

Leading Design and Manufacturing in 2040:

A FOCUS ON MASS CUSTOMIZATION &
HUMAN-ROBOT COLLABORATION

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Frame of Reference

Blue Whale Group is a high-tech, global manufacturing industry with over 100,000 employees located in multiple locations around the world. The company works with clients globally; however, seventy percent of the clients are based in North America. The company currently serves clients from the automotive industry, healthcare, and aerospace industry. Due to growing concerns in the design of complex systems amid a rapidly changing world with many uncertainties that may give rise to unexpected or emergent behavior resulting in more challenges in the design of complex systems. As a big player in the industry, the upper management is concerned regarding the level of preparedness for the future. Also, the company would like to position itself to become a leader in the design and manufacturing industry in the next eighteen years.

Erica, a consultant working for the company, has been asked to prepare a report identifying potential challenges the company may face in the future. This includes identifying how they can continue to meet internal goals and succeed both domestically and globally in design and manufacturing in the year 2040. As such, Erica will need to understand what changes will come about in the next 18 years, and how those changes will influence business practices, individual behaviors, and environmental challenges. Additionally, characteristics of a successful design and manufacturing company will need to be identified. The founding members want to understand which aspects of their current business practices need to be reinforced, and where improvements or changes need to be made. Moreover, Erica will need to define the key research challenges that the company will face in 2040 and detail partnerships and technologies that will help address those challenges.

The World of 2040

Advances in manufacturing technology offer the potential for an increase in competitiveness and economic growth for a company, though the current manufacturing industry has transformed the manufacturing industry by integrating several technologies such as artificial intelligence (AI), cloud computing, robotics, Internet of things (IoT), cyber-physical systems, big data analytics and cyber security to achieve a smart manufacturing industry. By interconnecting machines, devices that can control one another all through the life cycle [1], thereby reducing the intervention of humans in the manufacturing process while increasing mass productivity and performance but failed to manage the growing demand for customization.

Customer engagement has dominated the business dynamics in the world today [2]. Diversity in customer needs has significantly increased with the technological advancements and social media revolution on the internet. These are now a driving force for customized products. For Blue Whale Group to be the front-runner in the manufacturing industry in the year 2040, mass customization should be the focus, in which customers can acquire personalized and customized products according to their tastes and needs. Therefore, it is important to leverage the unique creativity of human experts to collaborate with powerful, smart, and accurate machines; by bringing back the human touch to the manufacturing industry [3]. This will significantly increase manufacturing efficiency and create flexibility between humans and machines which aim to increase production at a rapid pace. It is imperative for Blue Whale Group to merge the high-speed and accurate machines with the critical and cognitive thinking of humans to succeed both domestically and globally in the year 2040.

Characteristics of Successful Company in 2040

With the anticipated and unprecedented level of complexities of engineered systems, and the demand for more personalized and customized products. a successful design and manufacturing company will need the following characteristics to attain economic growth and be globally competitive in the year 2040.

- Ability to provide more specific products, services, and content to every customer.
- Ability to meet the demand and deliver products at a faster pace.
- Human-robot collaborative manufacturing which facilitates the robots and skilled labor to work together to produce customized products and services
- Predictive maintenance ability to reveal and evaluate the uncertainties to estimate the manufacturing capacity and availability.
- Prevention and management strategies that respond to sudden, catastrophic incidents that damage life or property.

- Partnerships with academia and research institutions to translate newly discovered scientific principles into cutting edge technology
- Ability to provide pollution-free manufacturing processes that ensure sustainability by reducing waste generation.

Challenges and Partnership

Challenges

Blue Whale Group in 2040 can deliver the most customized services to the customers through the human-robot collaborative manufacturing process, but some of the potential challenges discussed in this section must be addressed.

Security: As we move towards a more digitized world, the security vulnerability must be double-checked in data handling and utilizing cloud services for diverse user and industrial data management. Security such as integrity, and authentication [4]. Integrity is a primary concern in the perspective of data security as controlling commands and monitoring data will be transferred over third-party networks [5]. The authentication of a huge number of different stakeholders such as machines, IoT nodes, communication nodes, and collaborative partner nodes is a critical requirement to establish mutual trust in the system [6].

Ethical Issues: Ethical issues must be considered while offering customized to the customer. Ethical issues involved with AI adoption must be considered, thereby avoiding possible drawbacks and negative societal impact on its success [7].

Privacy: Data is exchanged over the Internet to connect machines with humans, designers with other collaborators, and to exchange monitoring and control information. Such data must not be visible to malicious users on the Internet to ensure trust in the manufacturing ecosystem both physically and virtually [8].

