**Evolution and Societal Fears of Robotic Manufacturing**

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

# Evolution and Societal Fears of Robotic Manufacturing

## Societal Fear of Robotic Manufacturing

Robots are currently used for manufacturing in the United States at an ever-increasing rate. This industrial demand for automated robotics is due to their faster speed, higher quality, and lower cost than traditional manufacturing methods. Approximately 28,478 industrial robots were sold for manufacturing uses in 2018, a 16% increase from the previous year (Aeppel, 2018). While robotic manufacturing has increased productivity, a recent CNN article suggests that robots will take 20 million American manufacturing jobs by 2030 (Tappe, 2019). Manufacturing is defined as a mechanical, physical, or chemical process that transforms raw materials into a new product and manufacturing jobs account for nearly 8.6% of the American workforce (Yin, 2016). While the belief that automation will steal jobs from Americans, many researchers believe this strong fear of robot technology is misplaced. There is little evidence to show robots will completely revolutionize the manufacturing industry all at once (Paul, n.d.). Additionally, many companies are moving towards utilizing "cobots," collaborative robots that work side-by-side with a human counterpart, in their manufacturing plants rather than completely replacing the human worker. In order to understand the interactions between employees, manufacturing companies, and other relevant entities, actor network theory is used. The risk society theory is used to determine how the potential threat and public perception of robotic manufacturing has affected society in the United States.

## A Historical Case Study and Network Analysis

The research questions analyzed in this paper are: what is the evolution of automated robotic manufacturing and what are the societal fears associated with this technology? To answer this question the first method used is a historical case study. This case study focuses on the Ford

Motors Company's development of the moving assembly line and its implementation of robotics. The second method used to answer the posed research question is network analysis. Using this method, the following actors will be analyzed: government agencies, manufacturing companies, general consumers, and manufacturing employees. Using documentary research methods, both primary and secondary sources are collected and organized according to which actor they apply to. Each actor and its individual motivations are analyzed. For government agencies, legislation, policies, and relations between the United States and other countries are compiled. With respect to manufacturing companies, motivations surrounding robotic manufacturing and future projections are investigated. For general consumers, research on motivations and the purchasing process will be collected. Lastly, for manufacturing employees, news articles and academic papers will be collected.

**Robotic Manufacturing in the United States**

Autonomous manufacturing is a new and exciting technology not only in the United States, but also around the world. Manufacturing is a large and important industry in the United States accounting for nearly 11.6% of US economic output (Amadeo, 2019). Manufacturing companies supply nearly 12.85 million jobs, accounting for 8.6% of the American workforce (Amadeo, 2019). Automating these manufacturing processes has many benefits over traditional manufacturing techniques, including an increase in speed and quality and a decrease in production cost (Fleck, 1984).

In 1913 Henry Ford introduced the first automobile moving assembly line in Detroit, Michigan. The first assembly line was 150 feet long consisting of 140 workers completing 84 separate tasks. This new manufacturing technique reduced the time required to produce a Model T from 12.5 hours to under 6 hours (McKenzie, 2015). Since then, the automobile industry has

taken advantage of technological advancements. General Motors introduced the first industrial robot in 1964 (Robinson, 2016). Since then, Ford has acquired over 20,000 robots worldwide and is able to produce 16 cars every 60 seconds (McKenzie, 2015).

With the increase in manufacturing automation, there has become a strong public opposition to the use of industrial robots in the United States. The majority of the opposition comes from the perception that robots will replace human workers in countries with large manufacturing industries, like the United States (Chao, 1986). While the idea that robots will replace humans in the manufacturing industry is common among the public, there are many researchers who argue that automated manufacturing will not cause the detrimental impact the general public believes will occur (Paul, n.d.).

