provide for human workers. Beth Parkinson of Rockwell Automation described the environments suited to lights-out as "those involving high temperatures, toxic gases or high payloads, and applications like furnace and paint line management or carbon fiber cutting, which pose potential harm for humans" (Schweder 2017). This means that using LOM can lead to productive processes without risking harm to human workers.

Disadvantages of Lights-out systems

The largest hurdle that LOM must overcome is implementation in multiple manufacturing industries, each with their own specific needs. Industries not suited to LOM currently include cold and moist environments, such as food industries (both in creation and packaging), and industries that require a certain level of quality (Schweder 2017). Aircraft production is troublesome to automate for many reasons: "Assembly processes in aircraft production are difficult to automate due to technical risks. Examples of such technical challenges include small batch sizes and large product dimensions as well as limited workspace for complex joining processes and organization of the assembly tasks" (Mueller et. al 2017). As noted by Eddy (2013), "some parts are simply too complex to successfully manage without operator intervention." In fact, research by the McKinsey Global Institute (Chui, Manyika, and Miremadi 2016) found that only 78% of the predictable physical work for manufacturing could be feasibly automated. This would make lights-out facilities difficult to fully automate because even some simple tasks cannot be feasibly fully automated right now.

Another concern with LOM is equipment reliability. Nobody will be on site to deal with machinery malfunctions, and not every machine is capable of continuous operation. Some machines will have difficulty adapting to this production model. Problems with thermal compensation and jamming or clogging may occur if the machines have a communication error. If an operator witnesses issues with a machine, production can be shifted manually, but in a lights-out situation, issues are likely to build upon each other if left unchecked (Eddy 2013).

Human Roles in the Factory of Future

Technology aside, a human's mind and dexterous hands are powerful tools that are appreciated in factories. Human value to these processes must be considered when determining the immediacy of LOM implementation.

Human-Robot Collaboration Roles

Human roles in factories will shift to work with robots more efficiently and integrate robots into manufacturing processes in new ways. Use of robots lowers labor costs and provides other benefits such as time efficiency and higher quality product (Mueller et al. 2017). Although lights-out automation may lower labor costs, systems in which human/robots collaborations (HRCs) are more versatile in the industry. "Due to the versatility of HRC robot systems, this offers, in combination with the skills of humans, innovative possibilities to realize new automation processes" (Mueller et al. 2017). It should also be noted that robots specifically designed to work with humans are being developed. In the past, caged robots were developed because their size and speed posed a threat to humans in the vicinity. Recently, however, several robot systems have been developed that would allow robots to leave their cages. This, as well as recent developments for controlling robots through sight and sound, makes using HRC a very attractive option (Decker, Fischer, and Ott 2017).

Industry 4.0 and Human Roles

Industry 4.0 (I4) is the fourth industrial revolution that the industry is currently undergoing (Herman 2016). This change will be brought on by nine core technologies: "Autonomous Robots, Simulation, Horizontal and Vertical System Integration, The Industrial Internet of Things, Cybersecurity, The Cloud, Additive Manufacturing, Augmented Reality, and Big Data and Analytics" (Hermann, Pentek, and Otto 2016). These technologies are designed to convert factories into smart factories. Lights-out technologies are reliant on the development of I4 since autonomous robots are a major focus.

Within I4, there are many predictions about the developing role of humans. However, the consensus is that human roles within factories will change rather than be eliminated. To be specific, "the main role of humans shifts from an operator of machines towards a strategic decision-maker and a flexible problem solver" (Hermann, Pentek, and Otto 2016). The change in human roles is not the end of human manufacturing, but rather a shift to work with robots in a new, more efficient manner. Neil Kinson, chief of staff at Redwood Software, states that "when we talk about robotics, we are no longer talking about basic machines that replicate human activity, but an opportunity to re-imagine business processes and their interdependencies" (DeAngelis 2017). Even though LOM relies on the development of I4, the priorities of I4 do not include making machines that would replace humans like in LOM. Rather, the new robotic systems will change how the factories work without eliminating human roles.

I4 experts indicate that factories are going to go through a reprioritization towards I4 design philosophies before any other initiatives. So even though automation is a large focus of

I4, the industry is more likely to focus on its HRC initiative before LOM. However, despite the promise that I4 shows, the industry is still not prepared to go through such a drastic transition. A survey done by *The Economist's* (2016) intelligence unit found that out of 537 manufacturing companies of various sizes, 27% had experienced substantial transformation to I4, while 19% were in the process of it. This means 54% of respondents had not begun to transition. In addition, "more than a third of survey respondents acknowledge that they are struggling with recruiting and retaining talent," and "42% worry that over the next three years they will not be able to recruit new workers with the necessary prerequisites for on-the-job training" (Koenig 2017). The lack of prepared employees makes the transition to I4 and LOM a difficult one. The transition cannot occur on an industry-wide scale until companies are able to commit the necessary resources and manpower, and so the transition to LOM that will take place after I4 will take even longer.

