



Evolution of the PC Industry and Role of Data Analytics

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Abstract. The personal computer industry (PC industry) is a global industry that sells PC products to consumers. Since World War II, according to people's needs, the personal computer industry has developed in different stages. With the intensification of market innovation and competition, data analytics has gradually been applied to this industry. In this article, we first explore the history of computer and an overview of current PC industry. Then, the value chain of the PC industry includes product research and development, manufacturing and supply chain, marketing and sales, logistics, and after-sales services. Next, we will analyze the application of current data analytics access based on the PC industry value chain. Finally, the future directions and advanced applications of the PC industry will be examined.

Keywords: PC, business, analytics, market, future

1 Introduction

The future is not an extension of the past, but history provide listens that helps shape the future.

1.1 The History

The history of the PC industry could be traced back to post World War II. At that time, the US army needed to do a tremendous amount of work to calculate trajectories for different types of shells. Although they employed hundreds of researchers, it was stressful for them to do such complicated work every day. For example, on the average, it took a human 20 hours to calculate a trajectory by using mechanical calculators. Worse, tiny mistakes could affect the results and turn success into failure. In order to boost efficiency and improve the accuracy of calculation, ENIAC (Electronic Numerical Integrator and Computer), the first programmable general-purpose digital computer was

born in 1946. “With more than 17,000 vacuum tubes, 70,000 resistors, 10,000 capacitors, 6,000 switches, and 1,500 relays”, this complex machine could calculate a trajectory in only 30 seconds [1]. Unlike today’s cell phones or laptops, this computer was specifically invented to serve the war. Although it was not the first computer in the human history, it opened a new era of replacing human-based calculation with computer driven scientific computation.

Shortly thereafter, the world’s first commercial computer UNIVAC (Universal Automatic Computer) was released in 1951. On the foundation of ENIAC, UNIVAC could not only perform scientific calculation, but also do data retrieval. Because of this, it was sold to the American government to be used for complex calculation and for conducting national census [2]. Thereafter, computers moved out of experimental labs to serve people and companies – they began to drastically change human lives.

As time went on, computers became much smaller and more affordable to meet daily needs of common people. By the 1970s, The Kenbak-1 was designed by John Blankenbaker. It was first sold in early 1971. This computer was considered to be the world's first "personal computer" placed in the Computer History Museum in 1986 [3]. It shaped the foundation for mass-produced personal computers during the 1980s.

TRS-80, released in 1977 by Tandy Corporation was one of the earliest mass-produced retail home computers. Because of its small size, only 1.54 kilogram of weight and a relatively affordable price (599.95\$ minimum or about \$5,100 in today's dollars), it was widely accepted by consumers from the ‘70s to the ‘80s. APPLE II was also a successful product at that time. Compared with the TRS-80, it was offered at three times the price. However, it was much more powerful. For instance, it could display color images, which was a remarkable achievement at that time [4]. As a result, it brought huge profit to APPLE computer at very early stage.

IBM company released its personal computer (model 5150, commonly known as the IBM PC) in 1981. At that time, companies always kept the design of their PCs as a secret. However, IBM broke this rule with detailed instruction and technical manual for their customers. IBM aimed to let its consumers know how to use the IBM PC directly [5]. Consequently, the IBM PC could not only be used in Laboratories to do data collection and analytics, but also in schools and by families. Since then, people started to purchase PCs for working, entertaining, and gaming.

1.2 Current Business Dynamics of PC Industry

Today, several big companies with different strategies monopolize the whole PC industry. In 2019, Lenovo led the PC shipments with 62.97 million units. In the same year, “Lenovo, Hewlett-Packard, and Dell dominated over 60% of the market share of the PC industry” [6]. Lenovo competes on pricing and is focusing on the middle-class consumers, while HP with better-customized PC products targets consumers from all classes. Lenovo continually invests in innovation of their PCs (e.g., first 5G PC ever made, the Lenovo Flex 5G [7]), while HP continually improves product function like the unique eye-care screen and AI-driven audio optimization [8]. A market trend worth pointing out is the PC in the gaming industry seems to be growing rapidly. Not only

monopolizing firms like Lenovo, HP, and Dell are working hard in the gaming PC industry. Less dominated firms like ASUS, Acer are promoting their Gaming PC like ROG series or Nitro 50. Gaming PC industry requires less development on the CPU, instead, they usually spend more on screens with higher refresh rate or on the graphic capabilities.