An emerging alternative to traditional industrial robots is the "cobot". The term "cobot" stands for collaborative robot, and it is a robot that works side by side with a human counterpart to complete a task ("Industry 4.0," 2018). The robot is designed to take care of the strenuous and tedious tasks, while the human worker handles the more complex responsibilities. "Cobots" have accounted for only 3% of all industrial robot sales; however, it is estimated that sales will increase to 34% in the years to come (Hitch, 2019). Recently, Ford has implemented the "cobot" in its automated assembly lines. The "cobot" is able to sand a Ford Fiesta in 35 seconds while the worker supervises and carries out more complex tasks ("Ford Choreographs Robots," 2019). These examples and statistics demonstrate that the "cobot" is becoming a revolutionary alternative in the automobile industry.

**Actor Network Theory and Risk Society Theory**

The frameworks used to analyze this research question are actor network theory and risk society theory. Actor network theory consists of various actors, including, but not limited to,

humans, objects, and ideas, connected with different relations and interactions into complex networks. Ryudin and Tate (2016) write, “Here society is not put together from distinct elements in an additive way; rather society is the result of the assemblage or *agencement* of elements in which the relationships between elements – not the elements themselves – are the key focus” (p. 4). Actor network theory uses a web of interactions and actors to describe society and the development of technologies. This theory is used for many applications, including architectural practice, online university teaching, highway reconstruction, low-carbon commercial development, and metropolitan growth strategy (Ryudin & Tate, 2016). The wide application of actor network theory displays its ability to be applied to a myriad of fields. Some critics argue that actor network theory is misguided when dealing with the idea of intentionality, since actor network theory treats both humans and non-humans as equals among the network of actors. Critics argue nonhuman actors have no intentionality and therefore, cannot act. However, proponents of actor network theory distinguish between agency and intentionality. They argue that simply because a nonhuman object cannot have intentions does not mean it cannot have actions and that agency is through interactions between actors, not the actors themselves. In the case of robotic manufacturing, there are many individual actors at play, including manufacturing companies implementing robotic technology, the manufacturing workers, the consumers of manufactured goods, and government regulations on the manufacturing industry in the United States.

The theory of risk society is also used to analyze the development of robotic manufacturing. Developed in large part by Ulrich Beck (2000), a risk society is one in which “a threatening future, still contrary to fact, becomes the parameter of influence for current action” (p. 222). This theory describes a society preoccupied by fear of the future and of modernization

requiring it to make decisions in the present. This fear defines risk within a society. The risk society theory is often applied to instances of natural disasters, such as floods, hurricanes, or major accidents, such as the Chernobyl disaster. However, the risk society theory can also be applied to any object of modernization threatening a society. Robotic manufacturing is thought to present a real and increasing threat to society in the United States.

## Automobile Manufacturing Development and the Automated Manufacturing Network

The evolution of robotic technology in manufacturing in the United States is due to an increase in globalization. In order to compete with global competition, companies are developing new technologies to decrease production costs and increase productivity. Societal fears are also strongly associated with these new automated technologies. These fears stem from a lowered sense of job security since many manufacturing workers believe robots will steal their jobs. This fear is largely unfounded, since most jobs are not susceptible to complete automation. Additionally, the development of new technologies such as the "cobot" have decreased the risk of a robot revolution and increased job security of manufacturing workers for many years to come.

### *The Development of Automated Manufacturing*

To begin the analysis of the evolution of automated robotic manufacturing, it is important to highlight the beginnings of automation with the example of the Ford Motor Company. Henry Ford implemented the first moving assembly line into his manufacturing plant in 1913. As an experiment for the technology, the first moving assembly line was used to build the car's flywheel. Eventually, the moving assembly line was expanded to include the construction of the entire Model T from start to finish. The new moving assembly line allowed Ford to produce the Model T eight times faster than when stationary assembly was used (Tomac *et al.,* 2019). One

analysis of Henry Ford's contribution to the manufacturing industry states, "The enormous effects of the moving assembly line were seen immediately and they are still seen today. Every manufactured product, such as a television, telephone, refrigerator, washing machine etc. that the people use today, are available in large quantities at a low price and of a good quality that the Ford's invention made possible" (Tomac *et al.*, 2019). Based on the evolution of the moving assembly line, it is clear that manufacturing has always been on the forefront of new technologies to increase productivity and decrease costs allowing the company to be more profitable.

