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Research innovation and commercialisation incentives on the beginning and development of engineering education in the West and in Turkey

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Research innovation and commercialisation incentives on the beginning and development of engineering education in the West and in Turkey

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Abstract: Research, innovation and commercialisation loop runs infinitely under global effects and describes the influence of every contributor of the process, including the engineers who run it, the materials and the standards. England benefited the most from the discovery of the steam engine. Turkey learned about the consequences of the European technological advances in the battle fields and suffered the most, because of its proximity to the West, and then made efforts to keep up with the new technology. India and China were also among the losers. Japan did not lose as much, due to its far away geography.

Keywords: feed-back control loop; research, innovation and commercialisation loop; training of the engineers; competition between countries; Turkey.

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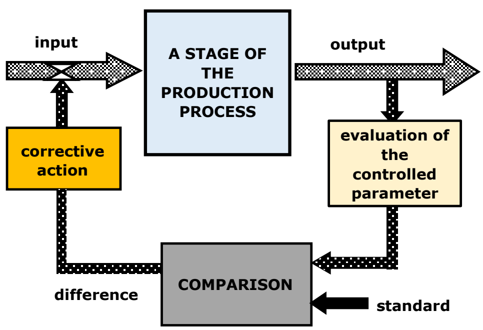
1 Introduction

1.1 The feed-back control mechanism

The mass production of the goods requires mass input of raw materials and energy to achieve to manufacture massive amounts of products. Considering the number of the people involved and the low level of diversity demanded, armies benefited a lot from the mass production. The uniforms, military food, guns, rifles, bullets, and munitions had to be produced fast, in large numbers and be reliable and be the same for every user. The concept of the 'mass production' evolved after steam, electricity and communication technologies were developed (Özilgen, 2011a). Research is carried out to design a manufacturing process. The products and the manufacturing process are innovated to sustain production in a competitive environment; if commercialisation should not be achieved process and the product fail. In addition to the materials and the production process, training of the labour occurs according to the feed-back mechanism described in Figure 1. This figure may describe a stage in a cascade of consecutive stages, or may be pertinent to a stage in simultaneous parallel stages. During the American Civil War, innovate methods were developed to manufacture firearms with interchangeable parts and with advanced methods of metalworking. Uniform standards and measurement techniques were employed for inspection and control of these processes (Wilson, 1998). In Eli Whitney's factories gradual transition to mass production was achieved during manufacturing of the fire arms (Mirski and Nevins, 1952). The mass production technology attained a more advanced level in the factories built by Samuel Colt (Edwards, 1957). Mass production relied heavily on engineers educated in the schools and needed less skilled labours to work on the production lines (Von Tunzelmann, 1997).

Figure 1 Description of the feed-back control loop employed to keep the production in agreement with the standard (see online version for colours)



Standards were needed the most during the wars. In the Gallipoli campaign, in 1915, Turkey fought against England and France. France and England had troops coming from their dominions, in addition to the ones coming from main lands, Australia, New Zealand, India and Africa. Ammunition and the equipment needed for these troops were manufactured in the mainland and the dominions of these armies. Strict standards were needed to combine them successfully. British Standards Institute was founded in 1901; American National Standards Institute was founded in 1918 and the Turkish Standards Institute was founded in 1960. In his book, *Şu Çılgın Türkler* (*These Crazy Turks*, first published in 2005) Turgut Özakman tells a story about the ammunition smuggled from the stores in occupied Istanbul to the Turkish forces fighting for the Turkish War of Independence. The Turkish artillery was designed for 70 mm ammunition, while the smuggled ammunition had 75 mm of diameter. Their diameter was reduced to an appropriate level in hand-run turn tables, by jeopardising the lives of the craftsmen. This was one of the consequences of establishment of the Turkish Standards Institute much later than those of its competitors were.

