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"China Manufacturing 2025" Challenges and Opportunities for Small and Medium Chinese Businesses

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Abstract

Rising labor costs and shifting consumer demands are causing Hangzhou manufacturers to reevaluate their current manufacturing practices. As part of China's push for internalization of automation, Greentech Investments wants to invest in the development of Chinese manufacturing. We explored automation implementation methods and workforce changes using surveying, interviewing, and field studies of manufacturers to assess current transition obstacles. We found that unskilled labor shortages are limiting manufacturing growth and developed a guide for industry automation adoption to combat this deficiency.

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This project could never have been completed without the aid of our sponsor, Felix Xia. Felix is the CEO of Greentech Investments, and has provided us with many valuable resources to connect with several manufacturing companies. We also want to thank Richard Million for aiding our project team translate our interviews with company executives and providing transportation to these factories, and Hanyang Xia for helping us contact companies and being a great friend. This project could not have been done without their help, and we are very grateful for their constant support.

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Executive Summary

Manufacturers are implementing the newest technologies to gain a competitive edge in the global economy, and countries that are unable to keep pace with the changing consumer demands fall behind their competitors. The world considers China to be one of the manufacturing powerhouses of the 21st century, but its status is beginning to change as national labor costs rise and the comparative price of outsourcing drops. Chinese manufacturers are facing the added pressure of a shifting consumer demographic. With the Chinese upper middle class expected to double in size over the next few years, consumers are no longer interested in the low-quality, high-volume products on which Chinese manufacturers rely. Due to these changes, the Chinese manufacturing sector is shifting towards the newest industrial development, industry 4.0. Industry 4.0 is the trend of manufacturing that promotes the expansion of automated processes with cyber-physical systems that monitor and control the flow of products. Through automated manufacturing, producers hope to increase the quality of their products while reducing labor costs.

Many manufacturers are attempting to use automated systems to remain competitive in the changing market, but effectively implementing this technology depends on understanding the new market and how these new systems affect existing manufacturing practices. For Chinese manufacturers to successfully transition to industry 4.0, companies must determine whether automation will benefit their production process and identify the necessary steps to implement high-tech manufacturing.

The goal of this project was to provide Greentech Investments with a guide on how manufacturing companies in the Hangzhou area can increase manufacturing technology and

identify why companies should consider implementing automation in their production lines. Our team accomplished this goal through the following series of objectives. We identified the effects of the changing workforce on the manufacturing industry through interviews with managers of companies from the electronics, metal, and appliance manufacturing sectors. Our team identified the individual benefits of automation inside select manufacturing facilities and used a combination of interview and observational data analysis to compose a list of indicators that signal when automation is necessary for a company to remain competitive. We evaluated how a company's available resources directly affects its ability to automate, and compiled this data to determine the best strategies to effectively implement automated systems.

Based on these results, our team provided a report identifying future opportunities for manufacturers in China. We combined the results of our studies to map out the transition steps for automation implementation, and we documented industries' behavioral trends regarding the changing climate of manufacturing and the ethical concerns of automation. Our study forms a foundation for continued manufacturing innovation and growth in Hangzhou and provides recommendations for continued research. Our research recommendations can help manufacturing companies maintain a competitive advantage and supply our sponsor with a better understanding of the current manufacturing practices used in the Hangzhou area.

Our research provides a basic guideline for companies looking to increase their manufacturing capacity. The key points of this guide are outlined as follows:

1. Identify areas of your manufacturing process that are struggling;
2. Consider what type of process upgrade would be most suited to your application: full automation, assistive automation, or increased number of workers;

3. Perform a cost-benefit analysis of proposed options considering operational lifetime, initial investment, and recurring costs;
4. Decide whether to develop a custom solution inside the company or source automation from elsewhere;
5. Implement the new equipment and train current workers on its use;

Based upon the summary and analysis of our research, our team composed a series of recommendations. These recommendations are broken down into three segments based on the target audience. These three categories include recommendations for our sponsor, recommendations for the industry, and recommendations for future research, which together form a summary of the current environment for manufacturing in China.

1. For our sponsor, whose primary interest is to develop assistive technology for manufacturers, we recommended focusing their efforts in high-flexibility robotics and manufacturing software.
2. For industry managers, we have formulated a step-by-step guide that highlights the industry-generic transitional procedures for automation implementation in manufacturing, and recommend referencing it as a potential educational mechanism.
3. For future research purposes, and entities who may be interested in pursuing similar directions of research, we recommend expanding the scope of sectors in addition to further exploring the societal and ethical dimensions of this topic.

Chapter 1: Introduction

In today's modern manufacturing industries, automation has become one of the most important factors in gaining a competitive edge by increasing productivity, efficiency, quality, and reliability (Eloot, Huang, & Lehnich, 2013). Companies face increasing labor costs, global market decline, and increasingly complex and precise product requirements turn to automation to meet these needs. Companies that do not proactively introduce automation into their enterprises face potentially drastic global market losses and could eventually lose business due to growing competition. This becomes very important for countries such as China that have been dependent on large, low cost labor forces. If manufacturing industries in China continue to rely on labor intensive and low-tech manufacturing methods, they will struggle to satisfy the demand for high quality goods.

For many years, China has relied on the variety and quantity of its products to keep its economy strong, with the result of sacrificing quality in its production (Ma, Gao & Chang, 1997). With a rapidly changing economic system, however, China may soon lose its position as the cheap manufacturing hub of the world to countries that can manufacture these goods for less. Therefore, Chinese companies are upgrading manufacturing processes to increase high-tech automation equipment. Making this transition is a difficult process for companies that currently lack the infrastructure to produce these higher quality goods.

Past research indicates that increasing labor costs, shifting consumer demographics, and inadequate labor skills are issues detracting from Chinese manufacturing growth (Eloot, et al, 2013). With the increase in labor costs, Chinese companies are losing their monetary advantage of manufacturing in China and must rethink how they will stay competitive in the global economy (Wadhwa, 2016). In addition to increasing market competition, manufacturers are also

facing a fundamental shift in Chinese consumerism (Gan, Hernandez, & Ma, 2016). The Chinese middle class is growing, and citizens are increasingly demanding higher-quality goods (Iskyan, 2016). Research based out of more developed countries, such as the United States, South Korea, and Japan, shows that automation is a viable solution to quality control issues and rising labor costs when used effectively (Finklestein, 2003; Weber, 2008; Jung, 2007; Infor, 2007). Chinese companies facing these same issues can utilize this knowledge to begin advancing the technology level of their manufacturing processes.

While foreign manufacturing companies have already experienced and solved many similar challenges, past research has not explored the specifics of how workforce availability affects urban Chinese manufacturers transitioning to high-tech processes. In particular, research has not clearly defined the steps manufacturers in the Zhejiang province need to take to transition to industry 4.0, the push for smart integrated technology. This lack of information stemmed in part from studies focusing on the before and after of implementing automation while ignoring the transition process. It was this process that our sponsor, Greentech Investments, was interested in understanding further.

The goal of this project was to provide Greentech Investments with recommendations for how to assist the Hangzhou manufacturing sector with automation implementation. We interviewed and performed field studies of manufacturing companies at various stages of automation implementation in Hangzhou to accomplish this goal. From these interviews, we determined how the changing workforce is affecting manufacturers and identified manufacturers' views on the implementation of automation. Through our findings, our group identified the steps necessary for integrating automation into a manufacturing company. Because these steps are different for each company, we have developed a general guide to assist with the upgrade

process. Based on the results of our research, we recommended that Greentech Investments invest in emerging industries that develop scalable robotic platforms for automation and manufacturing management software. In addition, we suggest how future research can expand our current findings to encompass additional sectors and geographic regions.

Chapter 2: Background

The manufacturing sector has been an integral part of modernizing the world and has gone through many revolutions to reach its current state of productivity. The most recent revolution of smart manufacturing, the integration of high-speed automated communication through a manufacturing line, is currently in full swing, with many countries racing to be at the forefront of high-tech manufacturing. China is one of these countries, and with 40% of its gross domestic product tied to the manufacturing sector, it is dependent on a successful transition (Central Intelligence Agency (CIA), 2017). In this chapter, we will begin by looking at previous case studies of industries that have already made the transition to automation to establish key components of transitioning an industry. Then we will introduce some of the core problems that Chinese manufacturers are currently facing followed by a description of the Chinese government's overall national push towards reaching the industry 4.0 standard. Finally, we will focus the national approach down to Hangzhou's efforts to reach manufacturing excellence.

2.1 Manufacturing- International Approaches

Manufacturing enterprises face several problems that they must handle in order to stay in business and plan for the future. Rising wages, high-tech product demand, competitor market shifts, supplier logistics-chain failure, global market fluctuations, and environmental impact are some problems that can halt the growth of a company (Eloot, Huang, & Lehnich, 2013). Here we

will look at some examples of automation practices that are used by companies internationally to combat these challenges.

2.1.1 General Motors

General Motors (GM), an industrial manufacturer of automobiles in the United States, had the largest national market share for car manufacturers at 48% for many years (Finkelstein, 2003). Unfortunately, in the 1970s to 1980s, due to growing competition from foreign car imports, increased investments to meet pollution regulations, and growing factory workers' demands for higher wages, GM started losing market share to other manufacturers. When the Japanese company, Toyota, started penetrating U.S. domestic sales in the 1980s, GM released a radical plan to upgrade all of its existing factories (mostly in the US) with new, automated robots. GM spent an estimated $45 billion to introduce automated robotic systems to replace inefficient laborers. However, the plan ultimately failed as GM lost even more market share, ending at only 30%. The lack of cost planning, GM's poor comprehension of the core problems, and not understanding how to implement automation properly resulted in this failed investment. GM did not consider the expensive indirect costs of integrating machines into the workforce, such as hiring technicians and trained workers to keep the robots running smoothly. Years later, Robert Lutz, a senior executive at GM, said:

> You need to look at every worker. You look at his value-added time versus his wait time and you arrange the production flow in such a way that you maximize the value-added time of each worker and reduce the waiting time. You concentrate on the worker not on the machinery. Use automation only where necessary (Finkelstein, 2003, p. 23).

His response shows exactly what others should learn from their mistakes of underestimating worker costs.

In summary, the strategy that GM adopted overestimated the advantages that robots had over their previous workforce. It failed to balance the costs and benefits that automation would bring them and ultimately paid the price through years of wasted resources and investment through poor implementation and execution. After its initial blunder, however, it learned the proper places for automation and has since implemented machinery effectively (Weber, 2008). GM shifted robots to areas where human laborers could not match their ability and small footprint, but the biggest contributor to GM's success was its use of computers to oversee human and machine cooperation to optimize workflow and address potential issues before they became larger problems. By reevaluating where to use automation and by using robots and human beings where they performed best, GM was able to increase the quality and quantity of its automobile production.

2.1.2 Toyota

Toyota, a Japanese car manufacturer, has had a different approach to automation and efficiency that involves a more worker-focused technique (Benders & Morita, 2004). Toyota's production lines use a model for manufacturing developed by Japanese companies and other global car manufacturers called Toyota Production System (TPS) (Sakai, & Amasaka, 2007). The key principles are producing just enough of a product to fulfill demand and using a smooth, uninterrupted flow that keeps products processed "just-in-time". This model sees inventory of in-process stock as waste and something manufactures should avoid to prevent undetected defects. Toyota also implements a continuous improvement scheme that allows employees to suggest improvements to any production process.

One of the most important approaches that Toyota uses in its factories is segmenting its assembly lines (Benders & Morita, 2004). Segmentation of assembly lines is the process of

creating independent modules of the factory that produce a specific product. Between these are buffers, which can contain up to five cars worth of the modules product. This system is extremely useful when unavoidable problems occur at any of the major segments, which can cause downtime. This downtime would normally halt production throughout the entire factory, but with small buffers, each segment can keep working while the problem is fixed. Toyota uses mechanization only for particular assembly tasks where it would be beneficial for a machine to work instead of a laborer, such as anything requiring heavy lifting, precise movements, repeatable measurements, or working in hazardous environments. Toyota keeps these machine workstations in the same segments that workers are using so workers can understand how the system functions rather than view it as a mysterious black box threatening to replace them.

2.1.3 Samsung

Samsung, a South Korean electronics company, uses an internalized production approach towards controlling and optimizing its global factories and preventing the issue of technological hollowing out (Jung, 2007). Hollowing out is when companies opt for low-cost overseas facilities and labor, which poses a threat to domestic employment.

Hollowing out is an important problem for workers when large companies switch to using international labor, but this is not the case for many companies such as Samsung (Jung, 2007). Samsung uses offshore factories in countries such as China, India, Brazil, and Vietnam as bases for its mobile phone factories. Instead of domestic job loss due to this outsourcing, Samsung's domestic employment went from 5,960 to 20,500 from 2002 to 2012. Samsung shifted its domestic workforce from low-paying assembly jobs to high-paying jobs in research and development, product design, marketing, and engineering, which caused the increase in domestic employment. The number of Samsung's domestic assembly workers dropped by 150

workers between 2008 and 2012, but jobs such as R&D, technicians, and other high-paying jobs increased by over 4600 because of the increase of high-tech automation equipment. In fact, a study by Gorle and Clive (2013) found that in 2011, the 1 million robots in global use led to the creation of nearly 3 million jobs. This creation of high tech jobs explains why Samsung was able to avoid hollowing out its workforce.

Among the jobs created by offshoring Samsung's factories, some included a group of manufacturing engineers that Samsung trained specifically to perform maintenance, monitoring, assembly line re-modeling, and automation implementation whenever Samsung opened a new international factory (Jung, 2007). These employees stayed in a "global manufacturing technology center", which increased from 80 employees to 1103 between 2006 to 2011. This technology center shows how correctly using educated and experienced workers can dramatically increase production efficiency in global factories and allow local establishments to focus on the overall production process instead of dealing with difficulties integrating automation.

This group of manufacturing engineers was also responsible for internalizing Samsung's production. Internalization refers to moving processes previously handled by an outside source to within a particular entity or company (Jung, 2007). This is important for manufacturing because any problems that occur in the supply-chain can cause severe losses in product throughput. By having a group of specialized engineers with direct access and knowledge of all Samsung's international factories, Samsung was able to internally address production problems.

Although these case studies are a good way to analyze how other enterprises approached implementing automation, they do not consider some of the specific challenges that have arisen

in the past few years. In the next section we identify common manufacturing problems that an automation contractor must solve.

2.1.4 Infor Contracting

Infor, a US based cloud computing software company specializing in enterprise resource planning solutions, is commonly contracted by large manufacturing companies to transition to industry 4.0 standards by offering services that monitor production from supply chain analysis to end-user software design (2017). Instead of increasing its own automation similar to the previous companies, we can use Infor's practices as a way to learn more about broader approaches to increasing automation from a company with more experience. Infor's software can strategically monitor production to increase automation agility and efficiency by predicting maintenance and throughput requirements. Its software alone can increase productivity of manufactures by 28.3%, while also decreasing downtime, inventory costs, and maintenance costs. Because of Infor's wide range of customer applications, it encounters a large number of different problems and have a great deal of experience creating adaptive solutions.

Infor argues that the most important process improvement is shop floor automation (2015). Without a strong automation floor, industry 4.0 standards are unreachable. Smart sensors, GPS tracking, and barcode scanning are all simple tools that create the link between production and IT solutions to allow for full automation. One of the largest barriers to shop floor automation is reluctance to change. Companies are resistant to change due to both technical and business challenges. Shop floors can be very complex, having numerous machines with different control systems that make it difficult to link into one network. Additionally, companies often need capital intensive infrastructure changes. Business owners may not invest in changes that do not guarantee dramatic results. In order to determine how to implement shop floor changes,

companies must continually evaluate the current processes and look for opportunities for improvement. With the current speed of technological change, manufacturing solutions will be changing constantly, so it is important to implement flexible solutions that do not require heavy infrastructure changes that make future growth more difficult. Speed of delivery, volume of production, and complexity of shop floor operations are all factors that will change the level of operational autonomy that manufacturers require. In order to provide a full analysis, we will first look at what problems China faces and compare them to these cases to form a better understanding of manufacturing in China.

2.1.5 Enterprise Resource Planning

Enterprise resource planning(ERP) software has set the standard in the last century as the most advanced approach to company and plant management (Oracle, 2017). ERP software combines relevant data and analytic resources into one cohesive system that allows managers and supervisors to evaluate a plant's production metrics. They track key business activities such as project management, resource procurement and product manufacturing to form a single data source with all of a company's core information. Companies can then use this database to streamline their business operations by identifying inefficiencies in their process and responding accordingly. Additionally, this type of software enables material usage and product demand forecasts to be far more precise than was possible in the past. By considering all aspects of a company's operations, they can use past data to form improved predictions about the future. These predictions allow real-time control of key manufacturing processes to ensure that companies meet product demand without wasting additional resources.

As the technology level of manufacturing companies increase, the advantages of using ERP software also increase. With smart manufacturing systems that report current status, tool

wear, production cycle time, and a variety of other production statistics, ERP solutions can keep machines running at their peak performance (Appendix E). Some of the most advanced ERP software is even using artificial intelligence to better transform this data into meaningful information, decisions, and actions (Baat, 2016). This software can execute transactions such as purchasing materials or responding to a new contract, and in some cases, can even respond to customer service requests. By integrating this technology, manufacturing companies around the world are making management decisions simpler by collecting and analyzing data, and executing decisions automatically. This in turn reduces overhead management costs, and allows companies to discover trends previously unrecognized by traditional analytics software.

2.2 Problems Affecting Chinese Manufacturing

China faces many of the same challenges that caused other companies to adapt their manufacturing practices, but the specific cultural, economic, and political climate of China bring along their own set of challenges (Eloot, Hung, & Lehnich, 2013). The rising wages for factory workers, changing market demands, and global pressure are quickly forcing Chinese companies to reevaluate their approach to manufacturing in order to remain competitive in the global economy. As a country dependent on manufacturing, with 39.8% of its gross domestic product (GDP) coming from secondary industries, these changes will have wide ranging effects, changing China's role in the global manufacturing economy (CIA, 2017).

2.2.1 Rising Wages

China's low-cost labor has been a core component of its manufacturing success, but increased wages are threatening its position as one of the world's top manufacturers (Gan, Hernandez, & Ma, 2016; Banister, 2005; Dongxia & Nuthall, 2014). Gan et al. observed that a 10% increase in minimum wages corresponds to a 0.9% decrease in export sales due to companies choosing lower cost alternatives for their manufacturing needs. As a point of reference, in 2013 this estimated 0.9% decrease would correspond to around 20 billion US

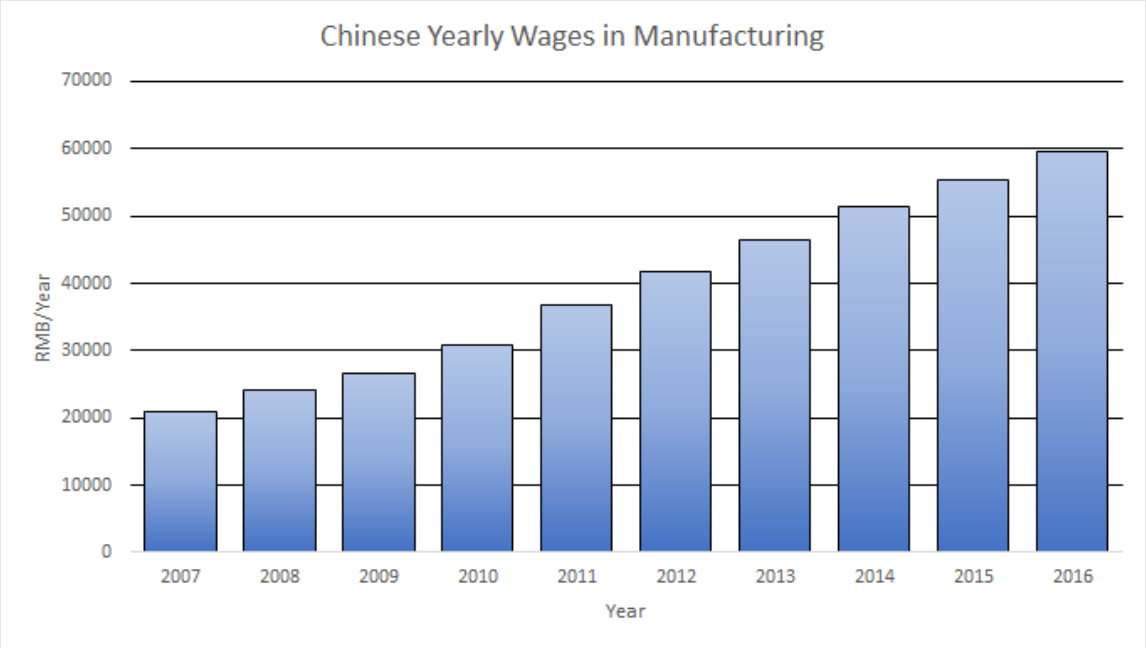

Figure 2.1 Manufacturing Wages in China 2007-2016, adapted from Trading Economics, 2017

dollars of lost revenue. Comparing this to the rate at which the wages in manufacturing are rising shows that companies will need to adjust their manufacturing strategies to retain their profits. Figure 2.1 depicts the yearly wages for an average manufacturing worker in China. The y-axis represents the average yearly wage of a worker, and the x-axis corresponds to the data collection year. As shown in the graph, the overall trend is that wages have been steadily increasing as time goes on, with a nearly 300% increase in wages over the past decade. Because of this, Chinese

manufacturing companies are losing their competitive edge in low-cost manufacturing for labor-intensive goods, and companies are looking to shift manufacturing beyond China to reduce costs (Eloot, et al., 2013). If the trend depicted in the graph continues, manufacturing costs in China may become too expensive causing countries such as Bangladesh or India to become the new low-cost factories of the world.