Automobile manufacturing continues to be a leading innovator in manufacturing technology. In 1961, General Motors introduced the first robot in its automobile assembly line. By 1969, an academic research lab developed a six-axis robot arm called the Stanford Arm. The new robotic arm "could move and assemble parts in a continuous repeated pattern" (Corday, 2014). In 1982, the Ford Motor Company installed 6 spot-welding robot arms at its manufacturing plant in Cologne, Germany. Today, Ford utilizes thousands of automated robots in its manufacturing plants around the world (McKenzie, 2015). The introduction of robot, similar to the introduction of the moving assembly line, has caused a dramatic increase in manufacturing efficiency. However, there may be adverse side effects to such a large increase in manufacturing production.

Since the Great Recession of 2008 and 2009, the automobile industry in the United States has recovered. However, the increase in the industry's value has largely outweighed the increase in manufacturing jobs for automobile line workers. Figure 1 shows the relative growth for both automobile industry value and number of industry jobs.

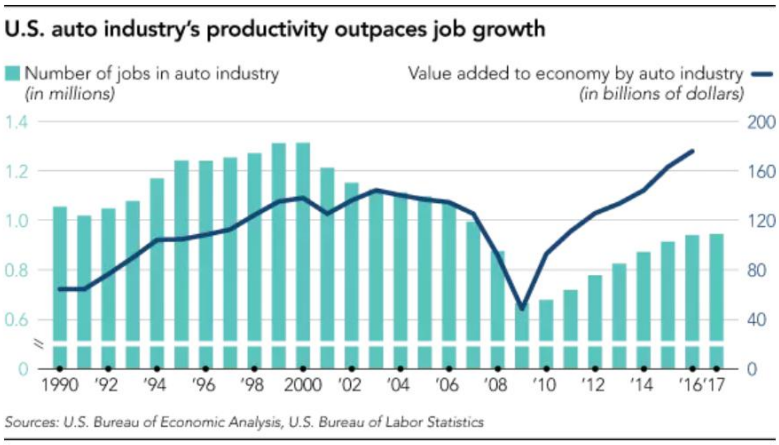


Figure 1: Auto Industry Value and Job Growth vs. Time (Nakanishi, n.d.)

The industry's value has increased at a much faster rate than the number of jobs in automobile manufacturing. Many experts suggest that this difference is due to the increase in automated robotics in manufacturing. According to the International Federation of Robotics, "55 percent of the total demand for industrial robots comes from the auto sector alone" (International Federation of Robotics, 2016). The large investment in automation by the automobile industry can explain why there is an increase in the industry's value without an equal increase in manufacturing jobs.

Some experts believe the automobile industry is the first of many sectors that will see automation replace manufacturing jobs in the United States. An Oxford report recently estimated that "8.5% of the global workforce could be displaced by robots by 2030" (Lardiera, 2019). This staggering number has many unskilled manufacturing workers concerned about their job security. These workers worry they will be replaced by robots capable of doing their jobs faster, more consistently, and cheaper.

*Automated Manufacturing Network*

The second method used to analyze the use of robots in manufacturing in the United States is network analysis. The four actors analyzed include, the United States government,

manufacturing companies, general consumers, and manufacturing workers. Each actors' motives and connections to the manufacturing industry and other actors are explored.

*United States Government*

The United States federal government has a strong invested interest in the welfare of the manufacturing industry. As of January 2020, the manufacturing industry in the United States encompassed around 12.8 million jobs which is about 8% of all American jobs ("Industries at a Glance," n.d.). Additionally, the United States has the largest manufacturing production in the world accounting for nearly 18.2% of the world's goods. American manufacturing output is larger than Canada, Mexico, South Korea, and even China. Experts estimate that "Every dollar spent in manufacturing adds $1.89 in business growth in other supporting sectors, including retailing, transportation, and business services" (Amadeo, 2019). These statistics demonstrate how vital manufacturing interests are to the United States. Government regulations on manufacturing companies have a strong impact on a company's profitability and ability to compete with foreign companies. For instance, the federal government is responsible for implementing domestic legislation and agreements with other countries to manage how companies do business. While some of these laws are beneficial to American companies, many hurt the United States manufacturing sector. It is estimated that government regulations on manufacturing companies cost $180.5 billion, about 11% of total sales. Additionally, the corporate tax rate in the United States is 35% which is high in comparison to other manufacturing countries such as China, with a corporate tax rate of only 16.6% (Amadeo, 2019). Tariffs on foreign goods imported to the United States and tariffs on American goods exported to other countries have a strong impact on the profitability of the manufacturing industry. The changing political landscape in America and around the world, force companies to adapt and

