Chapter 2
Advancement in Science and Technology and Human Societies

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Abstract As the phrase civilization of science and technology suggests, modern societies are built on top of highly sophisticated advancement of science and technology. This chapter reviews how societal safety sciences relate to problems in human societies and overviews challenges in modern societies.

Keywords AI · Automobiles · Elevators · Information security · Power generation · Railway · Vulnerability

2.1 Advancement in Science and Technology and Changes in Human Societies

2.1.1 Human History and Transition of Population

This section overviews characteristics and problems of modern societies from the viewpoint of human history. A view over characteristics and problems with a subject, from a level higher than daily viewpoints and metrics, is an imperative preparation for scientific discussions in societal safety. Modern societies have plenty of debates in whether to accept or deny senses of values or technological evaluations; thus, having the habit of taking long-term overviews over discussions with different viewpoints and metrics is worthwhile. This act resembles looking for the Polar Star when lost. The Polar Star does not show which direction to take; however, it is a guide for us to confirm which direction to head into after all.

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S. Abe et al. (eds.), *Science of Societal Safety*, Trust: Interdisciplinary Perspectives 2,
https://doi.org/10.1007/978-981-13-2775-9_2

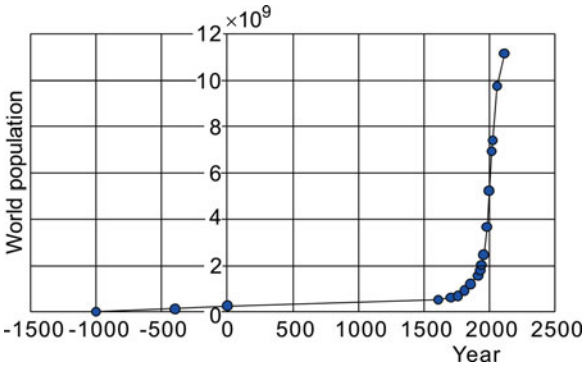

Fig. 2.1 Transition of world population. (Drawn based on the data of UNEP 2011)

In general, growth and decline of population are said to represent the ups and downs of societies. We will start our discussion with the transition of world population (estimate) in Fig. 2.1. The world population with nearly a flat small growth for years, throughout the long human history, shows a rapid increase in recent years.

Despite this rapid rise in population, if we now divide the worldwide food production by our population, the amount exceeds what we need per person. This means, although it is an over simplified calculation, the modern society has secured an ample supply of food and we are enjoying the prosperity. Our population only showed slow increase for a long time until the industrial revolution; thus, modern scientific technology has made large contribution to increasing our food production.

Our current birth rate shows a decrease; however, our longer lives resulted in United Nations' projection announced in June of 2017 that the world population would reach 9.8 billion in 2050 and 11.2 billion in 2100. Science and technology will keep advancing into our future; however, when we recognize that habitable space on earth is limited, we need to feel the higher sense of crisis toward the rapid growth of population.

The key in projecting how the world population will change in the future is how we interpret the transition of shifting into rapid increase. Statistics show that our population showed such transitions twice in the past. The first such point was the eighteenth to nineteenth centuries when the industrial revolution started, and the second point was the 1950s to the 1960s after World War II. The time after the industrial revolution to today is a short period within the long history of mankind. Factors that led to rapid population growths during these years were the energy revolution and power revolution. In the rest of this chapter, we will overview the energy revolution and power revolution in relation to the increase in food production that directly contributed to the rises in population.

2.1.2 Background of Population Increase During Early Stages of Industrial Revolution and Its Historical Meaning

United Nations Department of Economic and Social Affairs showed that the world population at 580 million in 1600 increased to 680 million in 1700 and 790 million in 1750. Once the industrial revolution started, the growth rate rose further, and the world population reached 980 million in 1800, 1.26 billion in 1850, and 1.65 billion in 1900. The rate is clearly different from that up to the sixteenth to seventeenth centuries.

The industrial revolution started in the mid-eighteenth century in the UK. Its driving forces were "inventions of machines" and "invention of steam engine" that used coal for its power source. Especially improvements of spinning machines and Cartwright's power loom powered by a steam engine greatly improved the industrial production centered around the cotton textile industry. The movement required factory workers and large capital. Around the eighteenth century in the UK, Norfolk four-course crop rotation, that allowed agricultural production throughout the year, started to spread over the three-field system and led to tremendous increase in agricultural production. This "agricultural revolution" made population growth possible and secured sufficient labor for the industrial revolution. The nineteenth century saw advancements of heavy industries, like the machine, steel, and coal industries, and new ways of transportation like steam boats and locomotives, to allow mass transportation of material and products.