With the increase in wages, manufacturers are finding ways to reduce their labor force while simultaneously increasing production capacity. Companies are increasingly using automated systems to augment their manufacturing ability, but the ethicality of replacing workers with machines causes a public backlash against these technological developments (Barton, et al., 2017; Bomey, 2017). The McKinsey Global Institute estimates that over half of all work activities in China could be automated which could cause widespread labor changes for hundreds of millions of Chinese citizens. With these technological developments, manufacturers will increasingly value digital skills while reducing the demand for less educated workers. This may result in an increasing social gap as the number of lower-class opportunities decrease. When companies decide how best to grow their company, they must consider the social and ethical consequences of their actions on a global scale and consider how to keep the current workforce employed.

2.2.2 Shifting Consumer Demographics

Rising wages bring with them a fundamental shift in China's economy. The increase in worker's pay enables people to move up the economic ladder, creating a large increase in the number of upper middle-class citizens (Barton, et al., 2013; Li, 2010). The National Bureau of Statistics reported annual wages for urban households which we used to determine the number of households in each economic bracket (National Bureau of Statistics of China, 2005-2012). As

Figure 2.2 shows, from 2004 to 2012, the percentage of urban households that the government considered middle class rose by over 35%, and this trend will continue in the coming years.

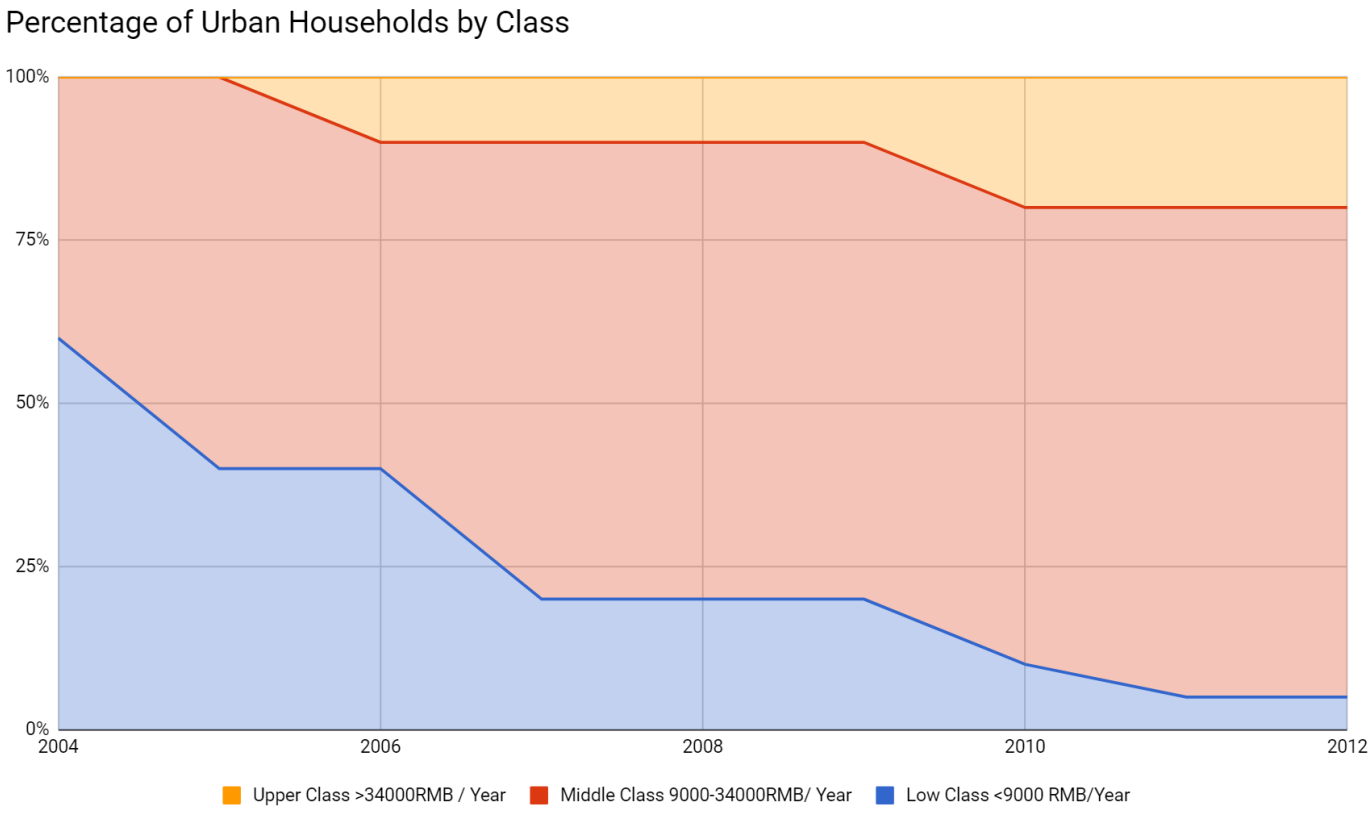

Figure 2.2 China's Middle Class is Expanding (Created from National Bureau of Statistics of China, 2005-2013);

Studies project that by 2022, 54% of Chinese citizens residing in cities will be considered upper middle class (up from 14% in 2012) and 9% of Chinese citizens residing in cities will be considered affluent (up from 3%) (Iskyan, 2016). Overall, this graphic certifies that the consumers are earning more (see Section 2.2.1) and as a result, are changing their economic standards. As people improve their standard of living, what they find desirable in a product is also changing. Rather than buying manufactured items because of their durability or their cheapness, upper middle-class citizens are citing status and social benefits as a core reason for

buying a product. Citizens are concerned about peoples' perception of their use of such products and are willing to spend more money for a higher quality or name brand product.

Chinese manufacturers are working to keep up with the high-end consumer product demand as the upper middle-class consumer market continues to grow and China increasingly expands overseas (Marsh, 2012). This shift in consumer tastes is causing manufacturers to try to establish brands for their products and produce higher quality goods (Ng, 2017). Old-style factories designed around producing a massive number of low quality goods using unskilled laborers are quickly adapting to this change and are taking advantage of this shift to rethink their manufacturing processes. As Guo Jingjuan, a director of Huafang Textile Company, states:

> Our company focuses on improved clothing and yarn quality. Compared with big production volume, we want to focus more on branding…Our executive thinks it is necessary to increase frontline workers' wages... because it stabilizes the workforce, which can make good quality products (Dongxia & Nuthall, 2014, p. 4).

By increasing wages, this company hopes to retain workers and create better products that can compete in the international and domestic markets. Making this transition to higher quality goods, however, is going to be an uphill battle for many Chinese manufacturers because other countries have a significant head start in doing so.

Because of China's long-standing reputation as a low-quality manufacturing country, companies are facing a cultural bias where foreign goods are deemed more desirable and of higher quality (Eloot, et al., 2013). This bias stands even when foreign companies are using Chinese factories to produce their goods, showing that the issue stems from consumer perceptions more than any other factor. In 2007, 63% of Chinese consumers said they preferred

foreign brand home appliances, but consumers are slowly shifting their preference as Chinese manufacturers improve (Kuo, et al., 2015). After many years of having lower standards for their products and not enforcing manufacturing regulations, it is difficult for existing and new manufacturers to gain the trust of the consumers and overcome this bias. This puts companies, whether they have advanced their manufacturing to using better technologies or not, one more step behind foreign manufacturers when it comes to selling high quality goods. Taking this into account and compounded with the fact that many foreign companies have already been established in industry 4.0, many Chinese companies are struggling to enter this new era of manufacturing and are cautious of the high capital investments required to make the transition to high tech manufacturing.

2.2.3 Gaps in Supply and Demand for Educated workers

Aside from the economic challenge of transitioning to smart manufacturing, research has shown that eastern coastal cities in China are facing a problem of educational mismatches across many industries (Qiang & Zhigang, 2016). As China works on moving towards high-end technology and services, the need for educated laborers with advanced skills is growing. The education system has produced a matching supply of college graduates, but because cities have varying sectors and sizes, there is a mismatch of what specific skills are being supplied and demanded. The disconnect between the education system and the industries' needs is creating dissatisfied graduates and industries are still looking for qualified labor. Qiang and Zhigang report that one third of university graduates leave their jobs in under 6 months due to unrealistic career expectations and low job satisfaction, while 70% of companies believe that what students are learning has very little practical value in their industries. There is an increasing gap in the education that manufacturers require to make industry 4.0 possible and the education that

universities are providing. Without the workforce to support these transitioning industries, many companies delay their move into high-end manufacturing or suffer the losses caused by having less educated workers in this new, more competitive environment.

2.2.4 Migratory Workers are Not Travelling to Cities

As China continues to develop, its socio-geographic distributions continue to evolve as well. Due to the sheer number of workers, China introduced a *hukou* system to restrict the number of people living in cities and limit the movement between rural and urban settlements (Chan, 2013). This system classifies citizens as belonging to a certain region or city, usually denoted as a result of marriage or birth, and makes it extremely difficult for citizens to live outside of their registered zone, especially when moving from rural to urban areas. However, this system only applies to permanent residence, allowing migrant workers to circulate between areas but barring them from many of the local benefits and rights that permanent residents enjoy.

As wages rise and standard of living increases in rural areas, previously rural migrant workers are finding it more preferable to remain in their permanent residences with their families instead of temporarily working for companies in cities (Wildau, 2015). In addition to the restrictions due to the *hukou* system, this demographic shift is making it more difficult for urban companies to find laborers. As a result, companies are beginning to operate factories in rural areas where these laborers are plentiful, fueling industrial growth and providing higher wages for rural workers. This, in turn, forces urban companies to offer higher wages to incentivize rural citizens to work in the city, cutting into overall profits. This has given rise to a difficult environment for producers, and even with current competitive wages and incentivization programs, sourcing assembly-line workers can be very challenging (Timms, 2015).

These challenges do not mean the end of manufacturing for China. Rather than relying on the low-tech, labor-intensive processes, which are becoming increasingly cost prohibitive, China is pushing towards adapting manufacturing to a more high-tech approach to meet the demands of its growing economy (Marsh, 2012; Kennedy, 2015; Meissner 2016; Baur and Wee, 2015). In order to achieve this goal and for China to remain a manufacturing hub of the world, the economics of increasing wages, shifting consumer demographics, and the geographic availability of laborers in cities needs to be addressed. To catalyze this process, the Chinese government is pushing the China 2025 manufacturing initiative to support industries and launch China into a new age of manufacturing greatness.

2.3 China 2025 Initiatives

In response to these growing manufacturing problems, the Chinese government has introduced the "Made in China 2025" initiative, which aims to upgrade Chinese industries to be more competitive in the global market (State Council, 2015; Kennedy, 2015). This initiative pushes for high-quality and high-tech products that can compete in the global market. To do this, China is focusing on developing innovative products, creating international brands, and upgrading its current manufacturing enterprises.

This policy is not limited to certain industries or particular regions but is a smart manufacturing revolution sourced from the Chinese government (Wübbeke, Meissner, Zenglein, Ives, & Conrad, 2016). Because of this, the success of all industries hinges on how well the government implements this policy. Central and local governments are flooding high-tech industries with funding to encourage the shift to high tech manufacturing by introducing several new funding campaigns like the Advanced Manufacturing Fund ($3.25 billion USD), the National IC Fund ($22.87 billion USD), and the Emerging Industries Investment Fund ($6.5

billion USD). In addition, China has invested an additional $6.5 billion USD in local funding for industrial robotics, and plans to have more than 70% of its robotics manufactured domestically by 2025. This funding comes in the form of subsidies, financing plans, and tax incentives, however it has many restrictions on which companies can qualify for the funding.

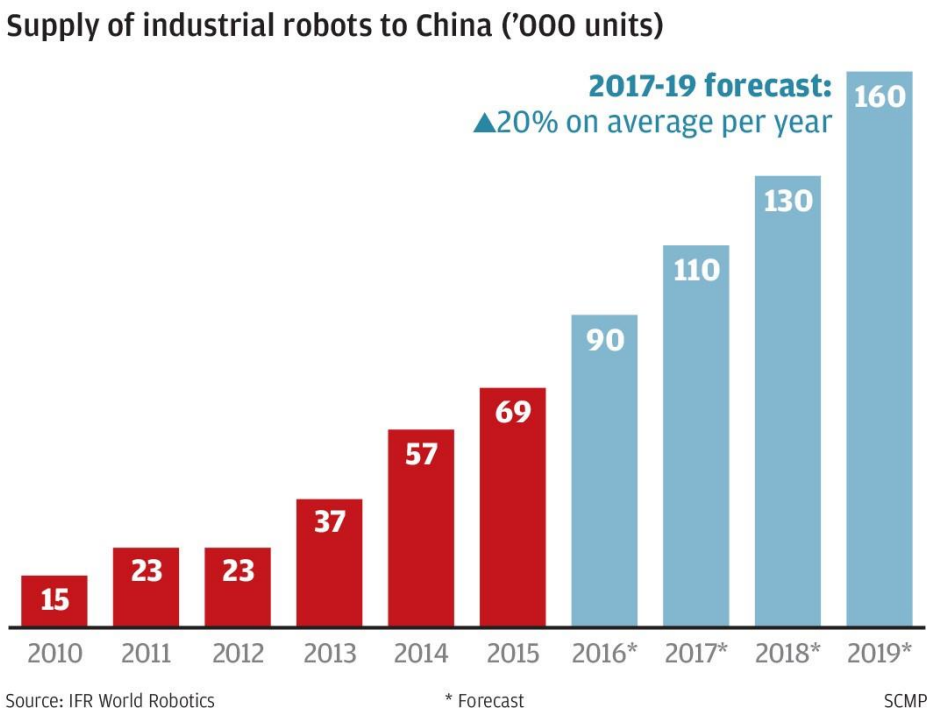

Figure 2.3 China's Increasing Robot Supply (Ng, 2017, p. 1)

Figure 2.3.1 depicts the number of industrial robots China has in manufacturing production in the past few years, where the y-axis represents the number of robots per year and the x-axis is the corresponding year. From 2010 to 2015, the number of robots has more than quadrupled with an increasing trend line (Ng,2017). From this data, it is projected that by the end of 2019 the number of robots will be greater than 160 thousand. This quickly increasing trend line shows that the demand for industrial robots is rapidly increasing. A reason for this increase in demand is due to the push for domestic industries to eventually replace their foreign competitors on the domestic market and on global markets (Wübbeke, et al., 2017). By internally sourcing the majority of their high-tech products, China ultimately aims to catch up to other global industries and become mostly self-sufficient. Effectively, by utilizing more automation,

Chinese companies hope to reduce manufacturing costs, increase production, and improve the quality of their manufacturing line to stay competitive in the foreign market.

Despite the benefits that the Chinese government has introduced for high-tech manufacturing, it can be difficult for industries to pursue smart manufacturing. Currently, the government's program has helped establish over 400 Chinese robotics companies, but many of them are only profitable due to the government's subsidies (Wübbeke, et al., 2017). In addition, only 21% of Chinese enterprises are testing or using industry 4.0 applications. In this way, companies that do not receive government subsidies are reluctant to invest in a high-tech program due to the hefty costs with limited gain. China is hoping that by expanding the market with new companies and rewarding those focused on smart manufacturing, it can draw in some of the more reluctant companies to join the China 2025 movement.

2.4 Hangzhou Innovation

The Zhejiang province's focus in Hangzhou has been aggressively moving towards financial backing for the vast majority of emerging businesses (Schuman, 2016). The province has implemented investment funds that directly subsidize the operational costs of many developing businesses. This support offered to developing businesses has been extremely well accepted, which has rapidly formed a culture sometimes referred to as "mass entrepreneurship," and led businessmen and policy leaders to flock in droves to this area of China. Despite the occasional concern that this forceful spending has been contributing to an over-inflated economic bubble, companies like Alibaba, an important member of the manufacturing supply chain, are the living proof that China's economy is creating an ever-increasing pool of dynamic, disruptively innovative business models (Wong, 2015).

The city of Hangzhou has provided enormous support for any organization with an innovative or entrepreneurial focus (Schuman, 2016). Innovation and entrepreneurial growth is a core pillar of the Chinese government's plan to reinvigorate the Chinese economy, and the city of Hangzhou provides benefits accordingly. Such vigorous support has actively attracted a wide range of new industries, while steadily continuing to grow their original manufacturing base. These new sector participants vary widely, spanning everything from single-person startups to university research centers supporting student interest.

Because of Hangzhou's strategic positioning near the coast, it has been a manufacturing and production hotspot since the 1970's (HSBC, 2016). Between then and now, the city has experienced growth of more than 45 times its baseline, mostly because of its manufacturing success. Despite this exponential growth, production in Hangzhou is increasing in difficulty as the city further develops. Minimum wage in Hangzhou is the highest in all of Zhejiang province, the additional cost of meeting quality requirements is becoming prohibitive, and some global distributors are shifting their providers away from China (Wage Indicator, 2017).

2.5 Summary

How a company handles shifting economic and political situations dictates its future success. From the case studies of GM, Toyota, Samsung, and Infor, we see that automation can greatly augment a company's manufacturing ability when implemented in key areas with a worker centric approach. While each company faced the same issues of rising costs, quality control, and increased foreign pressure, its solution to each of the challenges was different. By looking at the different approaches and results for each company, solutions that are flexible and plan for future changes have the best results for both the company and its employees. In the next chapter, we will discuss our plan for evaluating how the rising wages, shifting demographics,

and educated labor balance are affecting companies in Hangzhou as well as identifying how companies can best transition into industry 4.0.

Chapter 3: Methodology

The goal of this project was to provide Greentech Investments with a guide on how manufacturing companies in the Hangzhou area are increasing manufacturing technology and identify why companies should consider implementing automation in their production lines. In this chapter, we explain the methods we used to achieve our goal.

Our measurable objectives were:

- Identify how the changing workforce is affecting manufacturers;
- Identify the specific effects of automation inside manufacturing facilities;
- Determine factors that indicate when automation is necessary for companies to remain competitive;
- Determine how a company's available resources affect its ability to automate;
- Determine how to effectively implement automated systems.

3.1 Company Selection for Field Study

In order to complete our objectives, we collaborated with various companies in the Hangzhou region, making sure to include companies with various levels of automation to evaluate different perspectives of automation development. Below is the list of manufacturers we observed and conducted additional managerial interviews with and a brief description of their product, sector, size, and age.

- **Hangzhou Sanli Machinery Co. LTD (Sanli)** - Manufacturing of industrial refinery equipment for mining companies in the heavy machinery sector. Established in 2002, with 118 employees (see Appendix K&Q).