remain profitable. Actor-Network theory shows that the relationship between actors changes the development of technologies. In the United States, government legislation, regulation, and foreign policy change how companies do business. In order to remain profitable within the regulations imposed on them, manufacturing companies are forced to reduce costs. Robotic technology has allowed these companies to reduce costs to remain competitive in the global market.

*Manufacturing Companies*

Unlike the government's interest in the welfare of citizens, the main goal of most companies is to be profitable. In order to be profitable companies must balance their revenue with their costs. The source of revenue for manufacturing companies comes from the sale of the goods they are producing. In contrast, costs for a company are much more complex. These costs include the cost of employee wages, taxes, materials, etc. One cost that is detrimental to American manufacturing companies is the high cost of living in the United States. Amadeo states, "a unionized auto worker in Detroit makes $58 an hour, including wages and benefits. That compares to $8 an hour for a Mexican autoworker" (Amadeo, 2019). Additionally, government regulations and taxes add more costs to manufacturing companies in the United States. These additional costs due to labor and government regulation force companies to cut costs in other areas. In order to reduce costs and increase revenue, companies are implementing new technologies, included the use of automated robotics, on their assembly lines. These robots are capable of increasing speed, efficiency, and quality while simultaneously decreasing costs since robots don't have an hourly wage or benefits. A manufacturing company's relationship with the government, employees, and other companies is important. Companies are forced to compete with other companies both for workers and for customers. Therefore, these companies

must pay their workers well and price their goods competitively. By developing robotic technology, both of these become possible. Since robots don't take wages, costs are reduced and the savings can be passed to the consumer making goods cheaper. A company's goal of profitability and need to compete with other companies has driven them to implement robotic technology in their manufacturing processes.

*General Consumers*

There are many elements, including social, cultural, and economic factors, that go into the decision-making process when consumers decide to make a purchase. The two factors that differentiate one similar product from another are price and quality (Ali, 2016). By decreasing the price of a good and simultaneously increasing its quality, manufacturing companies are able to increase sales of their product relative to their competition. This competition for consumers is another strong reason supporting the development of automated robotic manufacturing. This new technology allows companies to reduce costs, thereby giving them the ability to lower prices. Simultaneously, automated robots increase the quality of products. Both these outcomes will increase the demand for a company's goods, thus increasing its profitability. A company's relationship with its consumers is vital since manufacturers are reliant on consumer business to make money. Consumer demand drives companies to implement robotic technology to reduce costs and keep the company competitive in the global market.

*Manufacturing Workers*

As stated previously, manufacturing workers account for around 8% of the American workforce. Recently, this group of workers have felt threatened by the emergence of new robotic technology in the manufacturing industry. The media industry has perpetuated this fear through recent articles suggesting that many American workers will lose their jobs due to automation.

Manufacturing workers feel helpless, with no power to secure their jobs from the prospective robot revolution. Many workers are looking at higher education or a career shift to avoid the risk of losing their job due to automation. The power imbalance in the relationship between employees and manufacturing companies has caused this fear. Many workers feel powerless in their job security, since the companies they work for have complete control over their employment.

In this respect, American society has displayed what Ulrich Beck has described as a risk society. Americans are fearful of an unknown future due to modernization. This strong fear is causing manufacturing workers to make life-changing decisions. These decisions are not based on their present circumstances, but rather the fear of the future. However, many of these fears are often overblown. The ability for an automated robot to complete a task and replace a complete occupation is extremely low. Most experts believe only 5% of occupations are susceptible to complete automation (Chui *et al.,* 2015). Many jobs will involve partial automation, such as in manufacturing, where the "cobot" will be implemented.