With the development of the sophisticated mass production methods, statistical quality control gained importance, as the manufacturers learned that the products, which would not achieve a minimum acceptable quality level would not be accepted by the consumers. During World War II, Walter Shewhart of the Bell Telephone Laboratories achieved to differentiate between the natural distributions of quality from the ones attributable to production problems. Based on the sampling inspection theories put forward by Shewhart, and Romig and Dodge, a US defence standard was developed. The original version of Military Plan 105 was issued in 1950; a newer standard was issued in 1963 (US Department of Defense, 1963). This standard was adopted by the American National Standards Institute (ANSI Z1.4) in 1971 and by the International Organization for Standardization (ISO 2859) in 1974 (Özilgen, 2011b).

The war of Isandlwana was fought between the British and the Zulu troops in 1879. There were about 20,000 Zulu warriors equipped with spears and cow-hide shields, there were 1,800 troops equipped with modern fire arms of the era, and 400 civilians in the British side. British troops lost the battle and 1,300 of them died in the battlefield. The ammunition was provided to the British troops in boxes with a sliding lid that was secured with a two-inch screw. There were not sufficient screw-drivers and the soldiers could not open the boxes by smashing them with their riffles. Numerous unopened ammunition boxes were found in the bottle field when inspected years later (Knight, 2002; Saul, 2004). The war of Isandlwana was fought before the establishment of the British Standards Institute; therefore, there were no standards available for the manufacture of the ammunition boxes.

1.2 Establishment of the engineering education

Although the Turkish translation of the word 'engineer' is 'mühendis' these two words has totally different roots and significantly different etymology. The opium wars were a milestone of the conflicts between the West and China. Commodore Perry's unwanted visit to Japan was a milestone in the conflicts between Japan and the West. Unlike with these two countries, it is difficult to find such a milestone for the conflicts between the Turkey and the West. Because of its geographical location, Turkey always had conflicts with the West, since the time that it emerged in the 13th century.

Savery's steam pump operated on the principle of creating suction to pull water from the depths of the minefield. In order to create the suction water was first evaporated in a chamber while its exit was open to the atmosphere. Then the exit was closed, the chamber was cooled and a vacuum was generated. In the second stage of the operation, the suction power of the vacuum was employed to raise water from the depths of the mine to the chamber. In the last stage of the operation, water, which accumulated in the chamber, was discarded out by reheating the chamber. Four centuries before Savery, Al-Jazari (1136–1206 AD), an important Muslim scholar, astronomer, inventor and a mechanical engineer, described his invention of 50 types of mechanical devices in the *Book of Knowledge of Ingenious Mechanical Devices*. One of these inventions was a double-action reciprocating piston suction pump. In this pump, Al-Jazari incorporated a crank rod to convert the rotary motion into linear reciprocating motion in a similar way as the basic mechanism of modern machines such as the steam engines, internal combustion engines, and automatic controls (Şen, 2013; Dirik, 2020). Al-Jazari's pump was used in Mesopotamia for the transportation of water without manual labour. A comprehensive review on the evolution of water pumps over the centuries worldwide is made by Yannopoulos et al. (2015). Savery's steam pump was improved later by Thomas Newcomen and James Watt. The steam pumps were evolved into steam engines spread rapidly and transformed the entire industry within a few decades (Clark and Jacks, 2007).

James Watt improved the atmospheric steam engine in 1776 by introducing a separate condenser, so that the cylinder would remain hot and the condenser cold throughout the cycle (Miller, 2008). In the 1750s, men, women and child labourers worked in the mines together under dreadful conditions (Barca, 2011). The child labourers who learned operating the steam engines employed their skills later to improve it. People who build or operate a steam engine are called an 'engineer'.

In the USA, the railroad companies gave land to the states to establish the 'land grant' university system. University of California, Texas A&M, MIT were among the universities, which received the land grant (Collier, 2002). Teaching agriculture and having a military education program was among the requirements of receiving the land grant. University education was available to the male students for many centuries. Ellen Swallow became the first female accepted as a 'special student' to a university in the USA. She established the Women's laboratory at Massachusetts Institute of Technology (USA) in 1876 to teach laboratory skills to schoolteachers. Stanford was among the first US Universities which accepted the female students (Özilgen, 2011a, 2014). *Inas Darülfünunu* was established in Turkey in 1914 to train women to be schoolteachers. Perception of the female talents and labour has gained more importance during the First World War. As men went to fight overseas, women filled many of the jobs previously done by men. The greatest increase of women workers was in engineering. In England more than 700,000 women working in the highly dangerous ammunition industry (Imperial War Museum, 2013).