- **CoTEK Robotics (CoTEK)** - Design and produce robots for inventory management in the logistics automation industry. Recently established in 2017, with 34 employees (see Appendix L&R).
- **Amphenol JET (Amphenol)** - Production of copper shielding for consumer electronics in the electronics industry. JET was established in 2003, and acquired by Amphenol in 2013 with a staff of 750 employees (see Appendix J&P).
- **Hiye Electronics Co. (Hiye Electronics)** - Infrared remote controls manufacturing for TVs, air conditioners, lights, and other applications. Established in 1992, currently staffed with 500 employees (see Appendix N&T).
- **Allied-Machinery Co. (Allied-Machinery)** - Industrial compressor and hydraulic housing manufacturer, established in 2001, with over 875 current employees (see Appendix M&S).
- **Helen of Troy Health & Home (Helen of Troy) -** Interview only- Consumer healthcare and home comfort products. Established in 1968, works with 20+ manufacturers in China (see Appendix I)

The observation protocol used to evaluate companies is in Appendix O, and the accompanying interview protocol is in Appendix H. We created these protocols using background information and our interview with a manufacturing consultant in Appendix E. Special considerations for these protocols included taking note of what automation systems are in place, how they were implemented, problems with the company's systems, and how it acquired and retained employees. Figure 3.1 below shows the regional distribution of companies we visited, and their automation score based on industry 4.0 standards.

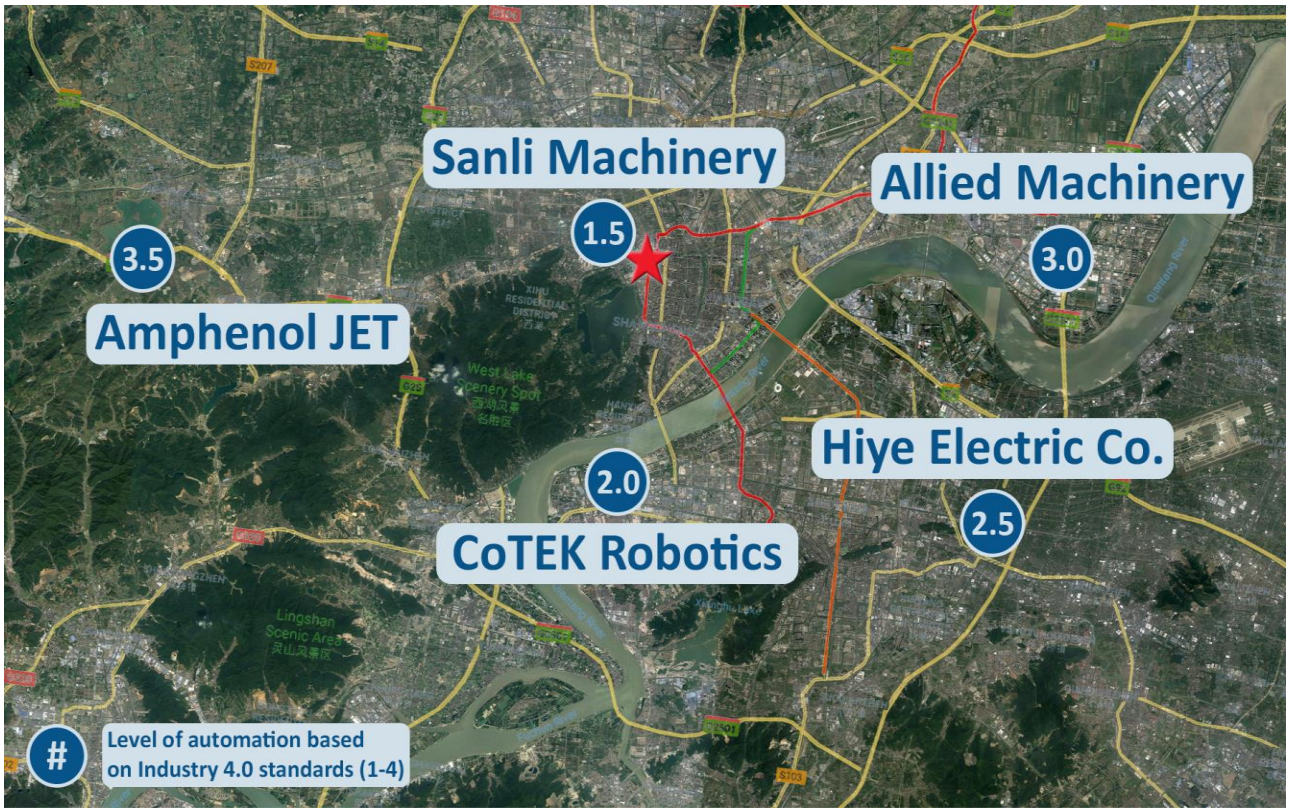

Figure 3.1 Hangzhou Company Map

3.2 Identify how the Workforce Affects Manufacturers

Our first objective was to identify how manufacturers view the current workforce and how changes in the workforce affect a company's decision to automate. We evaluated these effects from the manufacturing viewpoint and identified the future outlook of the workforce from the university perspective.

3.2.1 Manufacturers Views of Workers

In order to understand how the workforce affects manufacturers, we began by analyzing what companies look for when hiring a new employee. This gave us insight into what skills and qualifications were commonly needed to succeed in manufacturing and allowed us to evaluate how satisfied manufacturers were with the current workforce. To achieve this, we interviewed

managers at the six companies, detailed in section 3.1, to develop a better understanding of the current training for workers, the current skills that workers have and are lacking, and the education level requirements for different jobs. We were also interested in learning how manufacturers view the social and ethical consequences of increasing automation, so we inquired about their views on worker retention and worker replacement as manufacturers upgrade. These interviews were compiled and compared to generate an overview of how manufacturers view the current workforce and what they are looking for in the future. These companies did not allow us to distribute surveys for their workers, so all results were from the managerial perspective and did not consider individual workers opinions or self-evaluations.

3.2.2 Student Trends

Since a large part of automation success depends on having qualified workers to operate, program, and maintain these advanced machines, we evaluated student trends for schools in the Hangzhou area. Looking at student trends allowed us to see how the workforce may change in the coming years and determine if universities were preparing students properly for industry employment. We interviewed 3 professors of automation from schools in Hangzhou (see Appendices V-X) about their views on manufacturing and automation education. We identified trends such as student growth in the automation and manufacturing majors as well as student job placement after school and company involvement with the educational system. We also gathered surveys from first year students to determine why they are studying automation and gather their perception on the social and ethical challenges of replacing workers with automation.

3.3 Identify the Effects of Automation

Our next objective focused on understanding how automated systems affect productivity and logistics inside different manufacturing facilities. By identifying how automation can affect manufacturing metrics in different stages of production, we were able to understand why Chinese companies are working to increase manufacturing technology.

We observed 5 companies, in Appendix P-T and used the following guidelines to record their levels of automation for their facility. First, we looked specifically at how companies store inventory, as well as how automated their logistics system was. Logistics are the management of materials flow through an organization, from raw materials to finished goods with regards to a plant's organizational structure. This is especially important for high volume production because poor resource planning can cause slowdowns of production. Next, we looked at how efficiently space was being used by noting how much floor space was occupied by machines, workers, or storage. Wasted space can be a large expense because the overhead costs of factory upkeep are fixed while profits can be changed based on how much work gets done, so factories will lose money if they do not use their space effectively.

Lastly, we looked specifically at what automation equipment companies utilized, and how they implemented it in the production line. Specifically, we looked at the interaction of automation with workers as well as whether assistive or replacive systems were used. We also noted the flexibility of the manufacturing system to compare the adaptability of different automation equipment in varying applications.

3.4 Determine Indicators of Need for Increased Automation

For the third objective, our team focused efforts on determining the specific signals that manufacturing management would be looking for as indicators of a need for upgrading the level of automation in their current system. To accomplish this, we compiled the content from our interviews, observations, and surveys respectively, and identified consistent decision-making trends. We collected our data from plant managers, CEO's, our own observations, and professors who have applied industry experience. After identifying the common decision-making points, we compiled this data into a comprehensive set of steps in order to represent our information in an accessible manner.

One of the key points for our indicator evaluation was understanding the components that are relevant to the average customer. Demand drives supply, so studying customer's interests allowed us to understand how the consumer environment for manufacturing has been shifting, and in which directions. During each interview, we asked a range of questions regarding customer interest, primary goals, and general mindset. We analyzed this qualitative data to establish trends and obtain the most relevant factors to the average manufacturing customer.

For any company, money is always a driver and a limiter. We surveyed and interviewed companies to determine which factors a company takes into consideration for any upgrading decision, and how they utilize these indicators. Additionally, we used standardized interview protocols, so we could compile the consistent factors and compare and contrast the commonalities. Finally, our team conducted interviews regarding any additional non-standard factors or details which could contribute towards the upgrade process. We then considered this feedback in the perspective of a cost-benefit analysis to determine the major costs associated with upgrading a manufacturing process.

In addition to the financial scope, we considered the physical limitations of a facility. Our observational studies and interview questions gauged factors such as plant space, number of workers, number of machines, and other process specifics. By assembling a list of possible factors affecting plants across a range of similar sectors, we identified the standard physical limitations for manufacturers. We used these limitations to identify manufacturing processes that could benefit from automated development.

The fourth point of focus for our assessment was a company's interaction with external geo-political and societal factors. Not only has the Chinese government recently been active in creating relevant policies for manufacturing as described in section 2.3, but the workforce itself has also been shifting in availability. We identified both the political environment for manufacturers and the availability of workers for a plant and evaluated how these factors influence a company's manufacturing upgrade process. Additionally, using the same methods as with financial benefits, we determined the impact worker migration and labor shortages have had on each of the companies we studied. We then went on to list manager's efforts to retain employees, in order to add to our understanding of regional labor retention efforts.

3.5 Determine how resource availability affects a company's ability to automate

Because each company varies significantly from each other, there is no solution that universally solves the challenges of implementing automation. This objective identified how a company's available resources affect a manufacturer's ability to automate and how implementation strategies differ between companies. We considered resources such as money, labor, level of experience, and research capacity. To see how each of these aspects changed the

manufacturing approach, we first distributed a survey to manufacturers around the Zhejiang Province. We received survey responses from companies of different manufacturing sectors and determined initial correlations based off of these responses (see Appendix F). Using these correlations, we then compared this data to the field studies and interviews described in section 3.1 to gain an in depth look at individual manufacturing plants and how they were upgrading their manufacturing technology. The monetary and labor aspects were covered in detail in sections 3.1 and 3.4 respectively, but the more intangible aspects, such as experience level and research capacity, were addressed using more focused interview questions. To evaluate these effects, we looked into a company's familiarity with the China 2025 initiative and how it has automated in the past. Here we determined if the government initiative is a driving factor for companies to innovate and how previous experience impacts a company's decision to automate. We also determined how a company's knowledge about advanced manufacturing techniques affected its decision to automate by looking into the size of its research department and its decision to create its own automation equipment versus outsourcing to a more specialized company.

3.6 Determine how to Effectively Implement Automation

Our final objective was to determine how Chinese manufacturers can efficiently implement automation into their manufacturing process. In order to do this, we first studied the manufacturing process and observed how companies may have utilized automation in the workplace. In addition, we interviewed managers to determine where automated machinery is sourced from and what training programs are required for laborers to use and maintain the system.

To learn how companies used automation, we took a closer look at the company's manufacturing line. Direct observation allowed us to identify which processes in the manufacturing system were typically automated and determine the conditions that required such an upgrade. In addition, we were able to observe how laborers were utilized within the automated process and what obligations were required of them. From these observations, we were able to get insight into how a company decides to integrate automation in its company, and recognize the capabilities of an automated manufacturing line. We additionally conducted several interviews with industry managers at these same companies as detailed in Appendix H. Through these interviews, we were able to identify how companies determined which processes required further automation and the reasons why a company would consider automation. In addition, we were able to find out how workers were trained in these processes and how they received the resources for the automation process.

3.7 Summary

The information gathered through our interviews with company managers and direct observation of the manufacturing process was combined to form a summary of each company we were able to study. We then applied a series of metric-based comparisons in order to identify areas where the firms could potentially improve their process flow, and to identify general concerns in the manufacturing sector of Hangzhou. This next chapter will present the results of our study and how we analyzed these results to come up with recommendations on how to best improve Hangzhou's manufacturing sector.

Chapter 4: Results and Analysis

The goal of this project was to create a comprehensive guide for manufacturing companies in the Zhejiang Province addressing why they should adopt automation technology and how to do so. Our objectives were to identify how the changing workforce affects automation development, establish the effects automation has on a manufacturing line, determine the conditions that indicate when automation is needed, determine the conditions driving automation, determine how to physically automate the appropriate manufacturing processes, and identify the barriers to any such transition.

4.1 How the Workforce Affects Automation Development

Workforce environment and education are key aspects to consider when evaluating a manufacturing environment. Understanding the supply of labor, the education levels of the workforce, and the ethics of automating production were important components of our evaluation of the current status of manufacturing. This section analyzes how workforce changes are pressuring manufacturers and addresses the ethical concerns of replacing workers with robots.

4.1.1 Lack of less educated Labor is Pressuring Manufacturers to Automate

Past research indicated that finding qualified employees is a major challenge when upgrading manufacturing technology (Qiang & Zhigang, 2016). However, based on our interviews and field studies described in section 3.1, we discovered that manufacturers are having more difficulty finding less educated laborers than workers with advanced degrees in technology. The Amphenol manager, Jeeping Gao, highlighted the changing education system in China and the current availability of workers. While 5-10 years ago there was a shortage of

educated employees, in recent years it has become much easier to find employees with an advanced degree than less educated laborers (see Appendix J). Gerrit Dewitt, echoed this belief stating that, for the Chinese manufacturers he works with, it is easier to hire the 50 mechanical, electrical and computer engineers needed to develop and use an automated system than to hire the necessary number of less educated laborers to produce the equivalent output (see Appendix I). The CEO of Hiye Electronics goes as far as physically working on the manufacturing line himself to help meet the product demand because he could not find workers to fill the available positions on his assembly line (see Appendix T). All of the managers that we interviewed had experienced this shortage of less educated labor and are working to address this issue. Some companies such as Sanli are upgrading its current machinery and training existing workers to get more output for the same wages and Amphenol is increasing its use of automated systems to limit the number of new workers they need to hire (see Appendix J, Q). Other companies, such as the manufacturers that work for Helen of Troy, physically relocate its factories to areas with more workers to avoid the labor shortage in the cities (see Appendix I). Despite these adjustments, all of these companies have experienced an increase in labor cost over the past few years and are feeling the pressure to change their manufacturing practices to remain competitive. Whereas previously they had been able to lower wages because of the abundance of workers, these companies now avoid lowering wages for fear of losing its current employees and often pay workers more or increase working conditions to help retain employees (see Appendix T, J). Because of this decreasing supply of less educated labor and the corresponding wage increases (see Section 2.2.4), automation is becoming a more attractive option for many manufacturers.

4.1.2 Automation is Not Replacing Jobs

Automated systems are often evaluated by the number of employees they can replace, a linkage that spawns ethical concern about the prospective replacement of human jobs with machines and potential increases in unemployment. However, our research showed that these automated systems are filling gaps that human resources were unable to fill. Rather than replacing workers, companies use automated systems to upgrade their manufacturing capacity and reallocate and retrain workers to utilize their skills more effectively. Companies generally avoid letting people go due to the current shortage of workers.

With the less educated labor shortage, the companies we interviewed are doing everything it can to retain current workers, as finding replacements can be a long and expensive process (see Appendix I). In such a competitive labor market, workers will switch jobs for very small wage or quality of life increases so companies are increasingly placing more emphasis on worker satisfaction and training specific to their company. For example, Hiye Electronic acquires workers from nearby factories by advertising how the working conditions in an electronics factory are much better than a textile factory. Alternatively, Amphenol JET has a variety of specialized training courses to keep workers engaged (see Appendix N, J). Because of the limited labor market, companies that take care of its workers through training programs and worker feedback systems are the most successful. By offering quality of life improvements, these companies can mitigate the increasing wages since many workers are willing to sacrifice some wages for better working conditions. We discuss the specifics of how companies train these workers and what feedback systems exist in section 4.5.3. Even with these quality of life improvements, these companies must keep its wages competitive to retain enough workers and are thus experiencing the same labor cost increases as other Hangzhou manufacturers.

4.1.3 Number of Educated Workers is Rising

As the less educated labor force shrinks and companies use more advanced systems, the demand for educated labor increases. Since companies are unable to fill the low-skill less educated positions, they are instead looking to upgrade their technology level and hire educated workers who are qualified to manage such systems. The question about the driving force for workforce or industry changes thus arises: is the increasing use of automation causing the workforce to shift towards higher educated jobs, or is the shifting workforce causing more companies to use automation? While the two sides are intimately connected, our research shows that the workforce is the initial catalyst for automation development. Companies are having difficulty finding workers willing to do the low-wage manufacturing jobs and are thus switching to more advanced systems. This is supported by the background research that shows wages in manufacturing are increasing, as well as the fact that the Chinese middle class is growing in cities such as Hangzhou (section 2.2.2). These new middle-class citizens decreasingly want to work in these low-paying manufacturing jobs because they can now afford to educate themselves. From a survey of 37 first and second year automation students, the majority of them cited money or passion as one of their primary motivators for studying automation and thus would not be satisfied working in the low-paying and low-skilled jobs manufacturers previously offered (see Appendix C). These same students supported further automation development, with 77% of students holding the opinion that robots should be used to replace workers. While we expected such a result from automation students, this confirms that for our small sample, the future workforce will increasingly support using automated processes as the current workforce dwindles.

As the middle-class population rises, the number of educated workers is also rising as these citizens pursue education in technological fields. The three technology professors we interviewed at Chinese universities agreed that over the past few years there has been a marked increase in students majoring in a manufacturing related field (see Appendices V, X). With the government's push to increase automation development, schools are increasing the size of their automation departments and thus increasing the quantity of educated workers ready to improve manufacturing technology.

While the small amount of data we collected does not indicate the trends for all of Hangzhou, the overall trends of increasing wages, middle class population, and education could be explanations for why there is a shortage of less educated labor as discussed in section 2.2. The new generations of students whom we surveyed also rated money and passion as their driving forces for their jobs (see Appendix C). Both these characteristics support their displeasure in doing low-skilled, low-wage labor jobs. This is also supported with an interview with the manager at Sanli Machinery who tried to hire recent college graduates to work low-education positions and saw that they would often quit within a few months. Now, Sanli hires only workers with 10 or more years of experience in its sector of manufacturing to avoid losing workers (see Appendix K). This limited supply of less educated laborers, as well as a shifting migratory worker base described further in section 4.3.3, is causing more manufacturers to consider automation as a solution to their labor needs.

Although there is an increasing number of students going to college, there is a gap between what skills are being taught and what companies are looking for in new workers. Most companies have very little collaboration with universities, which was reflected in both interviews with companies and interviews with professors. The only interactions students have with

companies is at yearly job fairs. This lack of interaction creates a gap between student's education and real-world practice. In our interview with Allied Machinery, although it did not have any problems finding college graduates, Allied found that students did not have the skills or practice to begin working immediately. Instead, students needed lengthy additional training before they could begin work. Companies wanted Universities to incorporate applied teaching methods in the classroom to bridge the gap between theory and practice, and to properly prepare students for jobs after university.

4.2 Effects of Automation

Before analyzing if and how a company should automate its manufacturing processes, we determined the broader effects of implementing automation in manufacturing plants. Companies must consider the benefits and downsides of implementing an automated system, and understanding the strengths and weaknesses of automated systems allows companies to implement machines where necessary. This section identifies how automated systems can reduce the time and space requirements to produce new parts, how high-tech systems can reduce lead-time and overhead costs of logistics, but also how specialized machines can reduce the flexibility of a manufacturing assembly line.

4.2.1 Effective Use of Time and Space

A large effect of properly implemented automation is the increase in overall plant efficiency, including efficient use of space, workers, and time. An example of how automation can have such a positive effect is seen in a comparison between Sanli Machinery Co. and Allied-Machinery. A drilling process at Sanli Machinery was completed by a worker manually drilling different sized holes using two separate drill-presses. This required the worker to pick up and

move the heavy block he was drilling and transfer it between drills over 8 times per part. Conversely, the same process could be automated using CNCs (Computer Numerical Control machines) that Allied-Machinery uses for similar operations in a single setup. This setup both reduces the time it takes to drill many holes and increases the precision of the final product. With the manual machining used by Sanli, not only is the worker spending time moving the part between each operation, a lot of space is needed to contain two drill-presses. Another case in which automation increased efficiency was at CoTEK Robotics, where a single automated O-ring installation system could do the work of ten or more workers. The new system used the same space as a single worker, but with the efficiency of ten workers. This greatly reduced the space used and decreased the long-term costs of worker salaries. Companies striving to maximize efficiency in these areas should replace processes requiring medium to large sized labor forces to reduce long term costs.