*Technology Alternatives*

As discussed previously, the "cobot" is a collaborative robot designed to work side-by-side with a human worker to complete a task. The "cobot" is designed to handle the strenuous and simple tasks, while the worker is in charge of supervision and the complex tasks impossible for a robot to complete. This technology is starting to take hold in manufacturing industries around the world. Ford has been instrumental in utilizing "cobot" technology in its production lines. These "cobots" also offer additional benefits over traditional automated manufacturing techniques. They are much cheaper than traditional industrial robots and more adaptable. Previously, robots were purchased and implemented for specific tasks. Now "cobots" are easily

reprogrammed to complete different tasks as the structure of the assembly line changes. The use of the "cobot" will be overall beneficial to the manufacturing worker. The "cobot" is designed to do the "jobs that are *dangerous, dirty, or dull*," which will make jobs easier and safer ("Cobots Empowering Humans in Manufacturing," 2019). Overall, the risks of automation to manufacturing workers does pose a threat to job security, but the threat is perceived to be much worse than it is. Emergence of new technology, such as the "cobot", and the continued complexity of certain manufacturing jobs will require human workers for the near future.

Actor Network theory has helped offer deep insight into the evolution and development of automated robotic technology. By analyzing the various actors at play, including the government, companies, consumers, and workers, a deeper understanding has been developed. The connections between these actors simultaneously change both society and technology. Additionally, the theory of a risk society has helped to develop an understanding of the societal fear associated with autonomous robotic manufacturing. The fear of an uncertain future due to modernization is causing workers to make decisions based on the future, not the present. For example, many workers are seeking other careers and higher education to find a secure job for the future without the impending risk of modernization.

*Limitations*

There are some limitations to the research presented on automated robotic manufacturing. First, the data for specific manufacturing company's use of robotics is not easily publicly available. There are statistical figures, such as specific jobs and number of people being replaced by robots each year, that are not available and would require additional research of specific companies. Secondly, as this technology is fairly new in its widespread use across the industry, the aggregate data on trends over time is limited. Further, The Great Recession of 2008 and 2009

has skewed the data regarding economic output and jobs since these downward trends are due to circumstances external to the discussion of this topic. Lastly, it is difficult to ascertain what is going to occur in the future, especially with the changing political landscape around the world. Therefore, the determinations made in this paper on the future of robots in manufacturing are speculative.

### *Additional Research*

There are many areas where additional research can be conducted surrounding automated robotic manufacturing in the United States. More substantial data can be collected to allow for better predictions on the future of this technology. This data would require very specific statistics, such as those described as a limitation to this paper. Another possible area of research would be to explore how automation and robotic technology could impact inequality, such as gender, racial, and socioeconomic inequality in the United States. While robots may not completely replace workers in most occupations, they may change how workers function in the manufacturing process and change the overall landscape of the workforce in America.

## Conclusion

The evolution of robotic manufacturing stems from a need to increase productivity and decrease costs as a result of globalization and greater competition around the world. The societal fears associated with this new technology come from the risk of a new automated society where low-skilled workers will lose their jobs to modernization. This research highlights the strong fear associated with an uncertain job future for many individuals, especially those in the manufacturing industry. This paper concludes that automated manufacturing does have the chance to change the workforce landscape of the United States, but the emergence of new

technologies, such as the “cobot,” will help to secure American manufacturing jobs for the future to come.

References

Aeppel, T. (2019). U.S. companies put record number of robots to work in 2018. *Reuters*. Retrieved from https://www.reuters.com/article/us-usa-economy-robots-idUSKCN1QH0K0

Ali, M. (2016, September). *Factors affecting consumer buying behavior*. ResearchGate. https://www.researchgate.net/publication/316429866_Factors_affecting_consumer_buying_behavior

Amadeo, K. (2019). *5 Reasons Why America's Manufacturing Is Growing Again*. The Balance. Retrieved February 19, 2020, from https://www.thebalance.com/u-s-manufacturing-what-it-is-statistics-and-outlook-3305575

Beck, U. (2000). Risk society revisited: Theory, politics and research programmes. In B. Adam, U. Beck, & J. van Loon (Eds.), *The Risk Society and Beyond: Critical Issues for Social Theory* (pp. 211–29). Sage Publications.