In the 17th century, Ottoman Empire, in addition to its vast land in Europe, including the Balkans and a part of the Central Europe, was ruling most of today's Middle East, North Africa, and Crimea and its vicinity and was undisputedly a very strong country (Shaw and Shaw, 1976). During the religion wars fought between the beginnings of the 16th and the 18th centuries, between the Protestant and the Catholic countries of Europe military technology developed remarkably. The Ottoman Empire learned about this development in the wars fought against the Holly League between 1663 and 1699. The Holly League was consisting of the Holly Roman Empire, Polish-Lithuanian Common Wealth (including some parts of present Ukraine), Russia, Venice and Habsburg Austria, England, Dutch Republic and Spain. The Karlowitz Treaty was signed in 1699 to conclude this war at a cost of major territorial losses to the Ottoman Empire after centuries of expansion. The Karlowitz Treaty marks the beginning of the stagnation and decline periods of the Ottoman Empire and political hegemony of the Habsburg dynasty in the Central Europe (Agoston, 2008; Kurtaran, 2016).

Ottoman artillery was superior to those of the European gunnery between the 15th and the 17th centuries. There was tremendous similarity between the Ottoman and the European guns even in the 18th century, including their chemical compositions; but eventually the Ottoman guns became inferior (Agoston, 2008). Transportation of valuable metals from the newly discovered lands, like Argentina, to Europe caused inflation. Ottoman Empire did not get any share from the wealth transferred from these lands; decline of the quality of the Ottoman guns were attributed to inflation (Agoston, 2008). The era from 1700 to 1900 is generally described as one of profound transformation of the Ottoman military system by adopting European organisational and technological models (Aksan, 2011; Türk, 2012). In the 17th century, geometry became the fundamental knowledge of the artillery units of the European armies (Walton, 2000). Authors like the Spanish Aristocrat D. Pedro Antonio Ramón Folch de Cardona wrote books on 'military geometry'. Considerable research and innovation were done by Benjamin Robins (1707–1751) to develop the design, manufacture or firing of heavy guns. He conducted experiments on the effect of air drag on moving objects and on the relation between the power of gunpowder and the velocity of cannon balls, range of mortars and wrote treatises. His book *New Principles in Gunnery* (1742) set artillery on firm scientific foundations (Robins, 1805). Ottoman Empire learned about the importance of geometry in the battlefields at a very high cost, and then started tremendous efforts to find instructors to learn it from. Humbaracı Ahmet Paşa (Claude-Aleksandre Comte de Bonneval) served for the Ottoman Empire between 1729 and 1747 and established a modern military school in 1733 in Halic (Golden Horn) shipyard. Baron de Tott lived in Turkey between 1755–1793 and helped establishing Mühendishane-i Bahr-i Hümayun (Royal Naval School) in 1773. He was indeed a military employee of the French embassy and his duties were focusing on gathering information on the naval defence of the Ottoman Empire. Between 1882 and 1918 Ottoman military was heavily influenced by Germany, in addition to purchasing military equipment, ammunition and for training the officers (Türk, 2012; Topal, 2013). Although the first railroads of the Ottoman Empire were built by the British entrepreneurs, the later ones were built with the German help (Özilgen, 2011a, 2014).