Skilled Workforce: The major challenge involved with skill space is inadequate trainers in affording proper training to the humans working with collaborative robots. By 2040, the requirement for a skilled workforce will be more as well new technologies will grow, leading to adequate training for both the trainees and the prospective trainers.

Compliance: Bringing back man-force to the factory floor may be effective but practical issues and compliance in merging the human intelligence with the machine must be contained with effective training for both.

Scalability: Scalability is a significant challenge when making the robots or machines, and humans a companion by sharing their workload [9]. Blue Whale Group must be available for offering service at any workload, flexible enough to extend and provide a low-latency response without any data processing delays.

Partnerships

Partnerships In order to meet the challenges, Blue Whale Group will need healthy partnerships with a variety of actors. Most importantly , the company will need to partner with universities and research institutes. This in turn, will be helpful in addressing the research and technological challenges. Novel technology is often derived from a new understanding of the natural world, in other words, new scientific principles. Thus, supporting and promoting research and the discovery of new scientific principles is a worthy investment. Additionally, university affiliations can also serve as a channel for future employees. Blue Whale Group will also need partners within the industry. Finally, the company will need to partner with government agencies for regulations, standards, laws, and guidelines to help define the path forward for human and robot collaboration in the manufacturing industry and to serve as a leader in design and manufacturing.

Mode of Operation

To become a leader in design and manufacturing in 2040, Blue Whale Group must focus on mass customization with human-collaborative robot manufacturing where humans and robots work hand in hand. Collaborative robots are programmable machines but can sense and understand human presence. In this context, the robots will be used for repetitive tasks and labor-intensive work, whereas humans will take care of customization and critical thinking.

For Blue Whale to be globally successful in 2040, it must cultivate leaders who are not simply defined by their excellence and expertise in the field, but rather by their ability to inspire others to pursue a goal larger than themselves. As such, the organizational structure and design philosophy of Blue Whale Group must support not only delivering the best product to clients but also inspiring others to make a change for the greater good. Leaders must not only have professional and financial responsibilities to their clients and employees, but also an ethical and moral responsibility to society at large.

The driving principle of this high-tech global design and manufacturing enterprise must be cloud manufacturing. It's an innovative way to transform the traditional manufacturing model into an advanced manufacturing process by incorporating the latest technologies such as cloud and Edge Computing, IoT, and service-oriented technologies. In this manner, the designers are allowed to place their manufacturing plants closer to the raw material and countries where manufacturing cost is lower. Here, the control of the machines in the plant and the operations of the manufacturing life cycle, such as service composition and scheduling are handled by the cloud [10].

The monitoring and scheduling facility will serve as regional and global headquarters for Blue Whale Group since they will be situated in a few locations around the world. The distinguishing features of cloud manufacturing include reliability, high quality, cost-effectiveness, and on-demand capabilities. In addition, it has a positive impact on the environment as cloud manufacturing can eliminate the long-haul delivery requirements of raw materials for the manufacturing process. Fig. 1 illustrates the multinational collaborative nature of a typical cloud

manufacturing environment. Cloud manufacturing allows the designers to protect their intellectual components such as design files of manufacturing items by storing them in the cloud with robust access control and utilizing the manufacturing resources spread across different geographical regions.