During the mid-nineteenth century, the industrial revolution spread to other west European countries starting rapid industrializations in Germany and France. The revolution triggered colonialism in the late nineteenth century among the countries that wanted their hands-on cheap material for industrial production and looked for new market development to sell their products. The colonization race among the empires led to World War I in the twentieth century.

2.1.3 Problems We Face in the Modern Society

The world population kept growing into the twentieth century. The count 1.65 billion in 1900 kept rising at a rate of about 0.6% a year to reach 1.86 in 1920. After World War I, the annual rate increased to about 1% pushing the world population to 2.07 billion in 1930 and 2.54 billion in 1950. After World War II, the rate further rose to about 2% a year, and the population exploded to 3.7 billion in 1970 and 5.3 billion in 1990. Later, the rate dropped; however, the population kept growing to exceed 7.0 billion at the end of October 2011 and reached 7.4 billion at the end of May in 2017.

The primary sources of energy and power during the early stages of the industrial revolution were the combinations of coal and steam engines, but they drastically changed after World War II. People developed new energy sources of oil, natural gas, and nuclear material like uranium. The use of methane hydrate is now catching the attention as the energy source for the future. Machines to produce power started with the external combustion-type steam engine, and later human invented the internal combustion-type gasoline and diesel engines. Automobiles with the internal combustion types spread around the world, and the societies developed modern traffic management systems. We then moved on to invent motors in a variety of sizes that use electrical energy. Then the development of technology to distribute electricity led to its application in all aspects of our activities like production and transportation to consumption areas, and productivity, our lifestyles, and convenience were all improved. As a result, the lifestyle in advanced countries turned to the modern style of mass production and mass consumption.

The latter half of the twentieth century, as it is called the green revolution (Hesser 2006), was the time when mass production of grains started. Mexican wheat and Indian rice are well known. As we explained in Sect. 2.1.1, the world is producing food in an amount that far exceeds what are needed for the entire world population. The development of high-yielding varieties largely made possible a big increase in grain production. In addition, securing irrigation water, development of fertilizers and pesticides, and farming machineries to cover huge farming fields all contributed to the increased production. Crop breeding today has even started to reach into the genes. An increase in food production also affected other fields including chemical industries of pesticide, fertilizer, and food additives, civil construction industries of irrigation water management, machine industries of manufacturing farming machineries, and transportation industries of transporting the products.

On the other hand, we are faced with a number of problems we cannot ignore as the negative side of developing new technologies. They are the problems of environmental contamination caused by pesticide and fertilizers, pesticides for long post-harvest transportation, and food additives. These problems are new concerns with food safety fundamentally different from the food problem of famine in the old days. Developing new technologies always involve risks. We are at a stage where we have to rethink how far we want to take the food production technology with these risks.

Mass production and mass consumption result in mass disposition. The world started to recognize the problem of waste around the 1970s together with the other problems of environmental destruction and resource drainage. These problems of the modern societies that affect our environment may lead to concerns with the global environment and harsh weather conditions due to global warming. Nuclear power generation, once expected to be free of drainage in its breeding principle, is no exception. The delay in developing technologies for nuclear waste management and environmental contamination caused by NPP accidents further add to the complication in discussing energy resources.

UN Food and Agriculture Organization (FAO 2017) reports that about 815 million people in the world suffer famine in 2016 (777 million in 2015). The number is less by 132 million than 947 million in 2003; however, 1 out of 9 of the world

population is struggling with famine. The modern world is under a complicated situation with "societies suffering malnutrition" and "societies that enjoy excessive supply but suffer health problems from the satiation" that share the same earth and tightly relate to one another. As globalization makes progress, gaps between the rich and poor are spreading over the world. We need to start building global systems to eliminate the gaps of famine and wealth by stepping over the differences in culture, religion, and political systems.

Modern societies are built on top of energy and power from production, transportation, and consumption to waste disposal. For us to make use of resources and energy forever, we need to make fundamental changes to the way of human activities. There is a movement in Europe that claims the need to construct sustainable societies; however, the reality is that only few people recognize the need. We have not yet developed the technologies to make sustainable use of energy and power. To make the changes in our modern societies, we have to first acknowledge that forms of modern production and life are overly dependent on energy and power, and then we need to start active discussions on creating new sustainable styles of life and production.