Mühendishane-i Berri-i Hümayun, (Imperial School of Military Engineering) was the predecessor of the Istanbul Technical University (ITU) and one of the oldest engineering schools of the word (http://www.arsiv.itu.edu.tr/hakkimizda/itu-tarihi'). Numerous books and manuals were printed with educational purposes in this school and their copies are still preciously preserved in the ITU museum. One of the basic purposes of the Imperial School of Military Engineering was teaching geometry (hendese in Ottoman Turkish) to its students. In Turkish, the word 'mühendis' means a person who knows geometry. Mustafa Kemal Atatürk, the founder of the Turkish Republic was indeed an Ottoman general. He received his education in the Ottoman military schools and learned geometry as the part of his military skills. He authored a geometry book to demonstrate the use of the Turkish words in education (Atatürk, 1937).

Historical development which shaped the Turkish modernisation went parallel with which shaped those of Japan, China and India. Therefore, it is important to compare Turkish modernisation with those of the others. In Japan Meiji era (1868–1912), in the Ottoman Empire reigns of Selim III (1789–1807), Mustafa IV (1807–1808) and Mahmud II (1808–1839) were the times of restoration and modernisation. In the reign of Abdulmejid II (1839–1961) modern schools The Imperial School of Galatsaray (Mekteb-i Sultani) and Darülfünun-u Osmani, which was named as Istanbul University later, were established. During Meiji's reign, Japan sent delegations to Europe and America to learn about everything considered beneficial to the country. Students were sent abroad to make use of the West's pool of knowledge. On their return, they systematically taught what they had learned to their compatriots. In the beginning of the Meiji period universities and advanced high schools were set up across Japan. At that time, Japanese professors and their universities played a central role in absorbing knowledge from the West (Edgington, 2008). Kavalalı Mehmet Ali Pasha (1769–1849) of Egypt established the Ecole Egyptienne in Paris for the education of the Egyptian students in Paris. Ottoman Empire started to send the Turkish students to Europe for education 1830 some of these students attended to Ecole Egyptienne (Şişman, 2003). Imperial countries started mining schools in the 18th century with the aim of unearthing the valuable ores. Such schools were established in Russia in 1773, in Germany in 1765 and in England 1851. Most of the graduates of the British mining schools worked in the mines of colonies like Australia, Malaysia, and South Africa, West Africa and Canada, USA and the Ottoman Empire. After obtaining sufficient information about these resources they claimed right in these countries. Mosul and Kirkuk (Iraq) were part of the Ottoman Empire when the first clue emerged about the presence of rich oil deposits. British engineers started working in the area under the guise of 'archaeological expeditions' and at the end of the First World War; and England gained the control of the region (Sami, 2011; Dadyan, 2011). The Ottoman efforts to construct a railroad between Istanbul, Baghdad and Hejaz was supported by the Germans, who regarded these projects a step towards promoting the German interests in the Middle East, which had just started to emerge as a geographical region of rich oil resources (Earle, 1924; McKeen, 2010). Ottoman Empire did not have money to pay for the cost of the railroad and offered mining rights over the course of the railroad instead.

The drive for industrialisation in China dates back to 1874, and nationwide search for mines in the era of Qing government under Sheng Xuanhuai (1844–1916), who hired a British mining engineers to explore China's mineral resources in 1875, who located extensive reserves of high-quality iron ore at Daye. In the same era the Yangwu 'self-strengthening' movement, meaning restoration via learning Western ways without altering the existing order, started in China almost simultaneously with the Japanese reforms of the Meiji period (1868–1912). The Yangwu movement practices included starting westernised schools and trade, establishing a westernised army, building railroads and financing the economy for mass production (Liu, 2010).

Thomas Allom (1802–1874), visited the Ottoman Empire and China and made illustrations of what he saw there and published them in the books he authored. His books and the impressions of many other visitors to those countries were employed as a catalogue from where the imperial countries to choose the places to occupy.