Chao, G. T., & Kozlowski, S. W. J. (1986). Employee perceptions on the implementation of robotic manufacturing technology. *Journal of Applied Psychology*, *71*(1), 70–76. https://doi.org/10.1037/0021-9010.71.1.70

Chui, M., Manyika, J., & Miremadi, M. (2015). *Four fundamentals of workplace automation*. Retrieved February 21, 2020, from https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/four-fundamentals-of-workplace-automation

*Cobots Empowering Humans in Manufacturing*. (2019). Robotics Online. Retrieved February 21, 2020, from https://www.robotics.org/blog-article.cfm/Cobots-Empowering-Humans-in-Manufacturing/177

Corday, R. (n.d.). *The evolution of assembly lines: A brief history*. Retrieved February 19, 2020, from https://robohub.org/the-evolution-of-assembly-lines-a-brief-history/

Fleck, J. (1984). Introduction of the industrial robot in Britain. *Robotica*, *2*(3), 169–175. Retrieved from https://doi.org/10.1017/S0263574700000874

Ford Choreographs Robots to Help People – And Each Other – On the Fiesta Assembly Line. (2019, September 26). Retrieved from https://media.ford.com/content/fordmedia/feu/en/news/2019/09/26/ford-choreographs-robots-to-help-people--and-each-other--on-the-.html

Hitch, J. (2019,). The great robot takeover: Fact or fiction? *Industry Week*. Retrieved from http://global.factiva.com/redir/default.aspx?P=sa&an=IW00000020190617ef6700006&cat=a&ep=ASE

Industry 4.0: Rise of the cobots? (2018). Retrieved from https://www.essentracomponents.com/en-us/news/news-articles/industry-40-rise-of-the-cobots

*Industries at a Glance: Manufacturing: NAICS 31-33*. (n.d.). Retrieved February 21, 2020, from https://www.bls.gov/iag/tgs/iag31-33.htm

International Federation of Robotics. (2016, March 23). *US economy: Auto sector buys every second industrial robot*. IFR International Federation of Robotics. https://ifr.org/ifr-press-releases/news/us-economy-auto-sector-buys-every-second-industrial-robot

Lardiera, A. (2019, June 26). *Robots Will Replace 20 Million Jobs by 2030, Oxford Report Finds*. US News & World Report. https://www.usnews.com/news/economy/articles/2019-06-26/report-robots-will-replace-20-million-manufacturing-jobs-by-2030

McKenzie, S. (2015, April 29). *Rise of the robots: The evolution of Ford's assembly line*. CNNMoney. https://money.cnn.com/gallery/technology/2015/04/29/ford-factory-assembly-line-robots/

Nakanishi, T. (n.d.). *For US autoworkers, robots are the job killers, not trade*. Nikkei Asian Review. Retrieved April 10, 2020, from https://asia.nikkei.com/Economy/For-US-autoworkers-robots-are-the-job-killers-not-trade

Paul, M. (n.d.). Don't fear the robots. Retrieved from https://socialequity.duke.edu/sites/socialequity.duke.edu/files/site-images/Don't-Fear-the-Robots.pdf.

Rydin, Y., & Tate, L. E. (2016). *Actor networks of planning exploring the influence of Ant*. Abingdon, Oxon: Routledge.

Tappe, A. (2019). Robots could take 20 million manufacturing jobs by 2030. Retrieved from CNN website: https://www.cnn.com/2019/06/25/economy/robot-jobs-manufacturing-automation/index.html

Tomac, N., Radonja, R., & Bonato, J. (2019). Analysis of Henry Ford's contribution to production and management. *Pomorstvo, 33*(1), 33–45. https://doi.org/10.31217/p.33.1.4

Yin, R. (2016). Manufacturing process—an overview. Retrieved from https://www.sciencedirect.com/topics/engineering/manufacturing-process