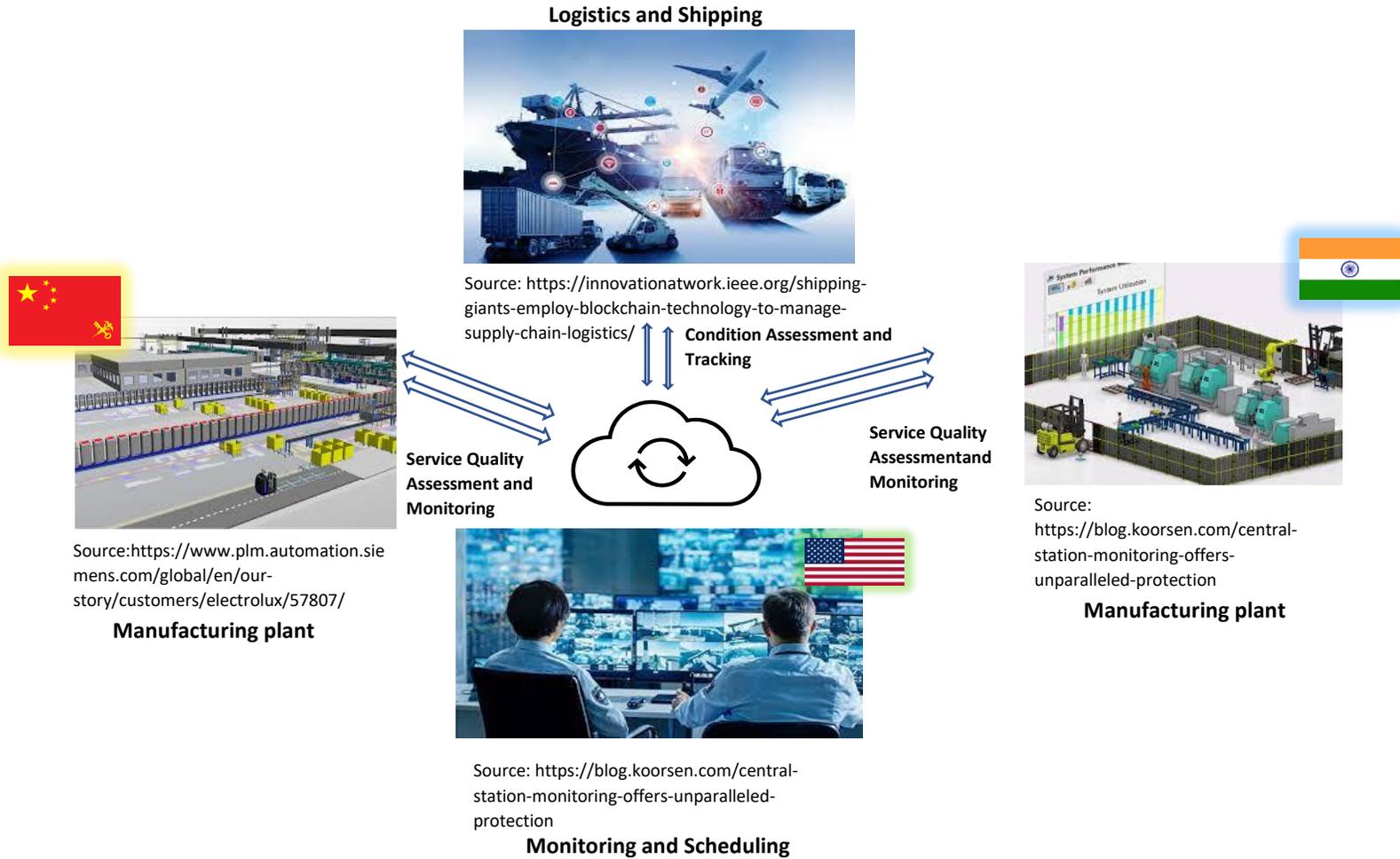


Fig 1: The Cloud Manufacturing environment

Facilitating Technologies

Several facilitating technologies such as Edge Computing (EC), Digital Twins (DT), Internet of Things (IoT), big data analytics, collaborative robots, 6G, and blockchain are integrated with cognitive skills and innovation that can help Blue Whale Group increase production and deliver customized products more quickly.

Edge Computing: The growth of the IoT and the provision of several cloud services have introduced a new concept, EC, which enables data processing at the network edge. EC can meet the expectations of Blue Whale Group related to latency costs, response time requirements, data protection, and privacy [11].

Digital Twins: A digital replication of a physical system is called a DT. Through IoT devices, the data from the physical system are fed to their digital counterpart for simulation. This mapping of real-time systems digitally through DT makes it possible to analyze, monitor the digital version, and prevent the difficulties before they occur in the real world [12].

Collaborative Robots: Collaborative robots are robots designed to work collaboratively with humans, and this collaboration helps to make human capabilities more efficient, and extremely easy to automate for individuals and manufacturing industries than ever before. Collaborative robots are usually embedded with sensors and are highly responsive to the detection of unpredictable impact, which gives them the ability to stop spontaneously when human workers detect any misplaced objects in their path. This tends to make them extremely reliable when it comes to safety at work compared to standard industrial robots [13].

Internet of Things: IoT is a connected link between people, processes, information, and things. IoT can provide significant value for the establishment of new opportunities for future manufacturing applications [14]. The use of IoT in the manufacturing industries provides an opportunity to minimize operating costs by eliminating bottlenecks on communication channels and reducing latency.

Big Data Analytics: Big data analytics represents a large and diverse set of data collected from all types of sources. Big Data Analytics tends to play an important role in the manufacturing industries to better understand consumer behavior to optimize product prices, focus on improving production efficiency and help reduce overhead costs [15].

Blockchain: Blockchain technology can offer significant value additions in the future Industry by enhancing security and privacy of data shared between organizations, individuals, and information systems. Centralized management of many diverse connected devices in the future Industry is a critical challenge. Blockchain can be used to design decentralized and distributed management platforms by enabling distributed trust [16].