2.2 Birth of Megacities and High-Speed Mass Transportation

2.2.1 Modern Societies and Megacities

About 10,000 years ago, when human settled and started farming, the communities faced the need for controlling large-scale erosion and flooding. Thus, human formed cities as the hub for politically organizing regions. People that control and use relatively stable supply of storable excessive products lived in the cities. The concentration of people led to large buildings, culture, and civilization and gave authorities to the controllers in the cities. Concentration of people, on the other hand, gives rise to risks of epidemics, fires, and famine. City sizes, thus, had their limits with populations about 100,000 on lands with diameters of 1–2 km. Exceptions like Edo (now Tokyo), during the seventeenth to nineteenth century with a population of about 1 million within a radius of 4–5 km, went through multiple occurrences of fires and epidemics.

The start of the industrial revolution in the late eighteenth century led to development of manufacturing industries, and their productivities made great leaps with cooperation and division of labor among people in the cities. The movement changed cities from controllers of excessive stocks to manufacturing cities. In addition to controlling and consuming excessive farming products, people in the cities started to produce properties and services and consume them. The disadvantages of epidemics and fires caused by concentration of people were then controlled with advancement in medicine and construction of social infrastructures. The

development of new ways of transportation eliminated spatial limitations, and outskirts of cities went through rapid expansions, to bring populations of the areas up to 1 to several millions, and in the twentieth century, megacity areas with populations that exceed 10 million emerged.

Functions to control societies in the cities, on one hand, were pushed aside by decentralized market-driven economics; however, on the other hand, the cities still needed central controllers to manage complications from multiple decentralized systems. Cities were the hubs to control regions, and with the advancement of people's economics, they turned into structural elements for people's nations and went through reorganizations.

Jacobs claimed that instead of being built after national economics, city economics grew by taking on functions that national economics could not control. Economic activities grow by innovation, and for healthy growth, corporations within a city have to execute their creations within creative and cooperative networks. National economics expand when a corporation within it innovates a new value. Without it, national economics will decline. Jacobs clearly showed the gradual influence of innovation within a city extending to the surrounding regions and eventually leading to advancement of the national economy (Jacobs 1984). The advancement of global economy is casting light onto this argument through re-recognition of surplus management function and creativity of cities.

2.2.2 Transportation Systems That Support Modern Societies

The transportation system is one of the social infrastructures in modern society that takes for granted ways for repeatedly and regularly transporting people, products, and information in massive quantities. Railways and steam boats were the main players in the nineteenth century, and in the twentieth century, automobiles expanded the range of people's daily livings and airplanes made the world narrower. Especially railways and automobiles made great changes to cities.

The railway was born in the nineteenth century as steam railways to connect cities. Within cities in Europe and the USA, horsecars debuted in the early nineteenth century which were taken over by electrically powered trams later in the same century. Cities, where people used to travel on foot, showed gradual increase in their spatial spread. Geographical spread of cities led to further concentration of economic activities and then even bigger expansion of city coverages. People who disliked city-specific problems that came with concentration of people moved out along railways extended to the outskirts and started to commute on railway networks. City areas then radially grew to radii over 10 km adding further complication to their problems of large-scale and dense population. Howard, in his theory of garden cities, suggested to link midsized cities with railways to resolve problems with overpopulated large cities (Howard 1902). The movement, however, whether intended or implemented without plans, led to giving birth to megacities with radii of tens of kilometers.

People started to buy automobiles after Ford's Model T debuted in 1908. Narrow roads and public transportation already in existence delayed their acceptance to city areas; however, the people and economics of cities were attracted to them, and every city started to construct road networks and build parking areas. The constructions, however, could not catch up with the rapid growth of the number of automobiles. People, with their automobiles, started to move to suburbs without railway service. Spatial expansion of cities overloaded road facilities. Developing low-population cities to lessen the load on roads made city areas grow even wider. The cities that used to grow radially then kept growing like galaxies into sizes that even exceeded radii of hundred of kilometers. When cities expand, the original attraction of them is lost. Today, we can probably say that there is no city free of problems related to automobile transportation.

Modern megacities are supported by two types of transportation systems: the railways and automobiles. There is another means of transportation always in place within megacities, and that is the elevator. Without elevators, skyscraper buildings cannot be built. Le Corbusier (1933) was the first to discuss the importance of them in his book "La Ville Radieuse (The Radiant City)," also known as "The Vertical Garden City." The reality of modern megacities with large numbers of skyscrapers built in random manners is not what he idealized; nevertheless, elevators are indispensable for them.