Table 1. Shipments and market share of PC companies in 2019

Rank	Company	2019 Shipments (million)	2019 Market Share (%)
1	Lenovo	62.97	24.1%
2	HP	57.92	22.2%
3	Dell	43.96	16.8%
4	Apple	18.35	7.0%
5	Acer	14.76	5.7%
6	ASUS	14.48	5.5%

1.3 Priorities and Challenges of PC Industry

In 2020, “31.8% of retail sales occurred on online platforms” [9]. This scenario is mainly due to the covid-19 lockdown and the rapid development of the Internet. Retail stores now face a real challenge where most consumers buy their PC online. That is, “retail sales activities decrease while giving a boom to online sales” [10]. Additionally, the pandemic caused an increase in the costs of transportation, human resources, distribution, and supervision. The low supply of important PC components caused a shortage of PC products and significantly influenced the sales. 51.6 million PC units was shipped in the first three months of 2020, “it is 12.3% lower from the previous year” [11]. As a result, most PC companies currently consider building a safe and efficient manufacturing and supply chain as their primary purpose. The main reason for this is that dealing with the supply chain is a powerful solution for short-term problems.

2 The Value Chain of the Computer Industry

The values of the computer industry include different stages of generating values, most of the companies within the industry have been using a similar process.

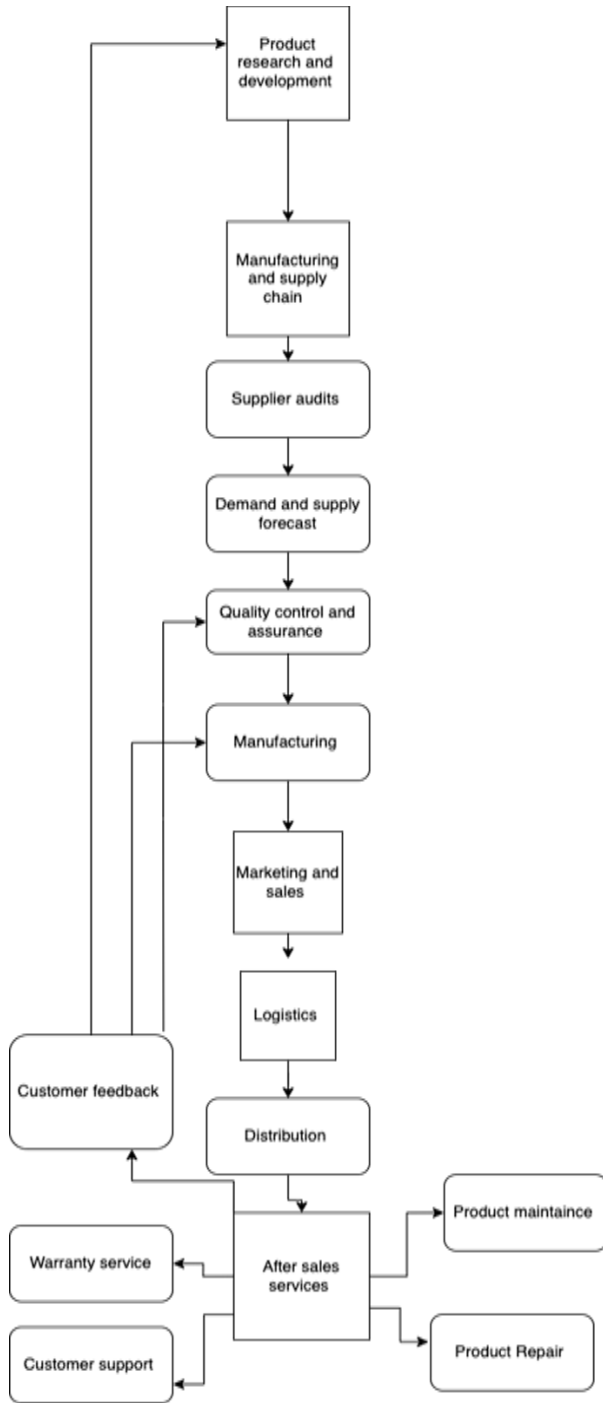


Fig. 1. Value chain flowchart example by Huai-Chung Yeh

2.1 Product Research and Development

Product research and development refers to the activities carried out by the company to innovate, launch new products, or improve existing products. Usually, these activities include market research and analysis (before manufacturing), and product design including the development of new features. Companies in the computer industry use this process to stay competitive in the market, staying ahead of other companies within the market. Companies such as Lenovo, which has been run in the computer industry market for decades, are willing to spend a significant amount of money on R&D; according to Lenovo's Annual and Quarterly Reports in the fiscal year 2017-18 the cost of R&D for Lenovo was 1.3 billion dollars [12].

2.2 Manufacturing and Supply Chain

After designing and component selection, the process before manufacturing companies would start to manufacture products, using components from suppliers to assemble the products.

When planning components orders, supplier audits will allow companies to evaluate the efficiency and stability of suppliers. Following this step will help the companies avoid some potential risks such as out of components. At the same time, it enables the implementation of operational and strategic targets. According to Apple's website, Apple was believed to be the first company who ever audited its facilities for social responsibility compliance in 2010 and the company has avoided many uncountable law and humanitarianism risks [13].