During the reign of Sultan Selim III Ottoman Navy became a very significant driving force for importing knowhow and developing the military industry including ship building in Turkey (Zorlu, 2014). A new organisation of the state had started and of the army and a new army Nizam-ı Cedid with particular attention to all matters concerning military organisation and training. The Janissaries corps was gradually dismantled and replaced by a newly trained army. European military advisors mostly Frenchmen and Turkish teachers were recruited and factories were built in order to meet the new military needs (Abdeljaouad, 2012). Sultan Selim III launched a comprehensive drive for industrialisation, parallel to the administrative, economic and military reforms set in motion in France after the revolution. The first permanent diplomatic mission of the Ottoman State was established in London in 1793 during the reign of Selim III. Besides conducting international relations, Ottoman ambassadors also provided steady flow information about the European countries to which they were appointed, thus played an important role in the acceleration of the reform movement and Westernisation, spearheading the country's modernisation (Altuniş Gürsoy, 2006). 'Modernisation' became synonymous with 'westernisation' for most of the Turks; this perception has extended over centuries (Boyar and Fleet, 2010). At the earlier stages of, westernisation, it was perceived as owning Western style institutions. Answer to the question 'how can a nation become modernised in order to survive?' was sought. And then inspired by the Japanese example, what the Ottoman intellectuals understood from the phrase 'modernisation' became adopting the science and technology of the Western world, while maintaining the national values (Bakan and Birdişli, 2010). The central administration was modernised and the powerful warlords ruthlessly eliminated and was undertaken a serious upgrading of the two schools of engineers for artillery and naval officers founded by the preceding sultan. In this era, French experts helped the Ottomans to improve their shipyards. In the years 1793–1794, he struggled to improve the equipment and weaponry of the Nizam-ı Cedit army, sought home production of guns, rifles and gunpowder and the transfer of European mining technology to the country. Muscle work of the animals was substituted with water power in gunpowder production. A new chemical formulation was employed for the gun powder production, even before elsewhere in Europe. In 1804, he initiated efforts to set up a paper mill and a factory for woolen fabrics for uniforms of the army in Istanbul at the Hünkar İskelesi. Like in many other European countries, the industrialisation started with the knowledge gained in gunpowder plants (Shaw, 1971). As a result of the policy of 'paying very handsome wages to foreign experts', which started with the ascent of Selim III to the throne, the number of foreign experts working for the Ottoman State towards the end of 1700s reached 600, half of them being French, and the other half English, Austrian and Swedish (Shaw, 1971).

Reforms of Selim III were rejected by the Janissaries (the old army) and the ulema (authoritative scholars who were responsible for interpreting the religious law). Many of the ministers and military aides of Sultan Selim III were murdered or exiled, after a year of public disorders and eventually he lost the throne (Abdeljaouad, 2012). The modernisation efforts of Meiji and those in China were also rejected in a similar way by the previously established armies. Prior to the Meiji reign, Tokugawa Shogunate ruled Japan for 250 years. In that era local lords, Shoguns, had considerable autonomy and the central Japanese government had no effective political control of the country (Hua, 2004). Before 1945, the Japanese universities were established after the German model. In the second post-World War era, American experts restructured the Japanese universities after the US model to reduce the German influence. The new system allowed doctorate programs in a limited number of universities. As Japan got richer after 1960s, the demand for university education rose. So did the quality of education and research (Gürüz, 2003-4).

The wealth of India lured the British interest in this country. East India Company was established at the beginning of the 17th century to exploit the wealth of this country (Farrington, 2002). Indian modernisation started with the appointment of Lord Dalhousie in 1848 as the Governor General of the East India Company set the stage for changes essential to a modern state. There has been a major uprising in India in 1857–1858 against the rule of British East India Company. Many of the state related organisations were established in India after those of Britain, including the universities, which were started to be established in 1857.