2.2.3 Disasters and Vulnerability of Megacities

Concentrated population is one of the attractive features of a city; however, it is also a factor of expanding the magnitude of damage in case of natural and social disasters. There have been a great number of cases where cities were attacked by large fires or serious epidemics as well as many cases of large city damages caused by natural disasters. The case of disaster in Pompeii in ancient Rome is well known, but more recently, for example, the 1755 Lisbon earthquake devastated the city of Lisbon and is said to be a factor for the decline of the Kingdom of Portugal. Rousseau, who lived in the same time, claimed that the damages would had been smaller if people were more scattered with less property. He emphasized the man-made disaster aspect of earthquake damages pointing to the large condensed population and people, to protect their properties, not fleeing (Rousseau 1756). There are plenty of other cases of natural disaster attacks on cities, and every time, people suffered great damages. These cases put us into deep contemplation about whether concentrating people to cities is really desirable.

There are many of conditions for establishing cities in the modern society. Means of transportation like railways, roads, and elevators are such conditions together with other indispensable infrastructure of information communication, electricity, gas, and water supplies. Also, cities have various structures including underground shopping centers, skyscrapers, and developed coastal areas. When such structures suffer large damages, not only the city functions are interrupted, but a great number

of lives and properties are lost; in other words, cities have natural vulnerabilities. Vulnerabilities of cities are evident with larger size cities. In fact, when we compare the 1995 Great Hanshin-Awaji earthquake with a death toll of over 6000 and the 2016 Kumamoto earthquake that took 267 lives in Japan, the level of damages was quite different even though the earthquake sizes were about the same.

Damages from disasters on cities depend not only on the level of concentration but also on their quality. One lesson from the Great Hanshin-Awaji earthquake was the damage grew largely due to concentration of wood-made houses that did not meet today's Building Standards Act in Japan. Natural disasters do not target areas with high population concentration. If we are to give up concentration by abandoning cities, we have to think about the values of what we will be losing. There are many lessons to learn from past experience of disasters, and some of the countermeasures are possible only in cities.

People have worked on controlling erosion and flooding and have built seawalls and breakwater. They were efforts to build robust cities against disasters. For cases that such systems and structures cannot prevent damage, we have prepared evacuation facilities and built systems for cooperation among civil organizations to counter disasters. If we continue to accept benefits from concentrating in cities, we have to think how to, at the same time, develop multifaceted systems of disaster prevention, mitigation, and reduction. The preparations by New York against hurricane Sandy, after learning from hurricane Katrina, were a success case. We have to avoid excessive concentration and monocentric concentration; however, if we acknowledge the vulnerabilities and take necessary measures, we can continue to enjoy the benefits of concentration to cities.

2.3 ICT, AI, and the Modern Society

2.3.1 Development of ICT and Highly Advanced Information Society

The history of modern industries consists of the time of farming up to the early eighteenth century, the time of manufacturing from the mid-eighteenth century to the twentieth century, and the time of information and knowledge in the twenty-first century. The world is making great changes from societies that valued farming and manufactured products to information societies that place importance in information and knowledge formed from them.

In the modern information society, where an enormous amount of information is generated, stored, and processed daily, information is generally processed at high speed by the computer and transferred to a wide audience via a variety of communication methods. Information and Communication Technology (ICT) that supports the information society showed rapid advancement in the 40 years starting in 1980. The personal computer first introduced in 1974 spread throughout the societies in the

1980s and the 1990s. The spread of personal computers led to digitalization of information enabling not only mass reproduction of information but also greatly enhanced accuracy, efficiency, and reliability of information processing and communication. During the mid-1990s to the 2000s, the Internet spread around the world explosively, and broad-band communication was made available allowing large volume communication at high speed. The high-speed Internet realized access to enormous quantities of multimedia contents at anytime from anywhere in the world, and in addition, everyone has the hands-on ways for broadcasting of information; that is, communication without limitations of time and space has been made available. As information systems and the Internet were shaped as one of the societal infrastructures, such functions as electronic trading or electronic government turned available, and economics, society, and government are all heading toward efficiency. Technologies for safety and security systems are also on the rise, e.g., keeping eyes on children with monitoring cameras and global positioning systems (GPS).

As computers turned smaller and faster like smartphones as well as the recording media, cloud computing popped up, and ICT is now accessible anywhere. The advancement into the time of ubiquitous network enabled anyone to access information at anytime from anywhere and any device and now into the era of Internet of Things (IoT) where a variety of things themselves hook up to the Internet to exchange information for automatic recognition, measurement, and control. How to make use of information and technologies is important in the advanced information societies. New attempts that apply state-of-the-art technologies like artificial intelligence to analyze big data are being tested, e.g., a new financial service "Fintech."