Trends of Manufacturing Automation

As mentioned earlier, I4 is the fourth Industrial Revolution. The first Industrial Revolution is the best-known one that began in the mid-1700s, but an industrial revolution occurs each time a major advance in technology changes how technology is used, such as with electricity or computers (*Economist* 2012). Each time a new industrial revolution comes, there is a large shift in manufacturing affecting many things, from how many workers are required to what manufacturing processes are used.

Past Trends

The industrial revolutions of the past had a large impact on employment in manufacturing industries. Therefore, it is important to consider that automation trends from the past could be repeated now. According to David Autor (2015, 9), manufacturing operators and laborers experienced a loss in employment shares between 1940 and 2010, with similar average losses per decade. Agriculture also suffered an extremely large loss from 1940 to 1980, but a very small one from 1980 to 2010. The similarity in reactions could be used to draw parallels between the manufacturing and the agriculture industry. It should be noted that in the past when jobs in automation or agriculture were lost, new jobs were created in other sectors that filled the void as needed (Economist 2016). Autor (2015, 9) noted that though productivity rose with new technology in the past, "rising consumer affluence spurred demand for manufactured goods and leisure complements." This would indicate that the increased productivity that would come with LOM and I4 must be matched by a larger demand for products to smoothly transition into I4. Companies looking to transition their factories to I4 must consider the demand for their products, and whether the transition would be economical.

Current and Future Trends

The implementation of I4 and some LOM can potentially cause a large shift in the workforce, though so far the job loss has been low. According to Daron Acemoglu (2017, 36), "because there are relatively few robots in the US economy, the number of jobs lost due to robots has been limited so far, equivalent to a 0.18-0.34 percentage point decline in the employment to population ratio. However, if the spread of robots proceeds as expected… the spread of robots could be much more sizable." In an aggressive automation scenario, "the world stock of robots will quadruple by 2025. This would correspond to 5.25 more robots per thousand workers in the United States, and with our estimates, it would lead to a 0.94-1.76 percentage points lower employment to population ratio and 1.3-2.6 percent lower wage growth between 2015 and 2025" (Acemoglu and Restrepo 2017). In Germany, losses in manufacturing are predicted due to I4 with "job losses .. reach[ing] 120,000 (or 4 percent) in production, 20,000 (or 8 percent) in quality control, and up to 10,000 (or 7 percent) in maintenance. Routine cognitive work will also be affected; for example, more than 20,000 jobs in production planning will be eliminated" (Lorenz, Rubmann, and Strack 2015). It should be noted that gains are also predicted, but in different roles such as human affairs or information technology and data.

Discussion

Total LOM will not become the norm in the near future. The implementation of lights-out technology is highly attractive due to labor costs, accessibility, efficiency, and other economic benefits. There is reason to wonder whether lights-out technologies could become the norm in the near future with fully automated factories. However, the practical disadvantages of LOM outweigh current advantages. Though LOM may perform extremely well at certain jobs right now, it is not functional enough to be economical in several manufacturing industries, such as aerospace. The technology lacks the precision to create large parts with many details, and it cannot work in various conditions. In addition, current lights-out systems do not have the ability to adapt to mistakes or mishaps as needed, which can potentially cause them to build on each other. This means humans are required on site to ensure the system is running correctly and shut it down if there is an issue. Features that will allow such checking are part of the I4 initiative, but I4 is intentionally giving the role of problem solver to humans, and trying to find ways for humans and robots to collaborate with each other. It seems unlikely that total lights-out factories will become the majority in the near future when large industry efforts are focusing on HRC technologies and when humans provide services that machines feasibly cannot. In addition to this, many companies are struggling to find the talent they need to transition to I4 standards, which makes a time when total LOM the norm even more distant.

Despite these drawbacks, current trends indicate that automation will continue to grow and continue to eliminate manufacturing jobs, just as it has in the past. The creation and growth of new jobs in other fields due to I4 verifies that we are still following the employment trends set by earlier industrial revolutions. This information, however, does not prove that LOM will soon become the most common manufacturing method. The loss of employment to automation has been consistent through the different industrial revolutions starting in 1940, which indicates that there will not be any significant layoff of human workers due to I4. If LOM were prepared to become the norm soon, the trends would see many more layoffs right now as it becomes implemented. Total LOM will not become the norm in the near future, though LOM will likely continue to develop with I4, and some jobs will continue to be lost to automation along with it.

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