4.2.2 Logistics Improvements

Automation can also improve inventory management and logistics, both of which have a high level of impact on plant operation. Quality of inventory management directly effects a company's lead time, the delay between placing and order and its delivery, which is extremely important for suppliers. Sanli Machinery Co. used no computers or automation equipment, only workers, to maintain and organize its inventory of replacement parts, tooling, and materials. This resulted in a disorganized shop where old parts are mixed with current inventory and space is not utilized well, creating a hazardous working environment. Figure 4.1 below shows a section of

Sanli Machinery's shop floor where inventory was piling up next to machines, because the factory did not have a designated inventory location.

Figure 4.1 - Sanli Machinery Co. Shop Floor (photo by Steven Viola, 2017)

This can be compared to CoTEK Robotics, which has automated inventory robots that enable same-day delivery of items in stock. CoTEK's systems can track and store thousands of items and autonomously retrieve them not only decreasing space used, but also improving production planning by sharing inventory status with other machines.

4.2.3 Less Flexibility

The effectiveness of an automated system depends greatly on the volume and customizability of the product. For high volumes of the same part, automation excels at producing goods quickly and efficiently but for customized product the setup time for an automated system can be cost prohibitive. For example, Amphenol JET has many large contracts for production of millions of identical parts, which makes automation a necessity to meet customer demand. For this application, the high volume, longevity, and consistency of the

contract made the automated solution much more affordable. This contrasts with what we observed at CoTEK Robotics where robots are constructed with almost no automation. The nature of CoTEK's business has resulted in small orders of customized robots, where automation equipment would take much longer to setup because each order would require specialized changes. In order to decrease product lead-time, its workers hand-make custom solutions for each robot rather than investing the time to develop automated machinery. Therefore, automation may not be the best solution for work processes requiring significant customization. However, for large volume production it is extremely beneficial to use automation.

In summary, automation solutions are most effective when companies apply them to large volume output and fixed design products, with short lead-time requirements that previously relied on many workers. In the following sections, we explore other advantages and disadvantages of automation.

4.3 When is Automation Necessary?

Once the benefits of automation in manufacturing have been made clear, it is important to highlight the specific criteria that determine the ideal point at which to transition a company. Based on interviews with plant managers and company executives, our team identified five foci used to evaluate the automation potential of a production line. While every manufacturing decision by management takes buyer-specific and product-specific considerations into account, these five factors guided them: customer demand, floor space, market environments, shifting workforce, and cost-benefit-analysis.

4.3.1 Customer Demand

Meeting customer requirements is the first consideration in any contract and it is generally the primary driver for manufacturing process change (see Appendix J). With every order placed, customers specify their criteria for the requested product. When the current plant equipment is not capable of satisfying the product requirements, the production team will have to evaluate the potential for a process change. Whether the concern is product volume, quality tolerances or long-term demand, the first priority of any company will be to fulfill its customer's needs. For example, if a plant's current workforce is not able to produce the required level of quality, a company could outsource, hire specialists, or automate with more precise machinery.

4.3.2 Floor Space

Cost and timeline aside, one of the most tangible limitations in manufacturing is sheer plant capacity. There is a limit to how much manufacturing technology can fit in any given location, or how many workers can function in close proximity. Floor space defines the maximum number of machines or employees possible without expanding to another location. In many cases an automated system will output the equivalent of several workers, enabling much greater volumes of production per area of floor space (see Appendix L). CoTEK Robotics was able to replace 10 workers with a robot that occupied the space of a single person's workstation, showing the increased effectiveness of an automated system.

4.3.3 Shifting Workforce

As Chinese society changes, the demographic characteristics of the available workforce also shift in varying regions of the country (see Appendix I). As mentioned in section 4.1, more of the urban workforce is turning to higher paying, high-tech oriented jobs, causing a dearth of less educated laborers that are necessary for the manufacturing processes. As new industries

emerge, and wages increase, it can often be difficult for companies to find enough less educated workers with the right kind of skills (see Appendix I-N). Workers are becoming more educated and rural farmers are no longer travelling to cities to work in manufacturing (see Appendix I). This is causing the wages to increase as fewer workers are available. As mentioned in section 2.2.4, some production facilities have relocated to rural areas to ensure that there was the necessary labor to meet production needs. As a result, urban companies are offering increasingly higher wages, which drastically cut company profits. For companies that are based in cities such as Hangzhou and do not have the resources to establish rural plants, it can be much more profitable to explore automation options as a way to operate with fewer less educated workers and provide jobs for high-tech engineers. While the initial cost of automation may be fairly high, the cost of hiring rural workers that migrate to cities can be much more expensive over time, especially as labor wages continue to increase.

4.3.4 Cost-Benefit-Analysis

Whenever it is cheaper to use an automated system than it is to hire more workers, a plant manager will likely choose automation. Because meeting customer demand is so crucial, once a manufacturer is offered a contract the plant's management team will immediately complete a cost-benefit analysis for all of their potential options (see Appendix J). If its current facilities cannot immediately meet demand, the company will evaluate the long-term cost of hiring additional full-time workers or leasing more production space in order to meet contract requirements. For many of the companies in Hangzhou that we interviewed, the decision to automate comes when the size of the contract or the requested product specifications warrants investing in higher levels of automation. Once a company understands the investment needed to meet customer demands, it can price its manufacturing services accordingly.

4.4 How Available Resources Affect Automation Implementation

We identified two main resources that play a key role in enabling a company's automation development. The availability of automation equipment and a company's knowledge about government support influenced how a company should go about implementing automated systems. The political environment created by China's "Made in China 2025" encourages industry 4.0 upgrades, and the specific financing incentives can be the difference between a successful implementation and a failed one. In combination with this, a company's access to high-quality automation resources is just as important as the base need for an ability to afford upgrades.

4.4.1 Manufacturing Familiarity with China 2025 Initiative

The China 2025 initiative tries to support small and medium enterprises as well as large enterprises through funding and innovation programs (section 2.3), but the lack of publicity and communication with manufacturers is limiting the effectiveness of the policy. The initiative offers many benefits to companies trying to upgrade their manufacturing technology, but many low-tech companies are unaware of how the government can help them advance. Low-tech companies such as Hangzhou Sanli Manufacturing Co. were not familiar with the advantages offered by the government and missed the opportunity to subsidize its technology advancement (see Appendix K). While the government initiative was not the reason these companies decided to upgrade their manufacturing line, looking at the initiative and seeing if they qualified for any support could have accelerated their transition processes. Gerrit Dewitt made the point that for some cases the Made in China 2025 initiative is hurting manufacturers (see Appendix I). Low skill and high-volume manufacturing was previously heavily subsidized to increase competitiveness, but with the new initiative, many companies lost their monetary support to

companies producing high-tech goods. These low-tech manufacturers are now struggling to meet customer demands and adapt to the changing market. This loss of support however should encourage them to begin using more advanced techniques. Conversely, high-tech companies with research and development dedicated to industry 4.0 are taking advantage of the incentives and subsidies offered by the China 2025 initiative to become increasingly competitive and push its technology levels even higher (see Appendix L).

4.4.2 Custom and Off-the-Shelf Solutions

While many manufacturers are successfully upgrading to smart manufacturing, the sourcing of automation equipment is still challenges that prevents a smooth and expedient upgrade process. Manufacturers consistently face the choice between custom and off-the-shelf solutions when selecting automation equipment. Off-the-shelf solutions are either hyper-focused and create a specific product very well or take a more general approach and can create a variety of parts but sacrifice precision and efficiency for the individual parts (see Appendix I). These solutions are usually the quickest and easiest way to upgrade a manufacturing line, but their success depends on the company's implementation. Companies that depend on these types of solutions also can be limited in what processes can be automated based on available technology. Companies generally select these solutions if it is a smaller company that does not have the capacity to develop custom solutions themselves or for smaller, shorter term products. Custom solutions on the other hand, can be designed to exact specifications but often take more time, money, and a dedicated research department to implement. Companies without research departments for automated equipment can instead spend more money to hire an outside contractor to develop the machines. With custom solutions, companies can create machines that meet a company's exact specifications, and, if designed correctly, also have the flexibility for

future upgrades. Amphenol, in particular, requires all custom machines to meet a minimum level of flexibility so it can easily change product requirements in the future (see Appendix J).

Where both of these solutions struggle, however, is with software development. Both off-the-shelf solutions and custom machines that have flexibility often require custom software to function correctly. The software development is one of the most time-consuming parts and can get very expensive for companies that need to hire outside contractors to create and maintain their software (see Appendix J). During this time, the machine is offline, and it often takes many iterations and failed part cycles to get a system working properly. Until a widely scalable and flexible system is developed, this challenge will continue to slow down manufacturing technology development.

4.4.3 Manufacturing Software Solutions

Advanced manufacturing software allows more competitive operating methods and is a core component of industry 4.0. By having interconnected systems, machines can automatically update their operating procedures to reach peak efficiency according to customer demands. During our interviews, some manufacturers had implemented plant resource planning software on a minor scale, but we found no exposure to more specialized analytics software or interconnected machinery.

Enterprise resource planning (ERP) software has been the international standard in plant management for several years. ERP software provides status information on all aspects of a production plant and can adapt to changing product requirements. Some companies are starting to implement this software as a replacement for manual forecasting, but implementing such complex software can be both difficult and costly (see Appendix M). For the companies we interviewed that had implemented some levels of automation, such as Amphenol, ERP software

can make automation planning and cost-benefit analysis more accurate and quicker to implement.

Special-purpose analytics software has become increasingly more prevalent in the manufacturing industry as companies transition from their growth stages into optimization stage. According to our interview with a manufacturing specialist consultant, these specialized programs have the ability to gauge tool wear, optimize production tooling methods, and predict production schedules. As such, ERPs are currently one of the most significant competitive components in manufacturing and are necessary for companies to achieve industry 4.0. Despite this, Allied Machinery was the only company we interviewed that had basic knowledge of this type of software, but it had not implemented ERPs into its factory because of the complexity and associated cost (see Appendix M).

4.5 Determining How to Implement Automation Effectively

The process of incorporating automation in an industry can be difficult and relies on several different factors. These factors depend on the status of an industry's manufacturing process, and can be different for each industry. In addition, the degree to which an industry will automate depends on the particular industry's need for automation and the resources necessary for such a move. This section details the factors that companies must consider to use automation effectively.

4.5.1 Selecting Automated Processes

When implementing automation, a company must first determine which processes would be best to automate. For many industries, processes that are dangerous, repetitive, or precise are indicators of potential areas that would benefit from automation. Companies such as Allied

Machinery use automation to transfer and machine heavy products using conveyer lines between large CNC machines on the manufacturing line (see Appendix S). This reduces human error using heavy transportation machinery and streamlines the manufacturing process by greatly reducing time for part setup, tooling changes, and transportation.

Amphenol JET utilizes computer vision systems for repetitive quality control tasks to check products for imperfections. In this case, the use of computer assistance allows the system to evaluate each product reliably without slowing down production. In addition, by automating quality control, the company does not need to spend resources on human laborers to do these tasks, as they are significantly slower and more error-prone (see Appendix J). Such a slow, human-based process was seen at Sanli Machinery, where workers individually checked random samplings of manufactured parts for errors using hand calipers and micrometers (see Appendix Q). Allied-Machinery, which produces similarly large metal parts with high quality standards, uses large probing machines to automatically check dimensions rather than by hand (see Appendix S). According to Jeeping Gao of Amphenol JET, it is more common for industries to automate quality control routines as a result of customer demand. This statement was also supported by Sanli Machinery that stated that the main reason that its company was upgrading, was due to the increase in demand for higher quality products. By not using automated or computer assisted processes, companies are forced to analyze each part manually, or, in the case of high production parts, a periodic random sampling of products, resulting in less quality confidence and slower production times. If quality is a highly influential factor for customers, manufacturers should adopt automated quality inspection systems.

As an international manufacturer, Amphenol JET serves a large variety of customers with a range of different products. With so many products, automation is necessary to keep up with

the demand. However, automating a product line can prove to be a costly and complicated investment. To determine whether to automate or hire more workers, Amphenol JET relied almost exclusively on the cost-benefit analysis of using workers versus automation (see Appendix J). For instance, Amphenol JET received a contract for mass production of an Apple product and needed to either hire 250 employees and associated managers, or purchase 7 automated machines and hire 30 workers. Depending on the requirements of the contract, it may be cheaper and easier to hire more laborers to work on a short-term or specialized project than to set up an entire automated system. By using a cost-benefit analysis, companies can choose what processes would benefit most from automation, and a company can determine the scale of automation to implement. In the previous example, Amphenol JET decided to utilize the mix of human and automated labor to complete the contract instead of relying on a completely manual or completely automated manufacturing line. For other cases, the use of more workers may be more beneficial due to the added flexibility. This helped to mitigate the initial cost of the manufacturing line and reduced the labor cost over time. In this way, the combination of both manual and automated manufacturing can be used to reduce overall costs.

4.5.2 Worker Training

For many manufacturing industries, automated manufacturing is a relatively new concept. Because of this, workers who are proficient with automated machinery are in high demand, and with increasing labor costs, industries are doing what they can to keep trained workers. High-tech industries such as Amphenol JET offer extensive training to its workers, including machine operation, automated system management, and workplace safety (see Appendix J). Growing companies tend to turn to third party automation contractors, who offer training sessions for their customers. Other, more low-tech companies, may offer training to its

workers, but only teach them the specific skills they will need at that company. Companies do this so workers are more likely to stay at their current company since they have fewer skill sets to offer other companies (see Appendix I).

Another way companies are retaining workers is though worker feedback programs. These programs allow workers to provide managers with feedback regarding possible changes in the manufacturing process and help to increase worker satisfaction. High-tech companies like Amphenol JET and Allied Machinery had sophisticated worker feedback programs, while more traditional companies such as Sanli Machinery did not have any apparent feedback system (see Appendices J, M, K). For example, Amphenol JET utilized yearly "360 degree" feedback mechanisms where workers and managers would work together and go through each part of the manufacturing process to ensure that the workers had no issues with the process (see Appendix J). Programs such as these are highly beneficial and encourage communication with all levels of the manufacturing line, leading to increased worker satisfaction and loyalty.

4.6 Summarized Guide to Automation

Based on the above results, our team created a concise guide for companies to reference when deciding whether automation is an effective strategy to increase their manufacturing capacity. This guide, illustrated in figures 4.2 and 4.3, presents the main methods that companies have successfully used to automate their production lines in the past. This guide is meant to serve as a starting point for companies considering automation.

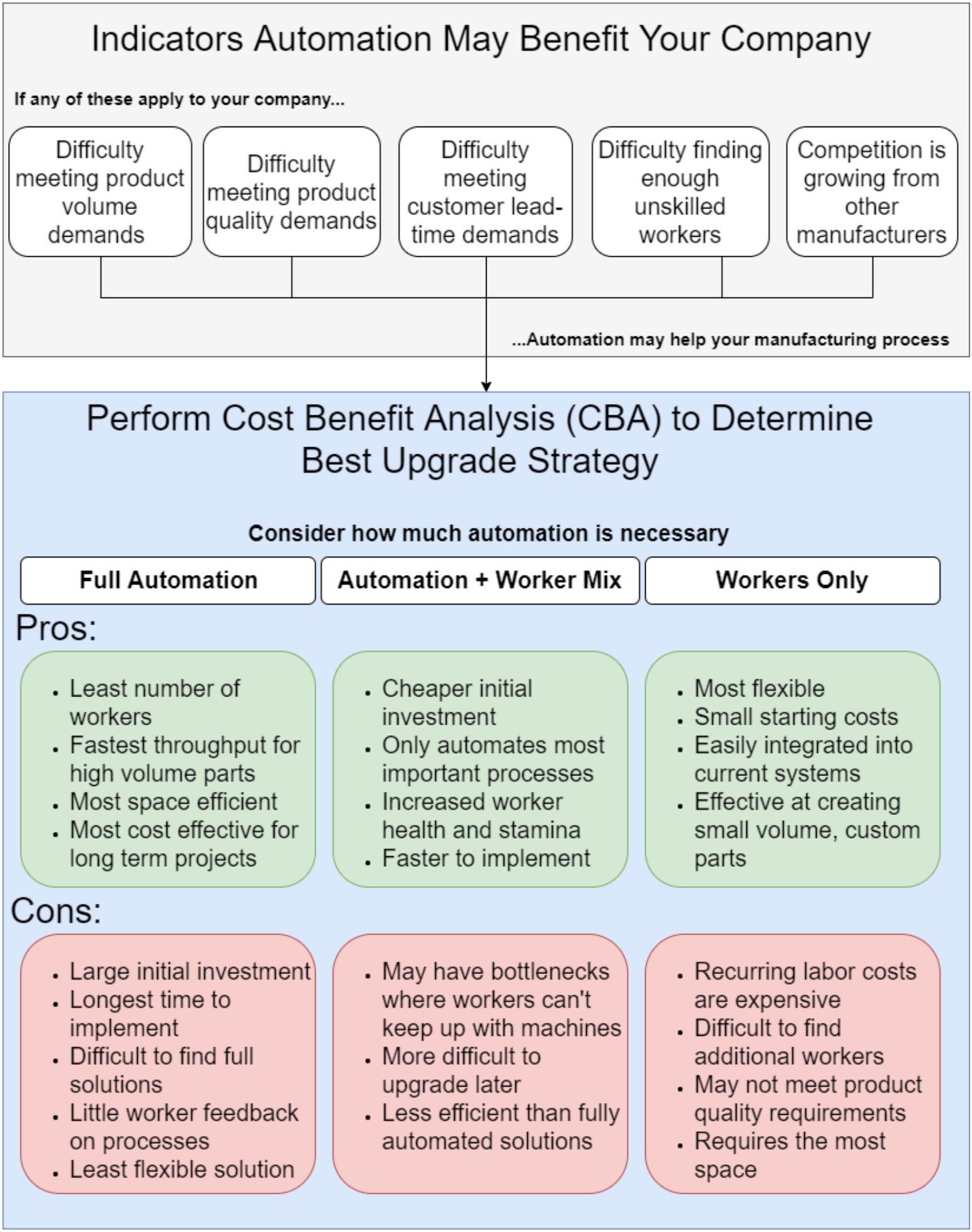

Figure 4.2 Manufacturer's Guide to Automation

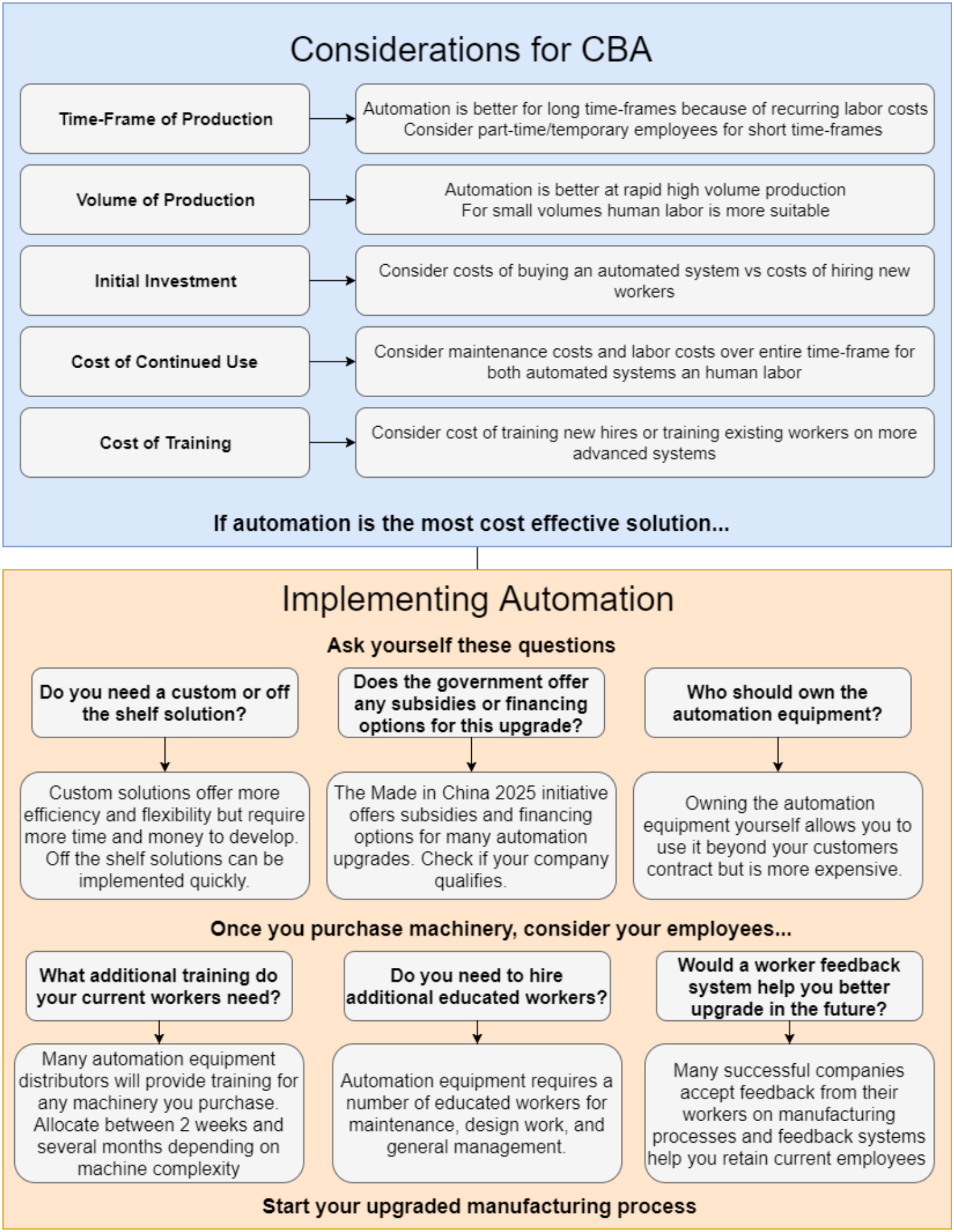

Figure 4.3 Manufacturer's Guide to Automation Continued

This guide represents the commonalities of companies that we interviewed, broken down into the order most feasible to implement practically. Because we focused on a relatively narrow manufacturing sector, we were able to explore the details specific to each of these steps. As with many new developments, if a company or manager has not had significant exposure to automation, the prerequisite knowledge can be an additional barrier to technological development. By outlining the framework of robotic upgrades, our team hopes to provide the foundation for a general understanding of the process.