1.3 Accreditation

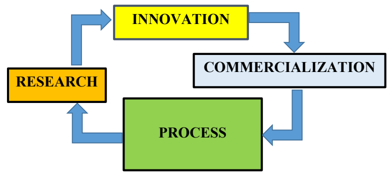
In the US difficulties in information sharing encouraged engineers to gather in professional organisations. With the development of telegraph, telephone and radio 'American Institute of Electrical Engineers (AIEE)' was established in 1884; and followed by the 'Institute of Radio Engineers (IRE)', established in 1907 to bring together the engineers working in the field of electronics technology. The first acts of both AIEE and IRE were standardising the units, definitions, and terms to facilitate the sharing of knowledge between their members. AIEE and IRE merged in 1963 to become

'Institute of Electrical and Electronics Engineers (IEEE)'. A similar path was followed by 'American Society of Mechanical Engineers-ASME'. From 1870 until 1910, there were at least 10,000 incidents of boiler explosions in the USA, and then the number rose to an annual average of 1,400. Dependence of the industrial production on steam engines necessitated the improvement of safety, efficiency and capacity of the steam engines through new designs. The first act of ASME was standardising the units, definitions, and terms to facilitate the sharing of knowledge between their members. In general, the individual branches of modern engineering spread to other countries many years after maturing in the USA and Britain. Since in the process the USA and Britain gathered vast quantities of professional knowledge, engineers of other countries did not feel need for solidarity at the same level, which was vital during the initial stages of their profession (Özilgen, 2011a, 2014). In the republican era engineering education was initially provided by Istanbul Technical University and Robert College (Tantekin-Ersolmaz et al., 2004). Accreditation Board for Engineering and Technology, Inc. (ABET) is a non-governmental organisation, established in 1932 in the USA. It aims achieving sufficiently high educational standards in post-secondary education of applied and natural science, computing, technology and engineering. In 1989, With the Washington Accord, 'qualifications accredited or recognised by other signatories are recognised by each signatory as being substantially equivalent to accredited or recognised qualifications'. USA, UK, Russia, China, Canada and Turkey are among the signatories of the Washington Accord. Standards described in Figure 1 is tried to be implemented in the Washington Accord Countries. However, it should be kept in mind that, cultural traits of each country heavily affect the implementation of these standard and the standards are subject to change with innovation.

2 Description of the progress with the research innovation and commercialisation loop

In the present study, description of the progress in the fields of weapons manufacture and engineering education will be described with the research, innovation and commercialisation loop as described in Figure 2 is an infinite cycle. It runs infinitely under the global effects. The global effects are perceived continuously in our global world. In the middle ages these effects were being received with the speed of the camel caravans, in our digital age they are being received with the speed of the light. Therefore, the research, innovation and commercialisation loop runs much faster than it was used to be in the past. As the global demand changes for the quality of the products, the standards as described in Figure 1 changes, in order to achieve the required quality improvement research is needed. To be able to compete with the rivals the products should be innovated, and then the competitors do the same thing in order to remain in the market. The research, innovation and commercialisation loop as described in Figure 2 runs continuously in a highly dynamic manner (Doğan, 2016). The product, process, and the organisation of a company may be innovated; and then the companies may focus on the marketing of the innovation. Governmental policies, availability of the competitive products in the market, may affect commercialisation of the innovated products, processes or technology (Meijer et al., 2019).

Figure 2 Research, innovation and commercialisation loop (see online version for colours)



3 Conclusions

The child labourers who learned operating the steam engines in the 18th century employed their skills later to improve it. People who build or operate a steam engine are called an 'engineer'. During the religion wars fought between the beginnings of the 16th and the 18th centuries, between the Protestant and the Catholic countries of Europe military technology developed remarkably. In the 17th century, geometry became the fundamental knowledge of the artillery units of the European Armies. Ottoman Empire learned about this development after experiencing a terrible defeat in the wars fought against the Holly League between 1663 and 1699 and tried desperately to find instructors to teach geometry to its military. Istanbul Technical University is one of the oldest technical universities of the world and established with the purpose of teaching geometry and other military skills to the Ottoman officers. 'Mühendis' the Turkish term for 'engineer' was adapted from Arabic and means the profession of the people who knows geometry.

In the 19th and 20th centuries Ottoman Empire, Japan and China tried to adapt the Western military knowledge to their armies by employing European advisors, but these efforts were strongly resisted by their older established armies. Military technology and training of the engineers and the officers was integrated to research, innovation and commercialisation loop. This loop is running continuously by each country to make themselves stronger than their competitors.

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