2.3.2 Information Security in the Information Society

As the societies are rapidly advancing into the information age, "digital divide" is now a social problem, which is the inequality among individuals in their abilities to make use of information and their communication environment. The advanced information society is also facing new problems including a variety of cybercrimes that misuse computers and networks, net troubles of careless slandering and bad-mouthing of others on the Internet, copyright infringement from reproducing digital information, and health problems from excessive dependence on Internet or smartphones.

In general, information security means to keep information in its complete form, so only the proper user with access rights can use it at any time. Events that threaten information security or that are highly likely to do so are called "information security incidents." Information security incidents are caused by cyberattacks; unauthorized access; transfer of malware; intended acts by malicious people, and further in addition by unintended acts due to operation errors or carelessness; and even natural disasters or malfunctions.

Today, a large number of cyberattacks are around with knowledge of human abilities and typical behavior for the purpose of stealing confidential information or money. An example is password list attack (list-based attack) that is one form of password cracking and is frequently reported. The attackers know people tend to use the same password because they have limits to how many they can memorize. A targeted threat or an advanced persistent threat pretends to be a customer and sends malware to members of target organizations. It is one of the cleverest ways of deceiving people among the number of cyberattacks. The amount of damage from illegal remittance via Internet banking amounted to over 30 billion yen in 2015 in Japan. Organized crimes of unintended withdrawal using fake cards do not fade out. Individuals and corporations suffer since 2015 from ransomware sent to users with programs that lock up computers or encode files and demand ransom to unlock the access.

We need countermeasures from technical, physical, organizational, and personal aspects to protect information assets from these threats. Over 80% of information leakage in Japan are caused by human errors. Protecting information assets in the advanced information society requires raising the information literacy of the users. The administration and corporations have to protect huge amounts of information compared to those of individuals, and thus they have to take proper measures against risks in relation to their possibilities and intensities. Furthermore, any countermeasure can be cracked sometime, and the idea of "defense in depth" that we protect information assets by taking multiple measures in multiple layers is important. We need to take these countermeasures at the entrance and exit points of a network and at each point within the network.

2.3.3 AI and Safety and Security in Human Society

One of the technologies that is making advances in an astonishing speed is artificial intelligence (AI). The 2010s saw a number of AI topics that caught the attention of the public, e.g., AI, at times, beat active professional Go (strategy board game) and Shogi (Japanese chess) players, or a novel written by AI passed the first round judging of a literary contest.

According to the 2016 white paper on information and communications in Japan (MIC 2016) up to the 1990s, AI mostly consisted of software that made guesses by searching simple rule bases or knowledge-based systems that stored various information in searchable formats; they were way far from computers that "behave almost like human." In the 2000s, the technology of machine learning was developed that once people teach features to identify and distinguish data, computers could then on learn rules and knowledge to categorize data without human intervention. In the 2010s, deep learning with models that resemble human neural network was developed. Deep learning extracts features from sample data; thus, AI itself understands and expresses the data concept (meaning), i.e., it executes information processing, that humans unconsciously perform within their brains, to certain extents.

AI is applied not only to information systems like search engines on the Internet but also to speech recognition and synthesis or voice-activated search systems with smartphones, and it is making changes to our daily lives. AI technology is making its way into appliances around us like robots that effectively clean the floor based on sensor data or convection microwave ovens that learn the user's preference. Fintech we touched about in Sect. 2.3.1 cannot perform its financial services without AI. There is no doubt that AI will continue to make large influences in various industries. It is said that AI will put automatically driven automobiles on the roads in 2020. Expectations are high for AI to contribute to improvements in convenience and safety of our societies by diagnosing illnesses and suggesting treatment plans in the medical field, building individual personality-based study plans for students in the education industry, crime prevention by detecting abnormality with surveillance cameras in the security industry, and application to decision-making support for disaster prevention.

Oxford researchers C. B. Frey and M. A. Osborne predicted (Frey and Osborne 2017) that with AI making its way deep into our societies, among the over 700 types of occupations in the USA, about 47% are likely to be replaced with AI or robots within the next 10–20 years. As people and AI start to head into their separate directions, people's work will be more creative leading to possible economic problems. We will have to start making multifaceted discussions about various problems that we can see coming in the future. They involve humans' sense of ethics and values being affected by AI judgments, responsibilities about accidents caused by AI judgments, legal issues related to using and protecting personal information and privacy, concerns about education to bring out creativity through learning the advantages and limitations of AI technologies, qualification of researchers in AI research and development, and many other problems that lie ahead of us (CAO 2017).

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