6G and Beyond: With the vigorous growth of smart infrastructure and potential applications with current networks, it will not be possible to meet rapidly increasing bandwidth requirements. The use of 6G and beyond in the manufacturing industries makes it possible to deliver better latency, support high-quality services, as well as extensive IoT infrastructure and integrated AI capabilities [17]

In addition to integrating several latest technologies like IoT, edge computing, collaborative robots, 6G and beyond, digital twins, big data analytics, etc. with the machines, the intelligence of the humans is needed in Blue Whale Group when making decisions. The human-robot co-working ability of future industry utilizes the intelligence and decision making of humans, supported by key-enabling technologies, helps in achieving mass personalization like never before across several sectors

Path to 2040: Research Issues worthy of Investigation.

- Research and development on relationship building and organizational behavior between humans and collaborative robots.
- Research and development on ethical issues associated with collaborative robots.
- Social science research on humans adopting a new way of working
- Development and implementation of collaborative technology to keep a global workforce connected and engaged.
- Developing a smart, safe, and user-friendly information processing system.

Research in these areas will need to be conducted in partnership with academic institutions, which will support the furtherance of scientific inquiry in terms of human-machine collaboration.

References

- [1] L. D. Xu, Industry 4.0 – frontiers of fourth industrial revolution, *Systems Research and Behavioral Science* 37 (4) (2020) 531–534.
- [2] Muehlbauer, P. (2017). Mass Customization the Global Mega-Trend. <https://www.linkedin.com/pulse/mass-customization-global-mega-trend-philipp-muehlbauer/>
- [3] S. Nahavandi, Industry 5.0 – a human-centric solution, *Sustainability* 11 (16) (2019) 4371.
- [4] P. Porambage, G. Gür, D. P. M. Osorio, M. Liyanage, A. Gurtov, M. Ylianttila, The roadmap to 6G security and privacy, *IEEE Open Journal of the Communications Society*.
- [5] X. Xu, From Cloud Computing to Cloud Manufacturing, *Robotics and computer-integrated manufacturing* 28 (1) (2012) 75–86.
- [6] M. Liyanage, A. Braeken, P. Kumar, M. Ylianttila, *IoT Security: Advances in Authentication*, John Wiley & Sons, 2020.
- [7] B. C. Stahl, Ethical issues of ai, *Artificial Intelligence for a Better Future* (2021) 35
- [8] L. J. Wells, J. A. Camelio, C. B. Williams, J. White, Cyber-physical Security Challenges in Manufacturing Systems, *Manufacturing Letters* 2 (2) (2014) 74–77.
- [9] D. Kiran, I. Sharma, I. Garg, Industry 5.0 and smart cities: A futuristic approach, *European Journal of Molecular & Clinical Medicine* 7 (8) (2020) 2750–2756.
- [10] Y. Liu, X. Xu, L. Zhang, F. Tao, An Extensible Model for Multitask-oriented Service Composition and Scheduling in Cloud Manufacturing, *Journal of Computing and Information Science in Engineering* 16 (4).
- [11] W. Shi, J. Cao, Q. Zhang, Y. Li, L. Xu, Edge computing: Vision and challenges, *IEEE internet of things journal* 3 (5) (2016) 637–646.

- [12] Y. Lu, C. Liu, I. Kevin, K. Wang, H. Huang, X. Xu, Digital twin-driven smart manufacturing: Connotation, reference model, applications and research issues, *Robotics and Computer-Integrated Manufacturing* 61 (2020) 101837.
- [13] A. C. Simões, A. L. Soares, A. C. Barros, Factors influencing the intention of managers to adopt collaborative robots (cobots) in manufacturing organizations, *Journal of Engineering and Technology Management* 57 (2020) 101574.
- [14] X. Li, L. Da Xu, A review of internet of things – resource allocation, *IEEE Internet of Things Journal* 8 (11) (2021) 8657–8666. doi:10.1109/JIOT.2020.3035542.
- [15] E. Hämäläinen, T. Inkinen, Industrial applications of big data in disruptive innovations supporting environmental reporting, *Journal of Industrial Information Integration* 16 (2019) 100105.
- [16] W. Viriyasitavat, D. Hoonsopon, Blockchain characteristics and consensus in modern business processes, *Journal of Industrial Information Integration* 13 (2019) 32–39.
- [17] M. Z. Chowdhury, M. Shahjalal, S. Ahmed, Y. M. Jang, 6G wireless communication systems: Applications, requirements, technologies, challenges, and research directions, *IEEE Open Journal of the Communications Society* 1 (2020) 957–975.