Journal of Social Sciences 8 (3): 429-434, 2012
ISSN 1549-3652

Eras of Material, Energy and Information Production

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Abstract: This study identifies and discusses three types of production: production of aterial goods, energy, and information. The production timeframes with the reference to each production era are about 10^3, 10^2 and 10^1 years. The necessity of education and the associated level of stress in different production eras were analyzed by comparing a typical length of a human life, which is about 10^1 years, with the timeframes of the production eras and technological progress. It was shown that the era of information production has a very specific feature because unlike the eras of material and energy production, its information production era timeframe is comparable with a typical human lifespan. Finally, a question was posed about the next coming production era and the future of mankind.

Key words: Energy, information, production, goods, energy production, material goods, production eras, significant effort, technical revolution, progress singularity

INTRODUCTION

The times we live in: Let's ask ourselves a question, "What is the most specific characteristic of our time, that of the first quarter of the twenty-first century?" Definitely, there could be many different answers to this question depending on point of view and other factors. This study discusses this question from the angle of production, rate of progress and the length of human life.

The notion of progress, though it looks self-explanatory, is quite complex and may have a variety of interpretations. Plato (427 BC-347 BC) defined progress as a process of improving "the human condition from a state of nature to higher and higher levels of culture, economic organization and political structure towards an ideal state measuring the progress of society," http://www.oecd.org/document/4/0,3343,en_40033426_40037349_41285956_1_1_1_1,00.html." Aristotle (384 BC-322 BC) suggested that "human advancement must not be seen only from an economic perspective" and made a significant distinction between moral and material aspects of life. Francis Bacon (1561–1626) used a pragmatic approach, believing that knowledge should serve humans to improve their well-being. Voltaire (1694-1778) saw progress as not referring to human actions, but to the human mind in terms of arts and sciences.

Measuring mankind's progress is a very challenging task because it is not clear what to measure and how to measure it. Even if we knew what to measure as progress, it would still be unclear how to quantify it and what kind of units to use. However, for the purpose of this analysis we will measure progress in technical revolutions, all kinds of them, big and small. It is obvious that such measurement does not provide a comprehensive view but rather is built on an understanding that any technical revolution brings up additional values to humanity. It is also evident that any technical revolution is based on an achieved level of progress and therefore progress proceeds with acceleration. With this perspective, it would be fair to say that progress evolves exponentially, which concurs with the commonly accepted understanding of progress (Modelski *et al*., 2008).

THREE DIMENSIONS OF A PRODUCT

Production of material goods: For thousands of years human civilization has been producing material goods. Material goods are tangible material objects that one can see and touch, such as the Great Pyramids, the Great Wall, the Taj Mahal, machines, household items, shoes, cloth, food and other tangible man-made objects. Producing an additional unit of a known material good-which is the same as copying a material good-implies a significant effort and the cost almost equals that of a previously produced original. In other words, variable cost of production of an additional copy of a material good is high.

Production of energy: Energy is another production component. A beautiful Venetian chair, though it is a material good, can produce a certain amount of heat if burned. This is an energy component of production. As apparent from this example, a material good also has an energy component in it. People have been collecting brushwood and producing coal as sources of energy for as long as human civilization has existed. However, massive production of energy for further consumption began quite recently, approximately a couple of centuries ago.

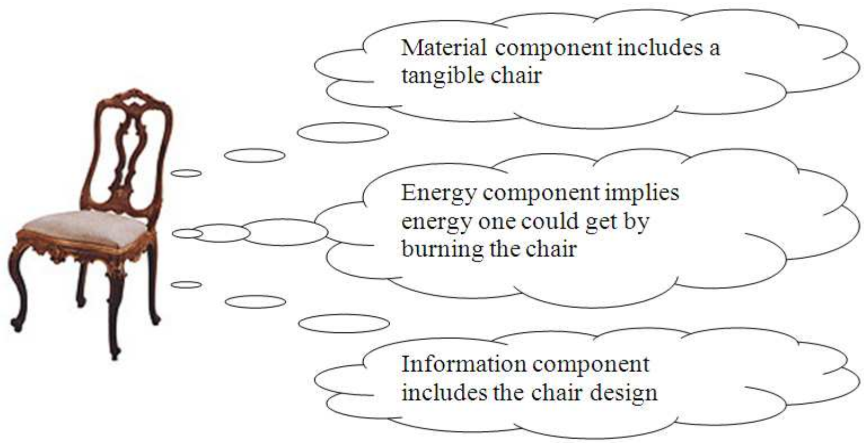

Fig. 1: Material, energy, and information components of a Venetian chair

With the invention of the steam engine, combustion engine and electricity driven machines, energy has become a significant item for separate production. The most vivid example of energy production is that of electric power. Gasoline also belongs to energy products because energy is its major component, however it also has quite a sizeable material component-liquid. Later, nuclear energy was added to the production line. One can neither see nor touch energy, but it can directly impact people and material goods. For example, electrical energy can make things move and it is possible to get struck by electric power regardless of its intangible nature. The above consideration applies to all kinds of energy.