4.6.1 Guide Usage Examples

This section discusses how a company can use this guide to implement automation in its factory by evaluating how Sanli Machinery could continue its upgrade process. This guide did not exist when Sanli Machinery decided to upgrade, so the answers provided are simulated responses and do not exactly represent the steps Sanli Machinery is following to improve its manufacturing ability.

For this example, we will analyze how Sanli Machinery is currently upgrading its factory and identify how this guide applies to its existing upgrade process. Sanli Machinery initially realized its manufacturing line was insufficient due to increasing quality demands from its consumers. The company's human workers did not have the precision or technical ability to manufacture parts according to the new product standards. This combined with the increasing market pressure from other mining equipment companies and the difficulty in finding experienced, manual machinists meant

that Sanli satisfied 3 out of the 5 main indicators we have identified and could almost certainly benefit from an upgraded manufacturing line.

Having decided that automation may solve its existing manufacturing challenges, Sanli can move onto the next stage where it evaluates how much automation is necessary and perform a cost benefit analysis for each scenario. Because of the new product requirements from Sanli's customers, it can already eliminate the option of only adding additional human workers. The quality standards that customers demand are not achievable by human labor, so Sanli can disregard this option. For other companies using more workers may be a better solution than automated equipment, especially for short-term production cycles. Since Sanli is a relatively small factory with no existing automated systems, upgrading to complete automation would require an entire factory overhaul, and the initial investment would be too high. For companies that already have significant automation or an abundance of money to initially invest, this may be a more feasible option. Companies with existing automated systems can also consider additional software solutions to reach the industry 4.0 standard. Because of these restraints and the added difficulty of hiring new workers, Sanli decided to keep its existing labor force and upgrade only the processes that need the additional precision. This limited its output volume and overall quality, but the cost of implementing additional automation outweighed the benefits. The limited volume and extended lead-time of its products meant that Sanli did not have to worry about bottlenecks where human beings could not keep up with the new machine's speed.

After deciding to upgrade certain machines, Sanli had to decide where to source automation equipment. This was an easy decision for the small firm because it had no in-house research and development for automated machines, so it had to outsource to a specialized contractor. Additionally, the machinery it needed had already been developed so an off-the-shelf solution would work. Companies with research capacity who need innovative solutions would need to consider the cost of producing automated equipment in house versus outsourcing more carefully.

With the sourcing of automation equipment solved, Sanli should have evaluated the China 2025 initiatives funding options. Sanli, unfortunately, was not aware of the China 2025 initiative, so it may have missed financing options, but it had enough capital available to complete the upgrade without government support. After evaluating available systems, it selected a company that would provide the machinery as well as associated training for its existing workers and bought several CNC mills and lathes.

Finally, after acquiring the machinery, Sanli looked at how its current workers would interact with the new system. Because the sourcing company provided training for these machines, Sanli easily transitioned its workforce to use advanced machines. The company allocated two weeks for the actual training process and an additional month to allow the workers to become accustomed to the machines and work out any errors before they resumed production. Sanli however, decided not to implement a worker feedback system, as it did not believe its workers were qualified to make recommendations, and it instead had management make any future upgrade decisions.

This example serves to show how a company can step through this guide to evaluate how automation could affect its manufacturing line. This was only a brief summary and does not include many details about the cost-benefit analysis as the specifics are company dependent. Using this guide, however, will allow manufacturers to ask themselves the correct types of questions and can reduce the barrier to entry for automated development.

4.7 Challenges and Limitations

Over the duration of this project, our team encountered a variety of challenges while collecting data. Obtaining information from a particular industry was fairly straightforward, but the process of finding companies that were willing to provide us with information was more difficult. The combination of distrust of foreign researchers and the lack of email response made it hard for our team to reach out to a large volume of manufacturers. For instance, when our team sent a survey to manufacturing industries asking about their current automation capabilities and trends, we received 16 responses out of more than 200 views, preventing us from drawing strong correlations from survey results.

Another challenge our team faced was the inability to survey the laborers who were working in the automated manufacturing line. Initially, our team intended to survey laborers about their thoughts on automation and how prepared they believed their industry was for the integration of manufacturing. However, none of the companies observed allowed us to distribute the survey, asserting that the majority of their laborers had no knowledge of automation. As a result, our team was not able to include the analysis of worker perceptions in our report.

It is worth noting that our report has certain limitations and does not necessarily apply to all manufacturers. This report sets up a series of evaluation guidelines that can be applied to Chinese manufacturers of any technology level and serves as an aid for further research in Chinese technological development, but it is not a comprehensive analysis of all industries in China or other countries. Additionally, since North-American firms own Amphenol and Helen of, there is the possibility for a bias towards North-American operational standards.

Given that we only had 6 weeks to collect data, we focused on a small number of manufacturers from metal and electronics manufacturing inside the Hangzhou area, as they aligned closely with the Made in China 2025 initiative and our sponsor's interests. Any examples outside of this region or the sectors specified in our report are likely to have similarities, but cannot be assumed to be representative of what our team was able to study. Additionally, interviews and companies for our study were selected by convenience so our results within the metal and electronics sector near Hangzhou may not be representative of the true population.

As acknowledged in section 4.3.3, the use of migrant workers is more prevalent to companies that have rural operational plants. As such, many of the issues regarding shortages in less educated labor are not as pertinent to these factories. Because our results came from Hangzhou, an urban environment who is leading the development of technology, these results may not be indicative of the state of automation in rural operational plants. Additionally, the high concentration of universities in Hangzhou may skew the workforce distribution and not apply to other regions of the country.

Chapter 5: Conclusion and Recommendations

Our study has provided an analysis of sectors impacted by the Made in China 2025 goals, focused specifically on industrial manufacturing inside of Hangzhou. In this chapter, we provide our conclusions and recommendations for our sponsor, future researchers, and the electrical, metal, and high-tech manufacturing industries in the Hangzhou area.

By analyzing how the workforce affects individual manufacturers, we discovered that a lack of appropriately skilled workers is pushing companies to adopt more automated processes to keep up with production. We recommend that all companies evaluate if automation may benefit their production process. Whereas previous studies have shown that a lack of properly educated labor limits technological development, interviews with company managers showed that the lack of appropriately skilled labor is limiting the growth of manufacturers. In addition to this shortage of labor, increasing consumer demand is pressuring companies to automate their production lines.

For manufacturing managers and executives who are interested in understanding the process of upgrading a production line into an automated system, we recommend referencing the guide that our team has formulated in this report. Across all of our interviews, process complexity has been the most significant impediment to automation. Production processes with a considerable level of flexibility or complexity are prohibitively difficult for automated machines, and such processes are best left human-operated. This lack of flexibility must be analyzed before implementation, as it may reduce a plant's ability to transition from one product to another if automation is improperly implemented.

We recommend inventory automation as the best form of automation for companies with large volumes of output, and also for those with a large e-commerce presence. Quality control

(QC) automation is another type of process we recommend upgrading because automated QC can increase the level of quality of output without affecting production volumes. Both of these common forms of automation, in addition to case-by-case solutions, are represented in the data collection used to formulate the guide presented in section 4.6, as well as the environment-specific information that we have reviewed previously.

Based on our assessment of the respective levels of technology in the companies that we work with, one of the most significantly lacking components of the industry 4.0 framework in China is interconnected "smart" software. Analytical software that provides data on important fabrication aspects (such as tool wear) was unheard of for the companies we evaluated. Because this software implementation is so scarce, it is difficult for companies to find out more information about its benefits, let alone attempt to implement it themselves. Further software development from an outside source would greatly benefit these companies as they automate more processes.

For our sponsor, Greentech Investments, we recommend investing in the fields of scalable robotics technology, manufacturing analytics software, and smart-manufacturing software. Manufacturers with little-to-no automation are looking for contractors with a wide range of experience implementing flexible solutions to provide them with automated systems. This does not, however, apply to highly-automated manufacturers as they already have the in-house capabilities for designing and upgrading robotic processes. This field of contract-based automation appears to be the most commonly used process to transition from fully manual labor into small-scale or limited automation.

We recommend that future researchers consider how automation will affect industries outside of the metal and electronics sectors and expand our research outside of the Hangzhou

area in order to address the limitations discussed in section 4.7. By analyzing additional areas, researchers could compare how each industry responds to the changing market and workforce to create a comprehensive automation guide usable by all manufacturers.

Because the companies we interviewed had not implemented the software component of industry 4.0, there may be additional challenges to manufacturing development that we were unable to explore. A more thorough analysis, including the most advanced companies, could provide greater depth to the guide we developed and provide additional analysis to the trends we have seen so far. Additionally, we recommend studying the effects of automation in less developed areas. Due to Hangzhou's size and technological advancement, it is likely that other more rural areas will respond differently to automation development and experience different manufacturing issues.

The final recommendation we have for future research is to further evaluate the social and ethical aspects of implementing automation. While the ethical issues of replacing workers with automation do not initially seem to be a problem in Hangzhou due to the shifting workforce, all of our results came from people in managerial positions at a company or from well-educated students and professors. To better understand the full picture of automation development, we recommend that researchers gather the workers' perceptions of automation and see how it differs from the company owners' and managers' perspectives. This analysis may reveal additional issues that were not visible when viewed from the managers' perspectives.

Chinese manufacturers have great potential for automation, but without assistance from continued research, investment in new technology, and the further development of automation, China's companies will not be able to remain at the top of the world's manufacturers. As manufacturing technology improves around the world, it will be increasingly important for

China's manufacturers to focus on its own technological development and work towards developing innovative solutions to the challenges they face.

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Appendices:

Appendix A – Greentech Investments Mission and Goals

Greentech Investments Limited is a private New Zealand based international venture capital group founded in 1998 that is dedicated to the introduction of advanced environmental technology and industrialization overseas (F. Xia, personal communication, Oct. 28, 2017). Greentech Investments is especially interested in introducing industry 4.0 technology and green electric vehicles to companies in the Zhejiang province in China as part of the China 2025 initiative striving to develop more technology for internalization of manufacturing. Greentech is also working on establishing international relationships with a focus on electric vehicle research and development.

Greentech Investments has offices in Ningbo and Hangzhou, China, with 10 and 30 employees respectively (F. Xia, personal communication, Oct. 28, 2017). Greentech focuses on innovation in the Hangzhou area, which is one of the most rapidly developing areas in China's tech-centric market. China was second only to the United States in venture capital funding last year, putting Greentech Investments in a very quickly emerging market (Schuman, 2016).

Appendix B – Manufacturing Student Survey

[Adapted from online Chinese survey]

Participation in this questionnaire is voluntary, you can skip any questions. Your individual responses will not be made public as this survey is anonymous. Overall results will be published as part of our degree requirement.

What class year are you?

(circle one) 1 2 3 4

What are you studying?

Why did you choose this major? (Rank from highest to lowest)

1. Money
2. Family/Friends
3. Job Security / Future Outlook
4. Passion
5. Workload
6. Location

When purchasing a product, what is more important? (Rank from highest to lowest)

1. Price
2. Quality
3. Brand
4. Environmental Impact
5. Manufacturing Location

Please rate the following statements from 1 (disagree) to 5 (agree)

I am familiar with the level of technology in manufacturing industries

I am familiar with the Made in China 2025 Initiative

China's manufacturing sector is growing

Increasing automation decreases the number of jobs

Manufacturing education is growing in my university

I am more interested in automation now than when I started school

Companies should interact more with university students

Chinese manufacturers excel at making high quality products.

I prefer to buy Chinese brands

Appendix C – Student Survey Results

		Why did you choose your profession? 1 is more important					
Year	Major	Money	Passion	Family	Job Security	Workload	Location
1st	Automation	1	2	4	3	5	6
1st	Automation	1	3	4	2	5	6
1st	Automation	1	3	4	5	6	2
1st	Automation	1	3	6	2	4	5
1st	Automation	1	4	2	3	6	5
1st	Automation	1	4	2	3	5	6
1st	Automation	1	4	6	2	5	3
1st	Automation	2	1	3	4	5	6
1st	Automation	2	1	3	4	5	6
1st	Automation	2	1	3	4	6	5
1st	Automation	2	1	3	5	6	4
1st	Automation	2	1	5	3	4	6
1st	Automation	2	3	1	4	6	5
1st	Automation	2	4	1	3	5	6
1st	Automation	2	4	1	3	5	6
1st	Automation	2	4	3	1	5	6
1st	Automation	2	4	6	1	5	3
1st	Automation	2	5	3	1	4	6
1st	Automation	2	6	3	1	5	4
1st	Automation	3	1	2	4	5	6
1st	Automation	3	1	2	5	6	4
1st	Automation	3	1	5	6	2	4
1st	Automation	3	1	6	4	2	5
2nd	Automation	3	2	1	4	5	6
1st	Automation	3	2	6	1	4	5
3rd	Automation	3	4	1	2	6	5
1st	Automation	3	4	2	1	5	6
1st	Automation	3	4	2	1	5	6
1st	Automation	3	5	1	4	6	2
1st	Automation	4	1	6	5	3	2
1st	Automation	4	6	5	2	3	1
1st	Automation	5	1	4	3	2	6
1st	Automation	5	2	4	3	6	1
1st	Automation	5	3	1	4	2	6
1st	Automation	6	2	1	5	3	4
	Average:	**2.6**	**2.8**	**3.2**	**3.1**	**4.6**	**4.7**

Figure C.1 – Student survey: Highlighting top answers

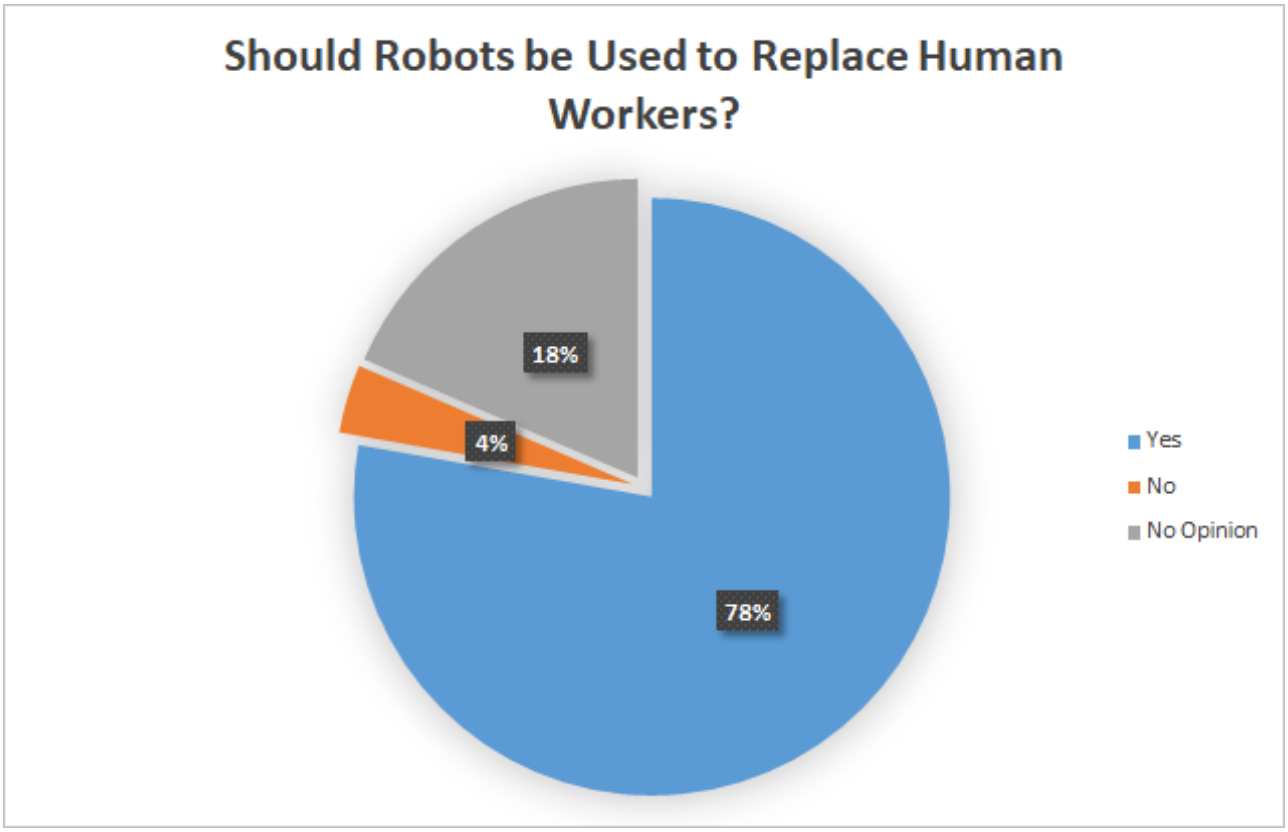

Figure C.2 – Student survey: Robots replacing workers

Appendix D – Interview Protocol Manufacturing Consultant

Company (Institution) :_____

Interviewer(s) :_____

Thank you for taking time to participate in our interview process. This interview should take no longer than a half hour and will be recorded for the purpose of easier transcription. The recording will be erased after transcription is completed. Participation in this interview is voluntary, questions may be skipped by the participant, and the interview can be stopped at any time.

Introduce ourselves –

We are an IQP team working in the Hangzhou China WPI project center working on a research project for Greentech Investment LTD.

Our research project is focused on improving manufacturing systems for some industries in Hangzhou and how implementing high-tech automation equipment may affect the industry. We are particularly interested in understanding the major problems associated with implementing automation into industrial manufacturing businesses. Our research on these subjects will be published as part of our school project requirements. Responses may be published, but no identifiable information will be attached with any responses (names/address/position).

Do you have any questions about our work before we begin?

1. What industries do you primarily work with?
    a. Based on answer:
2. What are the major challenges that are associated with that industry?
    a. Based on answer:
3. What major technologies are used in automating manufacturing processes in this industry?
2. What are the major problems that are associated with the introduction of automation?
    a. How is the labor force affected by these changes? (skilled workers? Labor costs? etc.)
    b. What steps can be taken to avoid these problems?
3. Are there any modern technologies that have significantly changed how automation is introduced?
    c. How has this affected production? (costs/labor/time/etc.)
    d. Have cloud based technologies been introduced into this industry?
        i. How? (based on answer)
    e. What are the advantages/disadvantages associated with this technology?
4. Which global industries are struggling with automation (industry 4.0)?
    f. What industries/sectors could benefit the most from automation?