After supplier audits, the suppliers will supply the components to manufacturing. Quality control and assurance is a process of controlling the quality of the products [14]. Quality control and assurance are two different processes. Generally speaking, quality control aims to figure out the defective products and correct them, quality assurance is about avoiding the defects and managing the quality. The process includes a quality report which demonstrates the quality of the product. The report is helpful in concluding and understanding the product's quality control and assurance [14]. Usually after this process the products are qualified to be sold on the markets.

The demand forecast is a forecast of the company's demand for products or components mainly used in optimizing production, including current and projected demand by industry and product end-use. Supply forecast: it is a collection of forecast data about current manufacturers and suppliers, trends of technologies, and factors that may affect supply. Demand and supply forecasting is rigorously used in the PC industry: According to Intel's official website, demand and supply forecasting are based on the most similar predecessor which relies on different variables such as price [15]. In addition, understanding market segments helps Intel create different manufacturing plans for different situations.

2.3 Marketing and Sales

Marketing is the process of making strategic decisions of exploring, creating, and meeting the needs of a target market for products or services. This process includes promoting, advertising, and delivering products to consumers or other businesses. Marketing is critical to survival and growth of all product-based companies and the PC industry is not an exception. Companies invest considerable funds to support the marketing process. According to Apple's financial report in 2015 apple used about 1.8 billion to advertise apple products and which got them 234 billion dollars for iPhone products, compare with last year, the cost to Apple has increased by about 50%, because marketing is the "key" to help increase sales, different companies like to use different image endorsements to represent different product lines [17]. For example, Intel chooses to sponsor CS: GO professional team Cloud9 to represent their gaming product line, this strategy is a very common strategy used by the majority of companies in the computer industry such as MSI, Dell, and Lenovo. The strategy has been proved useful and successful in these companies.

2.4 Logistics

Logistics is the overall process of managing how different resources are acquired, stored, and moved to their final destinations [18]. Logistics management includes identifying potential distributors and including acquiring components from suppliers and determining their effectiveness and accessibility. This process usually involves transportation, for example, "transportation of product to the consumers or distributors".

Distribution is the process of transporting items to different places. Distribution could be supplier transporting components to factories for assembling, transporting products to warehouses, retailers, or even to customers. Normally speaking, the distribution could be divided into different channels. according to Hitesh Bhasin "Intel follows different distribution channels for a different set of customers or products" [26], Intel uses retailers, resellers, and e-commerce to distribute values, products, or services to the customers.

2.5 After-Sales service

To ensure customer satisfaction, services are provided to customers after the product has been purchased [19]. In the PC industry, it usually includes operational guidance, warranty services, and maintenance which could be rendered by manufacturers, retailers, and/or third-party platforms. After-sales support is also considered a business strategy in the PC industry. The better support they offer, the higher satisfaction they receive from their consumers [19]. Consequently, companies could win higher brand loyalty and a better reputation with great after-sales service [19].

3 Current applications of Data Analysis across the value chain.

Overtime to improve processes and enhance profit making, PC companies have relied on applications of Data Analytics across the value chain.

3.1 Applications of Data Analysis in Product design and development

Nowadays, some technical methods also make some contributions to the product design and development. Because of the massive demand of chips used in PC, Intel had applied the Neuromorphic method to their product, in order to enhance learning and adaptation capabilities. For example, Loihi 2, the latest chip developed by Intel, had increased the processing capability about 10 times than the last generation, and with up to 1 million neurons with 15x greater resource density.[20] With this new chip, a new, open-source software framework called lava was opened to the public. Mike Davies, the director of Intel Neuromorphic Computing lab, said Loihi 2 is really good at dealing with sensible tasks, such as sight and smell. And because of the efficient processing power that ordinary chips do not have, it can be used on PC devices.

3.2 Applications of Data Analysis in Supply chain and Logistics

Due to the large scale and complex production system of manufacturing supply chain, Lenovo has created their own AI solution to optimize the supply chain. Lenovo has applied a reinforcement learning model to improve the performance of production scheduling. For example, the duration of planning process in supply chain is cut from 6 hours to just 90 seconds during the manufacturing. As a result, it helps to boost the efficiency and reduces the workload of Lenovo employees. “After 2019, this solution helps Lenovo increase revenue by more than 4.6 billion USD in total [21]. Lenovo also implements its Mark III system into the supply chain in 2018. Lenovo develops the system with machine learning, and it is capable of checking and testing the product quality simply by scanning the product line. This system improves the manufacturing quality and decreases the labor costs. Not only Lenovo, but Apple also uses its historical data with the analysis of machine learning to predict the sales. Thus, the data generated could be used to adjust manufacturing plans to maintain an equilibrium of the supply chain and the demand.