Production of information: A beautiful Venetian chair is attractive only because people who made it knew how to make it beautiful. One can spend the same amount of time, material and energy producing a chair that is ugly in its design or quality. The design is the information component of the Venetian chair. All three components of a Venetian chair are shown in Fig. 1. The information component has always existed in production and has always played a crucial role in high-end material goods; it was considered a trade secret and was never produced for mass consumption until quite recently. Just a couple of decades ago people started mass producion of information for further consumption, including software, audio and video records and broadcasting. Information is intangible; humans can neither see nor touch information directly, nor even sense its immediate impact in contrast to an impact from energy. Production of original information implies significant effort and cost, but copying information is incomparably cheaper and faster than producing the original version. For example, design and development of a software program may cost millions of dollars and takes years while copying it can be done practically in no time and at no cost except few cents for a blank DVD and a little energy for running a computer. We would hardly even consider the cost of information media like a blank DVD or the electrical power needed for copying when we put a price tag on information.

Three dimensions of a product: Actually, every good contains all three components-material, energy and information-as was illustrated in the example of a Venetian chair (Fig. 1). In this study, these three components are referred to as dimensions of a product. We differentiate and classify goods by their major dimensions. For instance, the major dimension for a chair is material even though it also contains energy-one can burn a chair if it is made of wood-and information-in its design. Since its major dimension is material, we classify a chair as a material good. Similarly, the major dimension for electrical power is energy, even though there are material and information dimensions like its carrier and the possible signal it can carry. In software, audio and visual information, though the two other components are present, the information component is the major dimension. Thus any good has all three dimensions: material, energy and information as shown in Fig. 2.

BOTH SIDES OF THE PRODUCTION ERAS

For thousands of years (~10^3 years) humanity has been producing material goods. On one hand, these tangible objects include examples such as the Great Pyramids, Great Wall, Coliseum, Taj Mahal, Cologne Cathedral, St.

Table 1: Major achievements and time periods of production types

Type of Production (years)	Constructive examples	Destructive examples	Destructive impact per act (# of people)	Time period
Material	Great Pyramids, Great Wall, Taj Mahal, houses, furniture cloth, food	Sword	$\sim10^0$	$\sim10^3$
Energy	Commercial electrical and nuclear power	Nuclear bomb	$\sim10^4 \div 10^5$	$\sim10^2$
Information	Software, recorded images and movies, internet, world-wide-web, eCommerce, automation, media information	Human manipulation and brainwash	$\sim10^6 \div 10^8$	$\sim10^1$

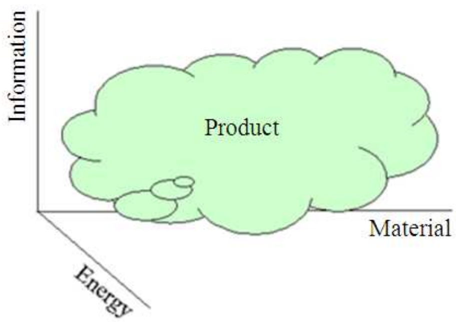

Fig. 2: Three dimensions of a product

Basil the Blessed, cloth, furniture, a variety of artifacts and mechanisms (Table 1). On the other side of the coin, people also produced objects with destructive consequences, such as a sword with which one person can kill another person one ($\sim10^0$ people) at a time.

In the era of energy production people have added commercial production of energy to their production pipeline. This type of product includes electrical power, nuclear power and other forms of energy for commercial consumption. Energy is intangible so one cannot see or touch it, but one can definitely feel it because it can make us warm, make objects move, or even destroy. Production of energy has led to extraordinary achievements of humanity such as automotive and airspace transportation and more efficient production of material goods. The progress made during this era exceeded the progress of the entire prior history of civilization. Unfortunately every coin has two sides and the other side of this coin has exposed the nuclear bomb that can kill hundreds of thousands people ($\sim10^4 \div 10^5$ people) at a time. This era has lasted for the last couple of hundred years ($\sim10^2$ years) as shown in Table 1.

The era of information production began only a couple of decades ago ($\sim10^1$ years) but the achievements have been enormous. Information production includes software, public media, recorded images and movies, television, cross-world communication, the Internet, the World Wide Web, eCommerce and others. Progress achieved in the past few decades has been impressive and would have been impossible without the production of information. Space exploration, images from Mars, sophisticated computerized systems, optimized control in business and other areas of human activities are just a few examples of the impact of information on our progress.