5. What do you think the next big development in manufacturing will be?
6. What infrastructure is necessary to implement any sort of automation to a business?
    g. Are there any demand requirements for a system to be viable?
7. How does the skill of laborers affect the implementation of automated systems?
    h. Is it difficult to train workers to operate these systems?
        ii. Easier to train existing workers or hire new workers?
    i. How costly can this be?
8. Do you have any other suggestions for our research?

Thank you for participating in this interview, for the purpose of the IRB, we will not use your name for any citations.

Appendix E – Manufacturing Consulting Interview Transcript

After introducing ourselves and reading protocol:

Noah: First just a little about you, what industries do you mostly work with, in terms of manufacturing? Textiles? Or ….

Interviewee: Here at WPI or in my other job?

Noah: Other job is probably closer to what we're looking for.

Interviewee: okay, so we're primarily focused on components that go into machinery, components that go into specifically machinery that is made for making semi-conductor parts, and also components for mirrors for telescopes, for laser targeting systems, things like that

Noah: Okay, so high-tech

Interviewee: that particular business is focused on grinding ceramics into components, and we specialize in silicon carbide, which is the hardest material besides diamond, so we can only cut it with diamond.

Noah: In those manufacturing processes, how much would you say is mostly automated?

Interviewee: we try not to have anything that's a real production run, not have automation in it. If it was a one-off prototype it might get made manually by a person, but as soon as the process is controlled, we automate steps.

Noah: and that would be to decrease tolerances? Or?

Interviewee: Speed throughput, we'll typically have 3 people and 15 spindles running at the same time. About a 5:1 spindle utilization per person when we're on the game

Noah: Do you use any very new technology that you have been focusing on?

Interviewee: we have never purchased a robot, we build one-off automation for stuff, we build robots, but never purchase them. We do a lot of automated machine metrology, the hard part there is with the materials we try to cut, the tool wear is excessive and when you're trying to hold tight tolerances on the part you have to cut, measure, cut measure, so we automate that process. The built in tool probe system that measures the part and readjusts the toolpath and recuts it. In theory when a part gets ready to the Cnc machines, we put it in the fixture, turn the machine on and it makes the part.

Noah: Next, have you dealt with introducing automation in a previously labor intensive process? And what major problems come into play when you're switching?

Interviewee: It was part of a project that we never did, but it was to automate the process of loading up trays and running them into a furnace, the things that we ran into, the employees were not part of the problem, they wanted to automate the process so they didn't have to do it. The problem we ran into was limited space, there wasn't a space next to where they needed to do this that you could dedicate to this. It was a passageway from one part of the building to another part

of the building, furnace right next to it, so they were basically working across the passageway that you couldn't block with a robot. That particular fire was gonna eat up any off the shelf robot, it was highly… oils, grit, high temperature, being next to the furnace. So they went with people doing it. We looked at a few proposals, and cost, they didn't want to invest in the capital, and the real problem was, not so much, investing in the capital, it was the uncertainty that the robot was gonna work once it was bought.

Noah: okay so that was more on the management side

Interviewee: well I think a lot of it is on the management side, I own a company with robot in the name and we don't own any robots, besides the ones we've made. It's tough to make that decision because their current state of the art is not as flexible and reprogrammable, certainly not as flexible and reprogrammable as a person. And so at one lever I'd rather higher you than buy a robot, now we need that to change, because I can't afford to hire you, I think people like universal robots are going in the right direction, they're trying to make this better.

Noah: So you think that was a past problem?

Interviewee: That was a past problem, another automation system that I worked on, and this one did work and it got installed in the field is. They injection mold those plastic flatware, like plastic forks and knives, when they do it it's on a big tree, typically they take 10 of those, stack them up and a person has to break them up and put them in a box, and they had horrible carpal tunnel problems with the people doing it. So we built an automated a system that did single part flow of those trays, they moved through a conveyer that broke them up and they fell into bins. So that was to… stop the company from having to deal with carpal tunnel lawsuits and worker comp. That was twenty years ago.

Noah: In comparison to reducing working compensation costs, for jobs like that, is there also the impact of having to hire technicians, does it come close to that or not the same costs

Interviewee: It's gonna depends, this was not rocket science technology in an already operating factory so in that case they already had people to maintain it. I think when you go install an automation system that is different technology that is different technology than the factory is currently using, you gotta take some existing employee and train them to use the new technology, or hire a new worker

Noah: And would you say that just depends on what you're doing?

Interviewee: It's pretty much that.

Noah: Are there any industries that you see that have the most problem with automation, or workforces with high cost that could benefit from automation?

Interviewee: I think the most challenging things to automate is the low volume high turnover manufacturing, companies like mine, 300 parts is a lot for us. We do plenty of one-off, or 5 of these, 6 of those. It's just because of the frequency of changeover. I'll be running 2 jobs on the same machine, I'll be making stock for one part while the machine is running the other job.

Noah: And that requires a lot of coordination?

Interviewee: You gotta know what's going on. If it takes half a day to set up the robot, and half a day to set up the job, you're going to just do the job. If you can make it so it takes 5 minutes to set up the robot. You're going to use the robot.

Noah: In terms of existing infrastructure in factories, do you think that most factories could already be used to bring in automated systems? Or are they lacking in terms of floor space, computers, are there any major changes that would have to be made to a factory.

Interviewee: I mean, current technology industrial robots use the same power that machine tools run on, so if you wanted to put a robot in front of a milling machine, they have that kind of power there but you have to bring the power to it. You can't just plug it into the same plug.

Noah: And that would be 280/440v?

Interviewee: It would most likely be 280 or 480 3-phase, which is going to exist in the factory that already has that milling machine. You are gonna have to run additional lines to the robots. If you line the machines up with good spacing for people to work, it's not necessarily good spacing for robots to work. There's companies that are trying to make robots to fit where people fit, there's people trying to bridge that gap, trying to make your robots more people sized.

Noah: So that's just to make robots a direct swap from people

Interviewee: Yeah.

Noah: In China they have a problem with low skill workers, low trained. How would you address putting in a system that replaces them or would you train them to operate the new system.

Interviewee: Well you have to train some of them

Noah: So you would have to take existing workers and train them?

Interviewee: Yes, low skill doesn't mean low intelligence, it just means they haven't been trained yet. You can't know in advance who you'll need to train.

Michael: I don't know what your background is in, but what we're gonna be doing is essentially transition consulting, because what's happening is that labor costs are up and up and up, but it's killing certain industries, so what they're interested in CBA and case studies that evaluate the feasibility of replacing certain processes and worker cells with an automated facility. What do you think would be the most visible or dramatic issue that they would have for switching from a manual system to an automated system?

Interviewee: Well any kind of change like this where you're trying to get efficiency improvements or whatever it is from.. You gotta have the workforce on your side when you do it. So one piece of advice someone gave me years ago, this was specifically implementing lean manufacturing techniques, he said "If you gonna lay people off, do it before you start". So if you are going to reduce the workforce, reduce the workforce, than make sure everyone who's still there know that their job is safe, regardless of the changes you're making. Because in order to

implement these changes you need their cooperation, and if they believe their job isn't safe, they're going to fight you, even if they don't mean you. Even if they mean to help you, they can't help but resist. If people are looking at doing a mass changeover, so if I had a factory here that made brains all day long, and I got a person carving these things out and I go to a new automated facility that makes brains with 3 people and a dog, and the dog's job is to make sure the people don't touch the machines. I would keep running this [manual] facility, build a new one, and when this one [automated] is ready to take over the production load, shut this one [manual] down. I don't think I should try to do it inside this existing facility. And maybe when this one [automated] takes over and becomes more profitable, you can find something for the old manual one to do. But I think trying to implement a large change in the middle of an existing factory is going to have complications. And I haven't really thought about that until you asked the question, but it makes sense. But, if you're only adding small changes, when you bring assistive technology in, when you bring in an assistive robot and put it next to me so it makes it easier to do my job, than maybe I can make parts faster so we increase throughput without having to increase staff, so I think it depends on the scale of the change.

Noah: So first, look the scale of the situation before looking for changes.

Interviewee: Yeah, it really depends on the scale. The other things is, if we have an old piece of equipment and a new replacement for it, the new piece of equipment, purely based on the fact that it's newer is gonna have automation features that the old one wouldn't have. So as you're transitioning equipment like that, you might need a more skilled operator on that machine. Changing out a manual milling machine to a CNC machine, on the operator level you actually need a less skilled person. But you need somebody that serves programs to that, one programmer could be serving 15 machines depending on how fast the part changeovers are.

Noah: In terms of cloud based systems, the computer controlled aspect, how much has that been introduced to systems you've dealt with? Completely computer controlled workflow.

Interviewee: You have to be able to do it. If you can't do it that you can't compete, I think we actually built some software last year that we realized was a separate company that we spun off as a software company. It's all about online ordering, online customer communication, all automated. The customer knows when the part goes in the machine, they can check on the status of their orders in process as they go, with the built ERP system. We're doing manual entries on the machine tool, that part is not automated. I have a friend that owns a company that makes software that will actually automate the machine tool to talk with the ERP software. He knows when your machine is crashing before you do, he's getting information from all the machines constantly. So yeah, if you're not doing that, then you're going to fail. We're an early adopter there. That automated and software side is more important that automating machines. The amount of time that it takes for the operator to set up the fixture and load the parts, is pretty minimal. You can effectively use a few people if you've automated setup tasks and you've automated getting the gcode tasks. We use tools like Esprit cam software. What you don't see in ME1800 here is that you can drag and drop models into esprit, press a button, and it shoots code to the machine. If you tell esprit what tools you have and what features you want to do, you can

setup algorithms to do that. So you can literally drag and drop it and it shoots the code to the machine.

Noah: Can it do the full part or just single setups?

Interviewee: Well you can automate it and tell it to do both sides, but we don't do that. We've automated other features, customers also want to know how much it's gonna cost and how fast it can be delivered. We automate a lot of software.

Noah: Well, thank you for your time, we won't be using your name for IRB reasons. Have a great day.

Appendix F – General Manufacturing Survey

[Adapted from online Chinese survey]

[About our project]

Participation in this questionnaire is voluntary, you can skip any questions. Your individual responses will not be made public and this survey is anonymous. Overall results will be published.

What is your company's primary product?

How long has your company been in business?

What is the size of your company? (Number of employees)

How much automation is used in your manufacturing processes?

[For the following statements, rank from disagree (1) to agree (5)]

Your company has experienced increasing labor costs over the past few years.

Increasing labor costs have negatively affected your company.

Higher worker wages create better quality products for your company.

Increasing automation in your factory is an effective way to reduce labor costs.

Your company is very familiar with the Made in China 2025 initiative.

Your company has had difficulty upgrading manufacturing processes in the past.

The cost of automation equipment is too high for use in your factories.

Your company is confident in its ability to increase manufacturing technology.

Your company has difficulty finding qualified workers.

Universities are properly preparing students for the workforce.

Your current employees are supportive of increasing the technology level of manufacturing processes.

Your current employees are properly trained to use and maintain automated equipment.

Appendix G – Manufacturing Survey Results

1.你们公司的主要产品是什么？(What is your company's primary product?)	2.你们的公司成立几年了？ (How long has your company been in business?)	3.你们的公司规模有多大？(可以用员工人数回答) (What is the size of your company? (Number of employees))	4.在你们生产制造的过程中自动化程度有多高 (How much automation is used in your manufacturing processes?)	5.贵公司在过去几年里经受了巨大的劳动力成本增长的问题 (Your company has experienced increasing labor costs over the past few years.)	6.不断增加的劳动力成本对贵公司造成负面影响 (Increasing labor costs have negatively affected your company.)	7.提高工人工资为贵公司创造更优质的产品 (Higher worker wages create better quality products for your company.)	8.提高工厂自动化是降低劳动力成本的有效途径 (Increasing automation in your factory is an effective way to reduce labor costs.)	9.贵公司对中国的2025计划很熟悉 (Your company is very familiar with the Made in China 2025 initiative.)	10.贵公司过去在升级制造过程方面遇到过困难 (Your company has had difficulty upgrading manufacturing processes in the past.)	11.自动化设备的费用太高致使其不能在你们工厂使用 (The cost of automation equipment is too high for use in your factories.)	12.贵公司对提高制造技术的能力充满信心 (Your company is confident in its ability to increase manufacturing technology)	13.贵公司公司很难找到合格的工人 (Your company has difficulty finding qualified workers.)	14.大学正在为学生将来进入社会提供劳动力做好了适当的准备 (Universities are preparing students well for the workforce.)	15.贵公司现在的员工支持提高制造工艺的技术水平 (Your current employees are supportive of increasing the technology level of manufacturing processes)	16.贵公司现在的员工受过适当的培训来使用和维护自动化设备 (Your current employees are properly trained to use and maintain automated equipment)
企业服务	2	5	2	1	3	5	2	3	4	2	3	2	5	4	3
农产品	4	12	2	5	3	4	4	2	2	4	3	3	3	2	2
智能语音交互解决方案	4	30	3	3	3	3	3	1	3	3	3	3	3	3	3
电子产品	5	50	4	4	5	5	5	4	5	4	3	5	3	4	2
陶瓷	60	300	3	4	5	1	5	2	5	3	3	5	1	4	4
plastic remotes	25	500	3	5	4	3	5	3	5	3	2	5	3	3	3
配电箱、高低压柜、箱式变电站。	48	600	3	1	3	4	4	3	5	3	2	3	3	4	2
Electrical connectors	14	750	4	4	4	2	5	4	2	2	5	1	5	3	5
Compressor Housings	2001	875	3	4	2	3	4	3	4	2	2	2	3	5	5
家电	38	6000	3	5	2	1	5	5	5	1	5	3	3	5	5
建材	30	120	3	3	3	5	5	3	5	3	5	3	5	5	4
各类汽车和通讯用连接器，接插件	20	2600	3	3	4	3	3	5	4	4	5	3	2	5	4
Baby car seat	10	350	3	4	4	3	5	3	3	3	2	3	3	4	4
服装面料	7	75	3	3	4	4	4	2	3	1	5	2	1	5	3

Appendix H – General Manufacturing Manager Interview Protocol

Company (Institution) :_____

Interviewee (Title) :_____

Interviewer(s) :_____

Thank you for taking time to participate in our interview process. This interview should take no longer than a half hour and will be recorded for the purpose of easier transcription with your permission. The recording will be erased after transcription is completed. Participation in this interview is voluntary, questions may be skipped by the participant, and the interview can be stopped at any time.

We are a research team working at the Hangzhou, China, project center of our US university working on a research project with Greentech Investment LTD.

Our research project is focused on improving manufacturing systems for some industries in Hangzhou and how implementing high-tech automation equipment may affect the industry. We are particularly interested in understanding the major problems associated with implementing automation into industrial manufacturing businesses. Our research on these subjects will be published as part of our school project requirements. Responses may be published, but no identifiable information will be attached with any responses unless you agree to allow us to use your name (names/address/position).

Do you have any questions about our work before we begin?

1. What is the primary product manufactured at your company?
2. How many employees do you have?
3. What systems do you have in place for employee acquisition?
    a. Where do you recruit from?
    b. What are their education levels?
    c. How satisfied with workers/retention?
4. How have labor wages changed at your company?
    a. How has that affected you company?
5. What training do you provide for your workers?
    a. Who provides it? (contracted, internal, etc)
    b. Are there any systems for worker feedback?
6. How familiar are you with the China 2025 initiative?
7. Has your company upgraded manufacturing technology in the past?

    a. Why?
    b. Do workers need training? New workers instead?
    c. What was the most difficult process for this?
    d. How did you decide what to upgrade?
    e. Who was your source for the new system?
8. Do you have plans for increasing automation?
    a. How will you be implementing this?
9. What is the largest factor preventing you from automating further?
10. Are the maintenance costs for your facility large? (renting, inventory, machines, etc)
11. Who are you customers?
    a. What is your form of communication? Advertisement?
    b. Do they care more about quality? Price? Warranty?
    c. What volume of orders is normal?
12. What growth in recent years has your company experienced?
    a. Compared with market?

Appendix I – Helen of Troy Health Global Interview Notes

- **What is the most common type of technology that you see?**
  - Consumer products- medical: humidification, air cleaning, water filtration, blood pressure, heat pads, stands, and heaters
- **Vendor Specifics**
  - Most have either automated process or automated robotics
    - Usually thermometry and water purification – lot of regulation and lots of product varying
  - Automation standpoint – spec out project, quote it and quote what they feel what is the most efficient way to build the project – more complex products more likely to invest in automation
    - Pure water filtration as Example – lots of automation and vendors in china is most capable of using automated assembly – just outside of Shenzhen
    - Filtrated water pitcher filter or faucet mount filter (much higher filtration)
  - Several vendors quoted and they spec out life of project, quoted from manual and automated standpoint and show you the difference – increasing labor gets expensive especially with lots of small parts
    - Provide selling forecasts for 3-5 years and they give recommendations- sometimes vendor itself invests in automation and charge Helen of Troy money so Helen own the automation
    - Sometimes they own the automation – not as many subsidies for automation so china vendors wont pony up capital for automation equipment
- **Automation**
  - Automation is in assembly line – in automated fixtures build testing equipment and some low-level robotics to move parts from point A to point B and assemble with automated fixtures, screwing or 3-4 part assembly or drilling or welding or other process
    - Picker robots – injection molded now better tools and robotics to pick parts out of machines and molds first automation they saw- screw pickers and small robotics to improve efficiency
    - 1-2 operators per 5 machines- just putting things in boxes
- **Are companies increasing automation?**
  - Producers in US, Mexico, and China
    - Quote project in all 3 places – vendors in all 3 areas are looking at ways to keep **labor at a minimum**
  - Helen of Troy does as little engineering as possible – engineering management is passed down to vendors
  - All areas are pushing to automate to take out labor – products cost between $12-$100 each, cost of business at China and Mexico almost equal – China is a tad

cheaper, and US is a bit higher but factories close to distribution win on freight and inbound duties
    - Customers care about speed, then price, then quality
    - Lead time is very important – US and Mexico are a lot shorter lead time- would move away from china because freight takes a long time to ship – 70% of business in US
        - Door to door in china is 42 days. Leaving factory to arriving in distribution center- saving month and a half is huge
        - Can pick up directly from china but inventory and lead times are increasing
    - Total cost of ownership goes way beyond cost of making a product, includes things like shipping, storage, etc.
    - China needs to be even more advantageous since it cannot meet lead time standards to other countries
        - Automation is a key way for them to stay competitive- can maintain more production, with less workers
    - 45% of sourcing operations and customer forecast and supply predication – complexity of getting door to port to stops to California to train to Memphis to US customs to paperwork to truck to warehouse to distribution center
    - Removing days off lead time is something that is analyzed very heavily
    - Product requirement side is simple – receive a quote with a solution – cross quote with people in and outside of china but changing demand and passing to factories. Venders have proprietary manufacturing systems to pass demand from US to vendors. Teams pass demand to china to a team in Shenzen – supply chain team review with vendor and vendor comes back with expected delivery date- 1-year forecast 8 weeks for actual purchase orders added weekly- allows them to buy parts and maintain inventory on a consistent basis.
- **Inventory management**
    - Just in time inventory, keep as little inventory as possible
    - Lead time 2-3 months for new orders. Manufacturers normally will not purchase stock until an order comes in
    - Helen of troy gives letter of authorization to manufacturers to buy stock and will pay for unused materials. Shortens to 8-week lead time.
- **Does your company use interconnected machines?**
    - No, most assembly lines are not that complex. Manufacturers have automation in individual sections, but they do not link together and communicate.
    - Some manufacturers in Mexico have communication integrated but it is rare, no manufacturers they work with in China use automation communication.
    - Only will consider advanced communication for custom solutions that have very specific needs
- **What types of jobs are automated, and which remain manual?**
    - Testing and quality control get automated