3.3 Applications of Data Analysis in Sales & Marketing

In the past, sales & marketing staff had to use manual search, physical outreach, and surveys to find prospective customers and potential demands. Requiring them to constantly keep current with changes in a wide variety of information sources causing massive waste of manpower and time.

Today, machine learning, deep learning, and reinforcement learning are used in sales & marketing. For example, Intel developed an AI system that could mine millions of

public business web pages in order to distinguish between different types of consumers and then identify them. Because of this, they are able to discover needs in different industries much faster and more accurately than using traditional methods [22]. HP developed a partnership system, Navigator, in 2017 to improve its marketing and sales efforts. It was a machine learning system that has been used to analyze the partnership data of HP, including current profiles, sales, training data, etc. This system improves the partner engagement in distribution channels with guidance from managers.

3.4 Applications of Data Analysis in After sale services

At present, AI has already been applied to the PC industries after sales service. For instance, Lenovo created its AI-powered customer service named Xiaole, which is capable of understanding customers' questions and offering them solutions. For example, if customers encounter some technical problems, they could just provide some key words to simply describe the situation to Xiaole. With the application of advanced Natural Language Processing (NLP) online, customers could access to personal service whenever they want. Also, it could learn from their customer conversation and adjust its performance and make the service more personalized and customized. In this way, this smart support has led to higher customer satisfaction. The official website of Lenovo services showed that about 99% customers were satisfied with Xiaole's service. As a result, it helped Lenovo gain a better reputation and let their products be more competitive.[24]

4 The Direction of Change & the Future.

Today, while the whole PC industry is growing rapidly, the gaming PC industry is expanding even faster in the end of current business dynamics. According to TechSpot, "there was a more than 25 percent of revenue (\$5.74 billion) increase on PC gaming hardware in 2021" [25] However, with the increase in total sales of gaming hardware, it might lead to a problem of decreasing consumer satisfaction. That is, some consumers may lack perfect knowledge of gaming computer configuration. As a result, they cannot get the best experience from purchasing. Therefore, a dvanced analytics on product development may be applied to solve this problem.

4.1 Advanced Analytics Applications

The application of artificial intelligence in the personal computer industry has always been of great significance. Deep learning, machine learning and algorithms based on human thinking and psychology are created to expand the target consumers. For example, PC companies aim to get more profits from different consumer groups. They may want consumers to purchase different PC products for their own purposes, such as converting gamers into consumers.

As we mentioned above, many consumers cannot get the right computers themselves because they are not familiar with the configuration of computers. So, it is hard for

them to make a choice from so many different types of PCs. Also, acquiring relevant knowledge is a tiring and time-consuming work.

However, companies could solve this problem fundamentally during the product development. In the future, computer chips are going to be more powerful based on neuromorphic computing. By imitating the human brain and nervous system, the computer could manage to do real-time learning without analysing large sets of data in advanced. For gaming, with neuromorphic chips and the reinforcement learning system, PC could keep up with users' demands in only several seconds based on the data analytics application of facial expressions to learn the emotional feeling of customers when they prepare to play video games.

For example, before using the ASUS computer to play games these days, customers always need to open an application called "Armory Crate" to adjust the mode and the Game Visual manually in order to get a better game experience. However, in the future, the computer could know human emotions and thoughts by analysing the facial expressions in advance and then alter the configuration simultaneously by neuromorphic computing and reinforcement learning itself. This could improve the consumers' satisfaction and let their advanced PCs be more competitive in the market.

Additionally, PC companies could potentially use advanced analytics to further improve their sales process. Most games show their minimum or best PC requirement on the game platforms such as Steam, Epic, Ubisoft connect, etc. The requirements influence the choice of gaming PCs. Therefore, the PC companies could collect and analyse the PC demand data for different games from various channels such as social media, the internet, etc. Firms could find the potential wanted PCs through deep learning and machine learning of the data collected. Thus, firms could post advertisements on account-related social media to meet the demand of potential customers for gamers' PC systems. This marketing & sales strategy could increase sales of gaming PC from gamers where gamers could have an easier and better purchasing experience. Thus, more purchasing would be happening.

5 Conclusion

To conclude, the PC industry is experiencing both challenges and faces future opportunities. For one thing, the PC industry currently encounter problems and challenges like the low shipments and low retail sales. For another thing, through advanced analytics, future opportunities like the gaming industry are likely going to promote more sales of gaming PC. On top of that, the PC industry uses different types of analytics in everything of its value chain which makes the whole industry energetic and prospective. Finally, in our opinion, the PC industry is a promising industry that promotes the development of technology, and it is worth investing on.

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