The progress made during the era of information production has exceeded the progress for the entire course of civilization before this period. For example, for thousands of years people performed calculations with pen and paper or with the help of simple mechanical computation devices. The first freely programmable mechanical computer, Z1, was built between 1936 and 1938 by Konrad Zuse in Germany. The first electronic programmable computer, ENIAC, was first introduced in 1946 in the USA and was regarded as a "Giant Brain." Since that time computers have significantly progressed. Now the Giant Brain-once used for calculations in the development of the first hydrogen bomb-if compared to a modern laptop can be viewed as a toy. Nowadays computers are engaged in practically all aspects of human activities. We cannot even imagine our civilization without computers, the Internet and the World Wide Web. Computers are used to run production plants, to design aircraft and cars, to accurately identify locations on Earth and in space, to communicate with other people around the globe and to calculate proper amounts of fertilizers for growing crops.

As another example of human progress let's consider sound recording. For thousands of years, people were passing on their songs from generation to generation by singing live and hoping the younger generation would do the same, passing the tune to the next generation.

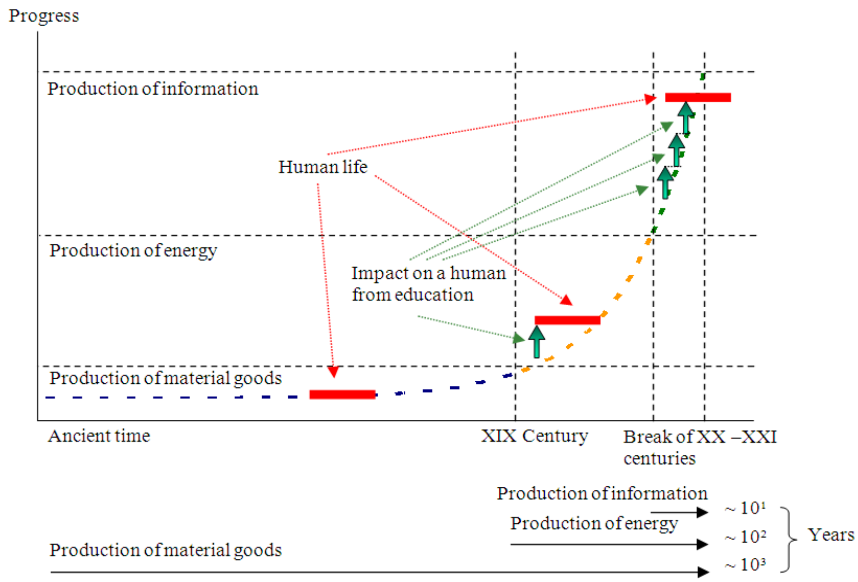

Fig. 3: Production eras, progress and education

The first mechanical recording device was invented by Thomas Edison in 1877 in the USA and stayed conceptually unchanged for a half century until the invention of magnetic tape by Fritz Pfleumer in 1928 in Germany. Compact cassette tape was invented by Philips Company of the Netherlands in 1962 followed by an avalanche of inventions for the past three decades including CD, DVD and flash memory. Though flash memory technology has not yet reached its greatest potential, new even more exciting technologies are already in research and development. Quantum memory or "qubits" has already appeared on the horizon to replace the existing information storage technologies in the near future.

The other, negative, side of the coin of information production is even more impressive than the positive side. With the mass production of information people can be easily manipulated and brainwashed. Brainwashing can impact millions or hundreds of millions of people ($\sim 10^6 \div 10^8$ people) at a time and such an impact can have devastating consequences.

PROGRESS AND HUMANS AS PART OF THE EQUATION

The term progress takes us back to a broad notion of wellbeing and welfare and to how these concepts are changing over time. It is a well-accepted belief that progress is evolving exponentially over time as shown in Fig. 3. About forty years ago, Gordon Moore, a co-founder and a former chairman of Intel, formulated his famous law about progress in computers based on his observations, "The number of transistors that can be placed inexpensively on an integrated circuit has doubled approximately every two years" (Moore, 1998; 1975). Later he refined the period to eighteen months. Though Moore believed that the trend would continue for about ten years, this rate of progress has kept up till now. Kurzweil (2001; 2006) has expanded Moore's law to other aspects of progress. Though measuring progress in general is a quite complex task, we will just illustrate progress on the intuitive level without any claims of accurate measurement. As is clearly seen from Fig. 3, a single human life ($\sim 10^1$ years) fits many times along the time scale of the era of production of material goods ($\sim 10^3$ years) while progress was quite shallow during this period (Table 2). It means that during one human life in the era of material production there were practically no serious changes in technology or any other parameters of progress. Children could learn needed skills from their parents (as they had learned from their parents) at a slow pace with low levels of stress.