        - Infrared ear thermometers – automated testing chamber that cycles through 24 hours
        - Quality checking and specification checking with different environments
- **What usually causes companies to upgrade?**
    - Labor is not as available as it used to be
        - People are getting more educated and there are no longer farmers coming to work in manufacturing.
        - Because of this, labor is getting more expensive.
- **What usually is the most difficult?**
    - Software is the hardest part to upgrade
    - Very customized, not off-the-shelf packets and getting entire system to talk to each other is difficult
    - Contract with other people to write programs and troubleshoot to keep it running
    - Not big enough to have department dedicated so must use 3rd party contractors
- **Expectation for downtime for automation upgrades?**
    - Prepares for automation upgrades in advance
        - Determines how long the process will be down for and build a surplus of product to buffer while upgrading
        - Ideally, vendors will store the surplus inventory
- **Reasons why companies may not want to automate**
    - Companies feel they will not get the payback soon enough. It depends on the customer. If they trust the customer they are more likely to invest in expensive automation solutions to gain future contracts.
    - Helen of Troy prefers a smaller number of large vendor because it allows more customer-manufacturer trust and automating larger companies
- **Major changes in contracting and manufacturing?**
    - Where they are focusing
        - Used to be in Shenzen and pear river
        - Looking to move north and west since labor is more plentiful
        - Ningbo – metalworking focus
        - Companies shifting to cheap labor and where subsidiaries are better
        - Shenzen are changing to high tech manufacturing so they are forced to relocate light industry stuff
- **Are you familiar with China 2025?**
    - Yes - Because they are not high tech, the initiatives have impacted them in a negative way
    - Incentives for low businesses hurt – low skill and high volume used to be strong for subsidies and cheap
    - Now items are low tech and the vendor base is struggling because they do not get the subsidies and China is pushing the smaller companies down in favor of high tech

- **Government creating incentive programs can make manufacturing more difficult for manufacturing**
    - Highly automated good incentives – do not have a lot of that so they are struggling
- **What are the most common levels of industry automation for HoT?**
    - 1.0 and 2.0 are the most common for Helen of Troy
- **Education level for workers**
    - High School or trade school level
        - General assembly line worker is basic education and keep training them
        - Do not have extremely high level of automation
    - 5-10 years ago there was trouble finding skilled workers, but now there is no issue finding skilled workers –everyone wants to be in it
        - If an operation requires 50 ME, 50 CS, and 50 EE workers, it is way easier to fill these days
    - Unskilled, less educated workers are useful as they can be trained in specific processes
        - Some companies try to keep employees captive – don't want to lose workers so they train them in-house and keep it very specific to what they do
        - This makes workers seem less useful for rival companies, thus preventing workers from finding new jobs
        - People will move for very small wage increases, so limiting their options is an effective, yet unethical program.
        - Retrain workers first, then replace if necessary
- **Push for automation background in education**
    - Most recent graduates are very well prepared for automation implementation
    - Chinese government and education is rigorous at high school level, and now is very tailored to providing kids opportunities in industrial revolution
    - Engineers and tech people have great work ethic and are smart – able to quickly take theory and adapt to practice
- **Feedback systems**
    - Still have master-servant type of relationship between workers and management
    - Factories are hesitant to give out negative feedback due to cultural differences
        - People are reluctant because they are afraid they will lose their jobs
    - Feedback systems exist at management level, but not at worker level
        - Great international management team, but they have been recently appointed

Appendix J – Amphenol JET Interview Notes

Interviewee (Title) : Jeeping Gao, Manager

Interviewer(s) : All

1. **What is the primary product manufactured at your company?**
   Midplane and backplane systems, used mainly in consumer electronics
2. **How many employees do you have?**
   750
3. **What systems do you have in place for employee acquisition?**
   Lower skilled workers are hired based on need for rapid turnaround on prototyping on large orders.
   a. **Where do you recruit from?**
      Hire from well known tech universities using network of connected alumni
   b. **What are their education levels?**
      Mostly university or above
   c. **Have you experienced any worker shortages?**
      Yes, 5-10 years ago we struggled to find highly educated engineers, but now there are plenty, and a shortage of lower skilled workers
4. **How have labor wages changed at your company?**
   Have been increasing, making automation more viable in long term based on CBA's (cost-benefit analysis)
   a. **How has that affected you company?**
      Just needed to readjust CBA to account for costs.
5. **What training do you provide for your workers?**
   Multiple training programs: first general training for company rules, followed by professional training. For operators, machine and safety additional training.
   a. **Who provides it? (contracted, internal, etc)**
      Internal
   b. **Are there any systems for worker feedback?**
      360 review system, allowing employees to evaluate company practices, foods, managers, and other systems.
6. **How familiar are you with the China 2025 initiative?**
   Familiar, as well as uses government incentives for taxes. Additionally, making automation patents gives tax discounts, research being driven by market (tax incentives)
7. **Has your company upgraded manufacturing technology in the past?**
   Yes
   a. **Why?**

Reduce costs for long term, while increasing quality for their customer product requirements to stay competitive in the market.

   b. **Do workers need training? New workers instead?**

      Trained workers, inside company

   c. **What was the most difficult process for this?**

      Balancing cost of running machine (employees per machine), as well as not being able to create a comprehensive logistics system because the factory expands incrementally.

   d. **Who was your source for the new system?**

      In-house design and technical department for physical system, potential contracting for software control (ERP software). ERP is used to for resource planning using customer forecasts for more in depth cost analysis.

8. **Do you have plans for increasing automation?**

   Yes

   a. **How will you be implementing this?**

      Design machines using company standards so it can be used for different applications in the future. Customer product lines change regularly so machines must be flexible to be profitable.

9. **What is the largest factor preventing you from automating further?**

   Logistics system is not built into the infrastructure of the facility, so fully automated control is difficult.

10. **Are the maintenance costs for your facility large? (renting, inventory, machines, etc)**

    Maintenance costs aren't very high and workers are trained with operation of machines.

11. **Who are your customers?**

    Various electronic companies, mainly make midplane/backplane for servers

    a. **Do they care more about quality? Price? Warranty?**

       Quality, then price

    b. **What volume of orders is normal?**

       Orders range from thousands to billions+, customers give forecasts for order to allow for material planning and machine CBAs

Appendix K – Sanli Machinery Interview Notes

Interviewee (Title) : Lou Junhua, Manager

Interviewer(s) : Noah Hillman, Steven Viola

1. **What is the primary product manufactured at your company?**
   Mining refinery equipment (tumblers, sifters, etc)
2. **How many employees do you have?**
   118
3. **What systems do you have in place for employee acquisition?**
   a. **Where do you recruit from?**
      Word of mouth, network of companies
   b. **What are their education levels?**
      50% from polytechnic schools, 33% university, 17% skilled workers with certifications. Only employees with 10+ years experience
   c. **How satisfied with workers/retention?**
      Students with low experience will usually leave company in a few months, so company only hires people with higher experience who know the work.
4. **How have labor wages changed at your company?**
   Yes
   a. **How has that affected you company?**
      i. Pressuring the company to:
         1. Increase market share
         2. Reduce management overhead costs
         3. Upgrade machinery to digital machines
5. **What training do you provide for your workers?**
   Currently little, because they hire experienced workers
   a. **Are there any systems for worker feedback?**
      None, workers only know about their obligations, not about the company missions/upgrades
6. **How familiar are you with the China 2025 initiative?**
   Not at all
7. **Has your company upgraded manufacturing technology in the past?**
   No, most machines are from initial establishment
8. **Do you have plans for increasing automation?**
   Yes, customers are demanding increased quality machines for new EPA requirements
   a. **How will you be implementing this?**
      Using a contracting company to provide machines and new training for existing workers. Machines are chosen based on technical department using CBAs. Major problems are market pressure, high capital investment,

and training programs will halt production for valuable time, and potentially lose business/credibility. Training existing workers instead of acquiring workers because it is difficult to find skilled workers/machinists.

9. **What is the largest factor preventing you from automating further?**
   Costs, they are only upgrading because quality requirements from their customers have increased.
10. **Are the maintenance costs for your facility large? (renting, inventory, machines, etc)**
    No, everything is owned
11. **Who are you customers?**
    Mining companies
    a. **What is your form of communication? Advertisement?**
       Existing company word of mouth, referrals, branches.
    b. **Do they care more about quality? Price? Warranty?**
       Price, quality, warranty (20 years)
    c. **Volume of order?**
       Low number of machines per order, 3-6 month fulfillment period depending on custom options.
12. **What growth in recent years has your company experienced?**
    In the past 2 years, decrease in sales because recent EPA changes that require different technology to legally refine/mine
    a. **Compared with market?**
       Entire market is declining because of EPA changes.

Appendix L – CoTEK Robotics Interview Notes

Interviewee (Title) : Jessica Wang, Secretary

Interviewer(s) : Michael Brooks, Ryan St. Hilaire

1. **What is the primary product manufactured at your company?**
   Inventory management and logistics systems, mainly warehouse retrieval for online shopping companies
2. **How many employees do you have?**
   34
3. **What systems do you have in place for employee acquisition?**
   a. **Where do you recruit from?**
      College students
   b. **How satisfied with workers/retention?**
      Good engineering background, but still need training
4. **What training do you provide for your workers?**
   3-4 days of training for new hires
   a. **Who provides it? (contracted, internal, etc)**
      Internally provided
5. **How familiar are you with the China 2025 initiative?**
   Very, because CoTEK makes automation systems
6. **Who are you customers?**
   Companies needing automation equipment for logistics systems (to be contracted)
7. **What growth in recent years has your company experienced?**
   Very recently established
   a. **Compared with market?**
      Large demand for AGV robots (164% increase in 2016)
8. **Product specifics for other companies**
   a. Robots pay for itself in under 2 years
   b. Many companies will estimate cost for worker to be 50K rmb per year
   c. Companies in China don't have a system for intercommunications across automated platform types, so everything has to be re-engineered per company

Appendix M – Allied-Machinery Interview Notes

Interviewee (Title) : Fei Teng, Manager

Interviewer(s) : Michael Brookes, Noah Hillman

1. **What is the primary product manufactured at your company?**
   Compressor and hydraulic housings for industrial equipment
2. **How many employees do you have?**
   875, 145 of which are engineers.
3. **What systems do you have in place for employee acquisition?**
   Job fairs and college administration networking through HR department
   a. **Where do you recruit from?**
      Colleges in surrounding cities/areas
   b. **What are their education levels?**
      Junior college or above
   c. **How satisfied with workers/retention?**
      Students only have very general knowledge, lack applicable skills for companies.
4. **How have labor wages changed at your company?**
   Wages have increased, but has had very low overall effect.
5. **What training do you provide for your workers?**
   Training for workers includes initial general and safety training, then specific job training. For operators, a two month apprenticeship with an experienced operator is expected before taking practical to determine operator skill. Monthly training is held for workers to continue improvement.
   a. **Who provides it? (contracted, internal, etc)**
      Internal management
   b. **Are there any systems for worker feedback?**
      Yes, improvement plan boards. Workers suggest improvement for difficult or un-optimized tasks, and engineers will look at suggestions to evaluate implementation. Rewards are given to successful plans to promote more feedback. Additionally, there are improvement plans for each workshop in the facility to increase overall productivity.
6. **How familiar are you with the China 2025 initiative?**
   Familiar with industry 4.0, but cannot use China 2025 financial support for their tech because it did not quality meeting automation standards.
7. **Has your company upgraded manufacturing technology in the past?**
   Yes, upgrading to CNC's from more manual machines, as well as an upgrade to automate foundry molding.
   a. **Why?**
      Keep up with production volume (adding machines, increasing efficiency)

b. **Do workers need training? New workers instead?**
   New workers and management (not replacing, just adding to workforce).
c. **What was the most difficult process for this?**
   Management was needed first to develop new training programs and find workers when moving to new location with larger workforce
d. **How did you decide what to upgrade?**
   Available automation equipment that is adaptable to their production line.
e. **Who was your source for the new system?**
   Sourced to external company to provide automated system with in house specifications

8. **Do you have plans for increasing automation?**
   Yes, but still looking for applicable products.
9. **What is the largest factor preventing you from automating further?**
   Finding the right adaptable product for their production system, as well as finding software that isn't too expensive (because there aren't Chinese ERP systems)
10. **Who are you customers?**
    Industrial equipment suppliers, for air conditioners, construction equipment, and other applications.
    a. **What is your form of communication? Advertisement?**
       Long term partnerships are formed, and company reputation increased.
    b. **Do they care more about quality? Price? Warranty?**
       Quality, order fulfillment time, than price. All products have quality guarantee.
    c. **What volume of orders is normal?**
       Orders of 10 parts, overall yearly output for foundry is 40K tons. Customers will provide yearly forecasts of production, with around 1 month lead-time expectation.
11. **What growth in recent years has your company experienced?**
    35% yearly growth in recent years (156M in sales last year)

Appendix N – Hiye Electronics Interview Notes

Interviewee (Title) :_____

Interviewer(s) : Michael Brooks, Noah Hillman

1. **What is the primary product manufactured at your company?**
   Medium sized electronic remote control designer and manufacturer - consumer electronics mostly- some larger scale b2b technology (large agricultural UAV)
2. **How many employees do you have?**
   500
3. **What systems do you have in place for employee acquisition?**
   Local advertising because nearby workers will see better working conditions/wages
   a. **What are their education levels?**
      Workers are HS, engineers/management are college or above
   b. **How satisfied with workers/retention?**
      Worker education has been satisfactory, but retaining workers is becoming difficult, but still a high priority
4. **How have labor wages changed at your company?**
   Necessary to increase wages to retain workers
   a. **How has that affected you company?**
      Short on laborers for low-skilled jobs
   b. **Are there steps to combat this?**
      Increasing automation machines to replace lost workers
5. **What training do you provide for your workers?**
   Specific training for job function, as well as 2 years training for engineers
   a. **Who provides it? (contracted, internal, etc)**
      Internal
   b. **Are there any systems for worker feedback?**
      No
6. **How familiar are you with the China 2025 initiative?**
   No, but familiar with industry 4.0 and automation
7. **Has your company upgraded manufacturing technology in the past?**
   Yes, new machines increased production by 30% at last upgrade.
   a. **Why?**
      Saving money for profit margins
   b. **Do workers need training? New workers instead?**
      New workers, and significant training for old and new workers
   c. **What was the most difficult process for this?**
      Keeping quality control regulated with new system
   d. **How did you decide what to upgrade?**

Low complexity, feasible processes based on automation availability.

e. **Who was your source for the new system?**

Buying existing technology, with financing from government

8. **Do you have plans for increasing automation?**

Yes, to replace lost workers

a. **How will you be implementing this?**

Finding contractors to make custom flexible solution

9. **What is the largest factor preventing you from automating further?**

Process complexity for existing production

10. **Are the maintenance costs for your facility large? (renting, inventory, machines, etc)**

Low costs, everything is owned

11. **Who are you customers?**

Businesses, retailers, 60% international customers

a. **Do they care more about quality? Price? Warranty?**

Price, than quality

b. **What volume of orders is normal?**

12 million units per year total, customers give order forecasts, and 2M items are kept in stock for safety

12. **What growth in recent years has your company experienced?**

Margins have decreased in domestic markets

Appendix O – Direct Observation of the Manufacturing Process Protocol

Company (Institution) :_____

Introduction for floor manager:

We are a student research team that is in Hangzhou, China, as part of our US university's project center; we are working on a research project for Greentech Investment LTD.

Our research project is focused on improving manufacturing systems for manufacturing industries in Zhejiang and how implementing high-tech automation equipment may affect the industry. We are particularly interested in understanding the major problems associated with implementing automation into your industrial manufacturing business. Our research on these subjects will be published as part of our school project requirements. No personal, identifiable information will be included with our results from this observation.

The duration of this study will be determined on a case-by-case basis, but will be approx. 2+ hours. This observation study will be used to analyze workflow, interactions between machines and workers, and process efficiency/throughput.

Do you understand the above information about our study and the information we will be collecting? Questions?

All data obtained through direct observation will be according to the criteria listed below:

- Products
    - Most popular products:
    - Complexity of manufacturing:
        - Flexibility of supply line:
    - Quality methodologies:
        - Number of employees to ensure quality:
    - Visual standards:
        - Safety Measures for workers:
- If automation exists:
    - What types of roles do robots have (vs people):
    - Age of implemented automation:
    - Level of integration with workers:
        - (assistive vs replacing)
    - Space occupation compared to workers
    - Integration with logistics/inventory management:
    - What are current concerns that automation hasn’t been able to fix:
- If automation doesn't exist:
    - What are areas that automation could improve:
    - What are current concerns that automation would be able to fix:

Observed Processes:

Appendix P – Amphenol JET Observation Notes

- Products
    - **Most popular products**: Midplane and backplane connectors for consumer electronic devices
    - **Complexity of manufacturing**: Complex part processes, multi-step processes, and small size
        - **Flexibility of supply line**: Very adaptable for micro flexibility because there is a department for manual operations for short term product supply.
    - **Quality methodologies**: Some processes are automatically checked for quality using digital systems, while other are using manual QC.
        - **Number of employees to ensure quality**: 10+ workers staged in QC room for visual inspection using assistive systems.
    - **Visual standards**: Very clean, walking lanes kept clear, machines kept well maintained
        - **Safety Measures for workers**: Guards on machines, safety equipment for workers handing parts.

- **If automation exists**:
    - **What types of roles do robots have (vs people**): For automated section of factory, workers supply machines/robots with materials, the machines output the finished product after molding/punching is complete. For manual sections, assistive machines feed workers parts on assembly line, workers must feed into next machine until all processes are complete.
        - **Level of integration with workers**: Assistive in some areas, completely replaced in other.
    - **Space occupation compared to workers**: Very large machines to produce high volume, still much less space than workers would take up.
    - **Integration with logistics/inventory management**: Currently very little logistics integration since factory expanded into new buildings without logistics planning.
- **If automation doesn't exist**:
    - **What are areas that automation could improve**: Logistics and material supply for automated systems.

Observed Processes

- In production, machines feed ribbons of parts to next machine, using automated system to keep a buffer between them. Input and output are stored on reels and manually moved once full.

- For large punching machines, 10 different punched perform an operation in a row to fully form the final product, completely automated.
- Robotic arms replaced humans in some machines by feeding/removing completed molds.

Appendix Q – Sanli Machinery Observation Notes

- Products
    - **Most popular products**: Mining refinery machines
    - **Complexity of manufacturing**: Appears to be simple part flow (step 1, step 2… step x) however large parts make machining and moving difficult.
    - Quality methodologies:
        - **Number of employees to ensure quality:** No quality department, quality inspection performed by operators.
    - **Visual standards**: Unclean, unorganized, overall dirty. Machines appear maintained, but not cleaned well.
        - **Safety Measures for workers**: Workers not using PPE, or other safety equipment.

- **If automation exists**: None
- **If automation doesn't exist**:
    - **What are areas that automation could improve**:
        - Inventory management software or other system to automatically catalog parts and tools to manage general organization in the shops.
        - Replace current manual machines to CNCs to improve part throughput and quality.

Observed Processes

- Workers drilling holes on two separate drill presses, manually moving and setting up each machine between holes.
- Large turning operations performed on older (~20 yrs old) machines. 1 operator per lathe, no safety equipment
- Inventory appeared to be managed by a single worker with a hand written log of usage.

Pictures of Sanli:

Figure Q.1 – Inventory management for replacement parts (photo by Noah Hillman, 2017)

Figure Q.2 – Drill press operator and shop floor machines (photo by Noah Hillman, 2017)

Appendix R – CoTEK Robotics Observation Notes

- Products
    - **Most popular products**: Automated inventory warehouse robots
    - **Complexity of manufacturing**: Very high complexity
        - **Flexibility of supply line**: Very flexible
    - **Quality methodologies**: Manual testing and inspection
        - **Number of employees to ensure quality**: None dedicated
    - **Visual standards**: Very clean, extremely organized
        - **Safety Measures for workers**: Safety borders, motion detectors for testing

- **If automation exists**: Fully manual, case-by-case manufacturing
- **If automation doesn't exist**:
    - **What are areas that automation could improve**: None, too flexible

Observed Processes

- Programming department, for creating systems to control their robots.
- Development workspace, used to create new automated robots using existing machines and combining with additional sensors.

Appendix S – Allied-Machinery Observation Notes

- Products
    - **Most popular product**: Metal housings for industrial compressors
    - **Complexity of manufacturing**: Very complex, machines require variable tooling, large variety of parts, low batch size.
        - **Flexibility of supply line**: Since products are already varying, chain is very flexible, able to accommodate most product changes
    - **Quality methodologies**: Large CMM machines for probing and measuring
        - **Number of employees to ensure quality**: 5+ monitoring CMM machine
    - **Visual standards**:
        - **Safety Measures for workers**: Operators using safety equipment, guards on machines

- If automation exists:
    - **What types of roles do robots have (vs people**): Large CNCs for machining, large CMM's for quality control. Workers manage inventory, and operate machines
    - **Level of integration with workers**: Automation systems are operated by workers, little interaction otherwise
    - **Space occupation compared to workers**: CNCs are very large, taking up almost all of the space in the factory.
    - **Integration with logistics/inventory management**: Manual inventory management, using ERP software. Large cranes for moving parts, carts for moving/storing tooling.

- If automation doesn't exist:
    - **What are areas that automation could improve:** Tooling automation and ERP software need to be integrated to reduce set-up times for machines since that is a large portion of throughput time.

Observed Processes

- Over 91 CNCs, mostly the size of a large car. Each machine running 24/7, 1 operator per machine.
- Large automated transport system between 7 CNCs, allowing for automated part flow. Consists of robotic platform on a sled that can load the part between CNCs for each process.
- Tooling room consists of manual shelving storage, and old cataloging software to monitor tool inventory. Carts are taken to the machines for tool swapping.

Pictures of Allied-Machinery:

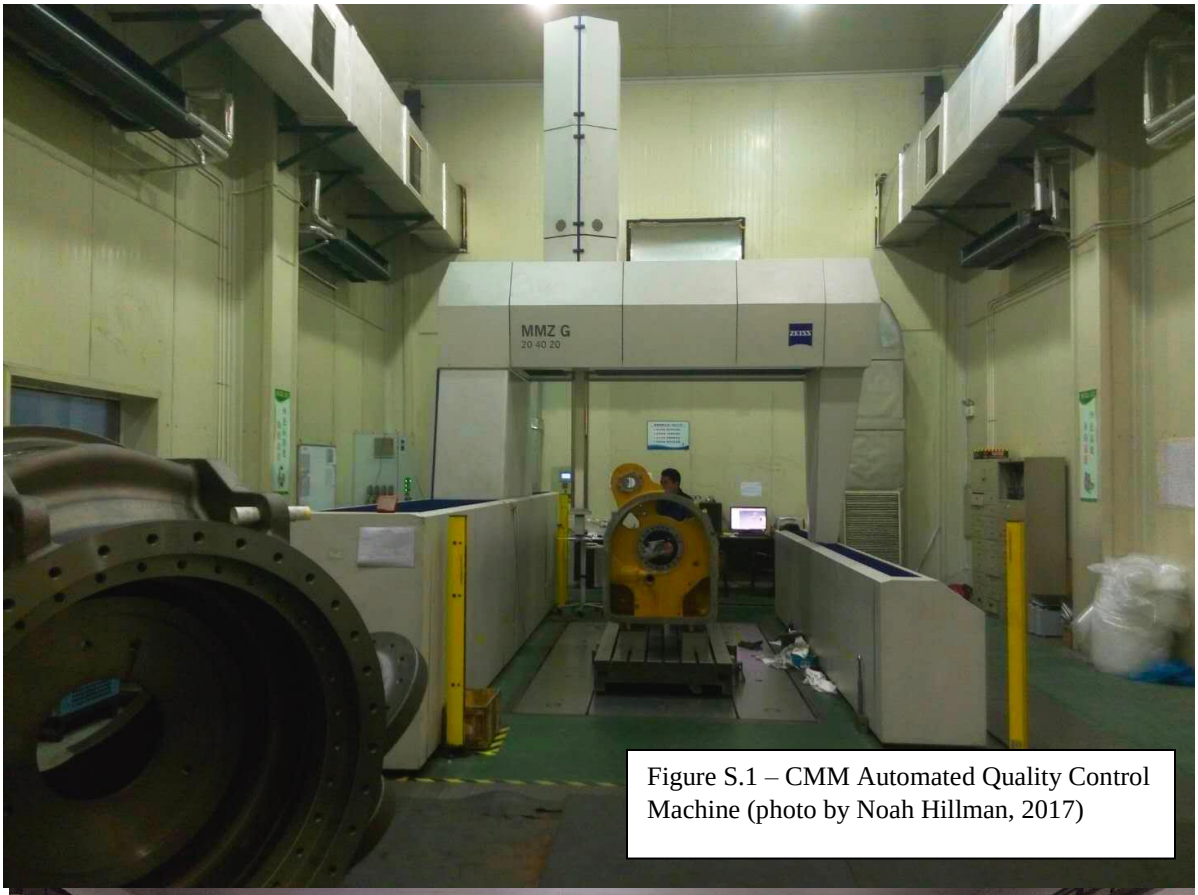

Figure S.1 – CMM Automated Quality Control Machine (photo by Noah Hillman, 2017)

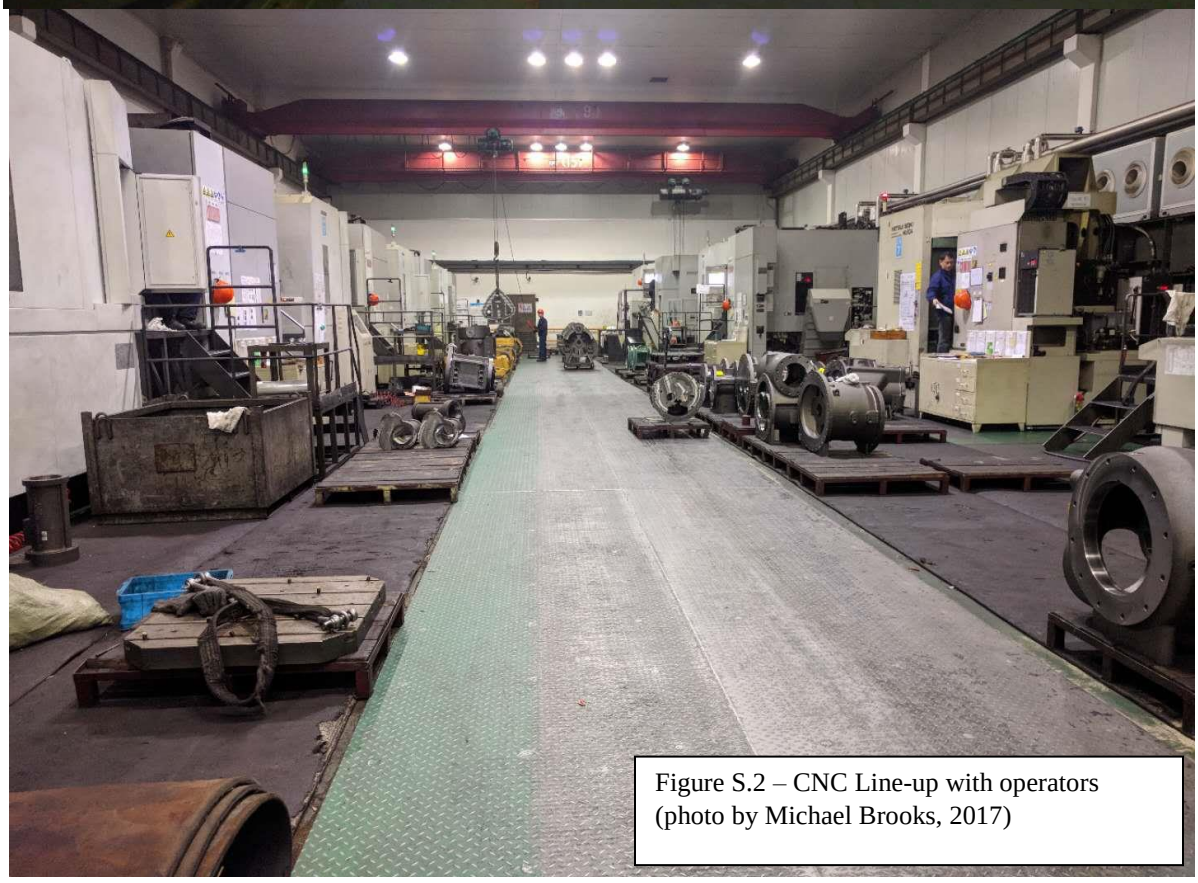

Figure S.2 – CNC Line-up with operators (photo by Michael Brooks, 2017)

Appendix T – Hiye Electronics Observation Notes

- Products
    - **Most popular products**: IR remote controls for various applications
    - **Complexity of manufacturing**: PCB design and produce, plastic molding, SMT machines, manual assembly.
        - Flexibility of supply line: Semi-flexible, machines for SMT and molding can be adaptable, but the assembly line lacks enough workers for efficient production
    - **Quality observations**: Molding can leave marks that need to be fixed later
        - Number of employees to ensure quality: 2 workers, verifying quality out of SMT machines.
    - **Visual standards**: Inventory kept in marked zones, overall well cleaned.
        - Safety Measures for workers: Strong fumes suggest need for respiration systems, but there are none.

- If automation exists:
    - **What types of roles do robots have (vs people):** Robots doing labor time-intensive and precise work for PCBs, while people are doing assembly and packaging. Some assistive machines to assist assembly process.
    - **Level of integration with workers**: Assembly line machines integrated well, automated SMT machines have very low integration
    - **Integration with logistics/inventory management**: Very little inventory management visible, large pallets filled as inventory storage.
    - **What are current concerns that automation hasn't been able to fix**: Creating adaptable solutions, since product line changes often
- If automation doesn't exist:
    - **What are areas that automation could improve**: Inventory management, and assembly processes.
    - **What are current concerns that automation would be able to fix**: Adaptable solutions for constantly changing product lines (with high volume)

Observed Processes

- SMT boards go through 2 machines, with a QC inspector visually checking for mistakes. Parts are than put on cooling racks to be worked on later.
- Long conveyer line with ~20 workers per line to assemble and package remotes.
- Assistive technology present: some workers used pneumatic press to close cases with molds. Air hoses installed at stations allow workers to clean out parts during assembly. Dremel tools used for installation.

Pictures of Hiye:

Figure T.1 – Remote control assembly line (Photo by Michael Brooks, 2017)

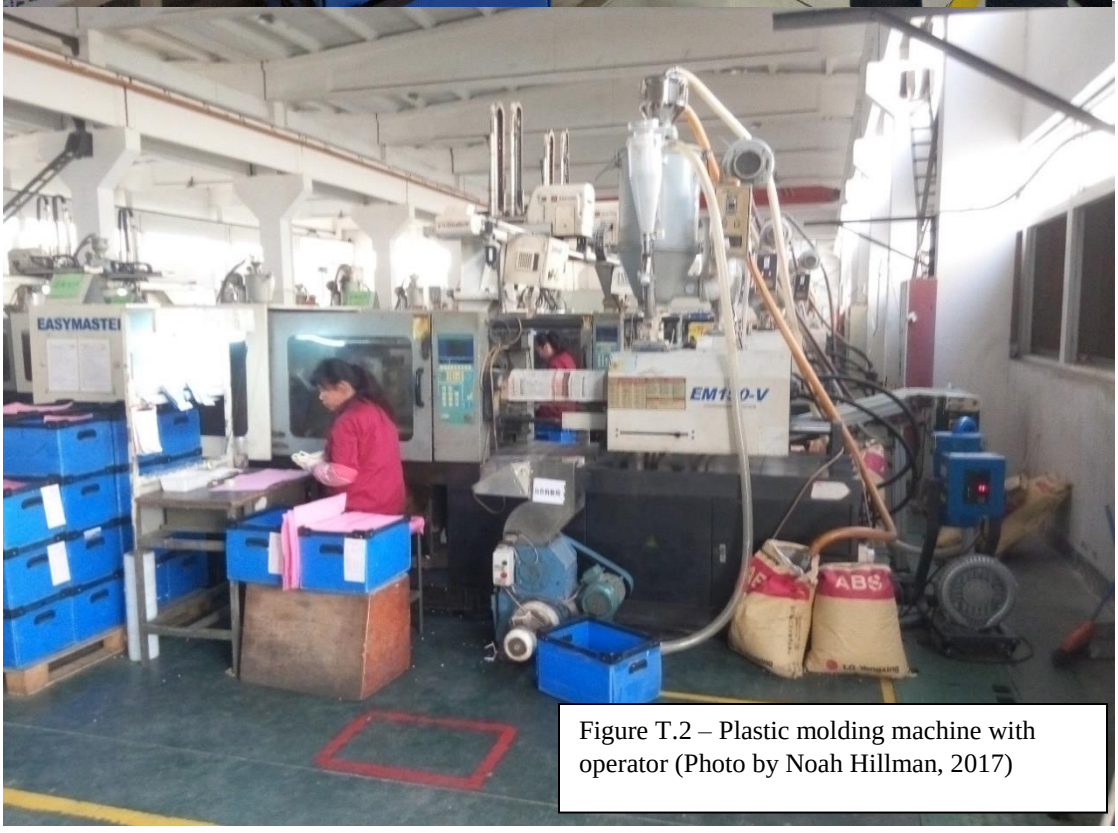

Figure T.2 – Plastic molding machine with operator (Photo by Noah Hillman, 2017)

Appendix U – Professor Interview Protocol

Thank you for taking time to participate in our interview process. Participation in this interview is voluntary, questions may be skipped by the participant, and the interview can be stopped at any time. Is it ok if we record this interview so we can review it later?

We are a student research team working at the Hangzhou, China, project center of our US university working on a research project with Greentech Investment LTD.

Our research project is focused on improving manufacturing systems for some industries in China and identifying how increasing use of high-tech automation equipment may affect the industry. We are particularly interested in understanding the major problems associated with implementing automation into industrial manufacturing businesses. Our research on these subjects will be published as part of our school project requirements. Responses may be published, but no identifiable information will be attached with any responses unless you agree to allow us to use your name (names/position).

Professor Questions:

- What subjects do you teach?
- Tell us about the automation major in China?
- What are your research interests?
- What do you think is currently preventing manufacturers from advancing to more advanced manufacturing?
- How do you see automation development affecting chinese manufacturers?
- Does your research bring you into contact with many manufacturing companies?
- Are you familiar with the Made in China 2025 initiative?
    - What do you see as the key points of the made in China 2025 initiative?
- How has the Made in China 2025 initiative affected your work/interactions with companies?
- How has the Made in China 2025 initiative affected education?
    - Increase in automation students?
    - Students familiar with government policy?
    - More companies looking for automation employees?
- Does your school study the social effects of automation?
- Have you worked with manufacturing companies in the past?
    - What do you see as key metrics for evaluating a company's technology level?

Additional Questions

- Is it possible to distribute a survey among students for any of your classes?
- Are there any contacts (professors or companies) who would be interested in our research?

Appendix V – Professor Xing Interview Notes

Professor Questions:

- **What subjects do you teach?**
  Currently an assistant professor, haven't taught any classes yet
- **Tell us about the automation major in China?**
  In other countries, there isn't a specific major for this, but in China almost ever college has a specific automation major because how fast it is growing.
- **What are your research interests?**
  Researches smart grid power distribution and vehicle charging
- **What do you think is currently preventing manufacturers from advancing to more advanced manufacturing?**
  AI is the core to developing a better automation system.
- **Are you familiar with the Made in China 2025 initiative?**
  Knows about the initiative, but isn't too familiar with the specific objectives
- **What do you see as the key points of the made in China 2025 initiative?**
  AI version 2, using big data to drive cooperation with machines
- **How has the Made in China 2025 initiative affected education?**
  - **Increase in automation students?**
    Recently, there is a large increase in students studying automation at HDU. Most students choose the major because there are large applications and many jobs available after graduation.
  - **More companies looking for automation employees?**
    Companies come to colleges for job-fairs to recruit students.

Appendix W – Professor Luo Interview Notes

Professor Questions:

- **What subjects do you teach?**
  - Engineering materials and molding techniques, CNC technology and applications
- **Tell us about the automation major in China?**
  This school focuses on PLC (programmable logic controller) control technology, machinery manufacturing information technology, CNC machining, Material molding manufacturing, smart manufacturing, and network alliance (sharing information)
- **What are your research interests?**
  Smart manufacturing
- **What do you think is currently preventing manufacturers from advancing to more advanced manufacturing?**
  The largest barrier is upgrading the mechanical structure and control
- **Does your research bring you into contact with many manufacturing companies?**
  Yes, companies looking to research robots to improve worker health using grinding machines to prevent dust pollution/inhalation. Also, a company developing smart robots to replace workers in dangerous conditions, like acids.
- **Are you familiar with the Made in China 2025 initiative?**
  Yes, familiar with the 10 year plan and industry 4.0.
  - What do you see as the key points of the made in China 2025 initiative?
    The emphasis on cloud manufacturing and information sharing using networks and intelligent manufacturing.
- **How has the Made in China 2025 initiative affected your work/interactions with companies?**
  - Companies can now get financial support for additional research and development spending, which also increases student employment rates at the college.
- **How has the Made in China 2025 initiative affected education?**
  Large impact, courses have more focus on intelligent control
  - **Increase in automation students?**
    Computer and IT in automation has had an increase in students
  - **Students familiar with government policy?**
    Students are introduced to the 2025 plan and trends for development every year.
  - **More companies looking for automation employees?**
    Yes, employment can be 95%
- **What do you see as key metrics for evaluating a company's technology level?**
  Manufacturing quality, assembly accuracy, and flexibility of machines

Appendix X – Professor Yu Interview Notes

Professor Questions:

- **What subjects do you teach?**

  Lab teacher for machine learning, programming.

- **What are your research interests?**

  Motion & Process control, image recognition, machine learning, deep learning, electronic transfer

- **How has the Made in China 2025 initiative affected education?**

  a. **Increase in automation students?**

     Automation is a very popular major because it has a great job outlook, and there are many still growing industries with many applications

  b. **Students familiar with government policy?**

     Not very familiar, but there are info sessions and robotics competitions to promote the automation major.

  c. **More companies looking for automation employees?**

     Companies are looking to reduce employee numbers (workers), they recruit through career fairs.

Appendix Y - Rauch Interview Notes

1. **Are there particular industries/sectors of manufacturing the SME 4.0 project is focused on?**
    - No particular industry/sector - working with all small and medium sized companies - need large participation so they aren't limiting size
    - Want to know what status companies are at with i40 - identify what methods small companies utilize to compete
2. **Do companies have incentives to adopt this tech? Government push? Funding support? Etc.**
    - Government push/public funding
    - Nobody was really interested in smart manufacturing goals - needs lots of investment and lack of initial funding support - difficult to get attention of industries (too risky)
        - Huge push for machine manufactures
            - CNC, robotics
        - European 2020 push - investing lots of money into European projects - smart factories > industry 4.0
    - Several different countries are supporting government initiatives to increase automation - not just China
    - Working with ARMs institute, smart manufacturing
    - Working in conjunction with other foreign research teams
3. **How familiar are you with the China 2025 initiative? Is there interest from the SME4.0 project in China?**
    - Getting in contact with companies
    - Familiar with policy, but not engaged with it
    - Generally interested in any initiatives regarding smart manufacturing and industry 4.0 - looking to collaborate
4. **What stage in evaluating companies is your project at?**
    - Has assessment tool to identify concepts of industry 4.0 - had about 90 metrics
        - 40 methods to assess industries - companies can do a self-assessment
    - Not publicly available - ongoing research,
5. **Are there rubrics/metrics that you are using for determining company's potential for automation?**
    - For each concept - has 1-5 levels of utilization depending on use of automation (uses RFID, QR, etc.)
    - Has a ranking of industry 4.0 concepts that ask companies about which concepts are the most important
    - No definitive metrics for automation - topics are used for ranking

6. **Have you looked into the effects of labor costs on automation importance and implementation practices? Wages in China are drastically increasing causing companies to look towards automated systems.**
    - Big issue - especially in US and Europe, luxury problems with lots of investments - Industries are realizing that outsourcing isn't as beneficial - resourcing to have more domestic manufacturing
        - Harder due to high labor costs - goal to have products cost the same to manufacture domestically than in countries such as China
        - China is having trouble competing with other countries - replacing China with African states - Chinese investors are looking toward foreign countries
        - High impact on industry 4.d0 industries - need high labor cost for welfare, but needs to be smarter than other countries to keep costs
        - Social replacement - unemployment, solutions involve education and training
            - Needs qualified operators, not less educated workers
            - Working with robotics producers that will be in manufacturing companies
        - Chinese investors are looking to buy robotics industries
            - KUKA industries - bought by Chinese investors - moving production to China

7. **Are there axiomatic design considerations for assistive vs. replacive technology?**
    - Will replace common work of unqualified worker - must be qualified to remain in field
    - Keep worker there (at center of production) that has specific skills that robots can't reproduce