In the era of energy production, which has lasted for $\sim 10^2$ years, technological changes occurred during one generation. For this reason, learning from parents was already not enough to keep up with progress. Young people had to have at least some education, say graduation from a university. Knowledge and skills accumulated in education gave a jump start that was sufficient for life. The stress level for such an education was moderate.

The information production era has a very interesting and specific feature. Its duration is comparable with the length of human life which is $\sim 10^1$ years.

Table 2: Rate of progress, learning, and stress level

Production Type	Skills needed and learning curve	Stress level	Time for technology to to change (years)	Comparison with human life (years)
Material	Needed skills stay unchanged for generations Can learn from parents and grandparents	Low	$\sim 10^3$	$>>10^1$
Energy	Needed skills are changed every generation Knowledge acquired at school is sufficient for life time	Moderate	$\sim 10^2$	$>10^1$
Information	Needed skills are being permanently changed, year after year. Knowledge acquired at school is not enough for life. Must keep learning during life time	High	$\sim 10^1$	$\sim 10^1$
Next era ?	???	Extreme	$\sim 10^0$	$<10^1$

Progress during the last couple of decades is comparable with the progress over the entire course of civilization. Knowledge that people obtained through their education at a young age in most cases becomes obsolete in a decade or even earlier due to the extremely high pace of progress. Gordon Moore (Gordon E. Moore is a co-founder and former chairman and CEO of Intel Corporation) noted, "The technology at the leading edge changes so rapidly that you have to keep current after you get out of school." People have to keep on learning to stay on top of the progress and possess sufficient knowledge and skills for professional activities, particularly in the high tech industry. This causes a high level of stress (Table 2). Be prepared for it and do not get upset if, for any reason, you feel that you are falling behind the progress.

WHERE IS MANKIND HEADING TO?

The era of information production has a very distinct and unique feature because its duration is comparable with the length of human life as shown in Table 2. This fact makes our time very specific and critical.

The concept of three components of a product and three eras of production are quite clear and logical from the view of today. However if we could ask people a thousand years ago about the next production era, the question most likely would sound confusing and nobody could even imagine anything beyond typical production of material goods. In the era of energy production, people would realize a difference between production of material goods and production of energy, but most likely they would have difficulties imagining any type of production other than material and energy. Nowadays, we clearly realize and distinguish three types of production including material goods, energy and information. But what if we try to identify the next type of production that will follow the information era? We probably find ourselves in the position of people in the past who could not even imagine a new type of production. Nevertheless let's try to engage our imagination and follow the logic of the existing type of production. The era of material goods production lasted about 10^3 years, the era of energy production lasted about 10^2 years and the era of information production about 10^1 years. A pattern appears that each new production era takes ten times shorter time than the previous one and progresses faster and faster. This is quite consistent with the exponential rate of progress. Following this trend, the next era may already be coming and it will last about 10^0 years.

Note that in order of magnitude it is shorter than the length of a human life. Quite a pace! What is that type of production about and would humans be able to keep up with it?

In the era of production of material goods people experienced quite low levels of stress for learning new knowledge and professional skills, in the era of production of energy the stress level was moderate and in the era of information production the stress level is high and we have to continue learning to keep up with the progress. If the observed trend (Fig. 4) is correct, the next production era will last on the order of magnitude a shorter time than the length of a human life and the pace of progress will be even faster than in the era of information production (Table 2).

In this regard, a series of questions arise:

- What type of production is coming next?
- Are humans capable of keeping up with such pace of progress?
- If not humans, then who?
- What will happen to progress?

I leave you to think about the questions and maybe you'll find the answers.

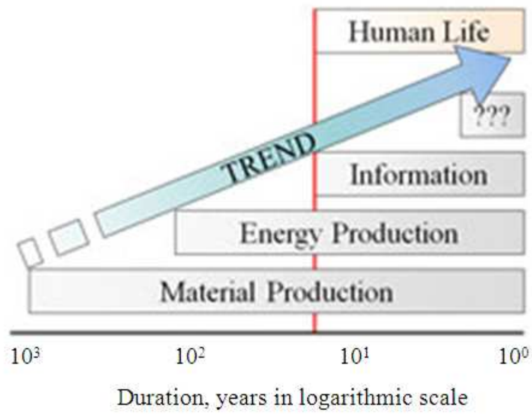

Fig. 4: Duration of production eras versus length of human life

ACKNOWLEDGMENT

The researcher would like to express his sincere appreciation and give a lot of credit to Mr. Ilya Z. Karas with whom he discussed the three production eras twenty-eight years ago and also thank him for his valuable input which is impossible to overestimate. The author would like to thank Professor Alexey Ivanov-Schitz for his constructive discussions and Nicole Marsh for her dedicated help in the preparation of this study.

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