BOB STRUIJK

ROBOTS ECONOMIC POSITIONING UP TO THE 2008 CRISIS

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To determine the position of industrial robots up to the 2008 economic crisis, a large number of factors can be investigated:

- the product life cycle that determines the growth of the sector and various types of robots;
- the growth phases that need to be followed, using the abstract "Heineken Growth Phases" model;
- the amount of market concentration;
- robot density per country and per industrial sector.

The 2008 position will provide the basis for future development of industrial robots and linked sectors such as military robots like UAV's and service robots, among others.

Az ipari robotok 2008. évi gazdasági válság előtt betöltött szerepét számos tényező szerint is megítélhetjük, amelyek közül a legfontosabbak az alábbiak:

- a robot élettartama, ami befolyásolja az adott szektor és a különféle típusú robotok növekedésének ütemét;
- az előírt növekedési modell („Heineken Growth Phases") követése;
- a piac koncentráltsága;
- az adott ország ipari szegmensének robot-sűrűsége.

A 2008. év az ipari robotok fejlesztése területén kiindulási alapként fog szolgálni a robotok, és más, kapcsolódó ágazatok (pl. UAV fejlesztések, kiszolgáló robotok, és más robotok) számára.

Literature overview

Industrial robots have their roots in the ever present desire to automate, mechanize tedious labor tasks. Today's robotics industry is organized in various platforms [1] providing information. To understand the future a modeling concept by classical marketers like Buzzel [2] can be applied. In [3] the product life cycle is explained by model of the parameters. Litzenberger [4] describes the past and present from an industrial point of view, underscoring the modeling used. In [5] Barclay presents a view of UAV deployment in a roadmap for the US Army. While statistical data from IFR [6] [9] show the rise of delta robots and the various densities of industrial robots worldwide. Schneider dealt in [7] with the gaps between military and industrial robotics, needs and offers. Struijk in [8] proposed a model to determine the growth phases over time in the industry. Szabolcsi in [10] introduced a complex stochastic mathematical model of the disturbances affecting aircraft motion and proposed for further applications. Szabolcsi and Mies in [11] give a short brief upon history and future of modern robotics. Szabolcsi published a series of scientific papers propagating results of the survey executed for derivation of flying and handling qualities of the UAVs applied for military [12], for firefighter [16], and police applications [17]. Szabolcsi derived basic steps and a special procedure for identification of the spatial motion of the UAVs [13]. In [14] Szabolcsi derived the possible flight path of the hypothetical extra-cheap UAV, which flight phases must be automatized. Szabolcsi derived normal and emergency flight phases geometry of the UAVs based upon customers' requirements [15].

Introduction

This paper will focus on the economic position of robots in industry. The author aims to determine how robots and their use – as part of flexible automation – have grown since their start mid last century till the landmark economic crisis of 2008. The way robots are positioned today, will allow making conclusions and statements about the future. Economic and Marketing tools such as Product Life Cycle and Concentration Curve Analysis will be used in the paper. Also actual market structure data and robot density charts will be used. Common sense dictates that robots are a part of our reality, their presence and abilities ever growing. This paper will underscore these wisdoms by facts and from the obtained results from the model analysis.

Robotics market from its industrial birth till 2008

Apart from a long history of automation machines, the real first industrial robot was designed and developed in 1956 by Josef F. Engelberger. A US-born engineer Engelberger founded Unimation Inc., the world's first robotics company [1]. The first robot was developed in the '50s and introduced to industry. This pioneering phase was followed by keen interest on the part of the US car makers. In fact, many current well known industrial robot suppliers found their origin within one of the car manufactures' automation departments. It can be stated that FANUC was lifted off after a merger between General Motors (GM) and FANUC Ltd. The German based robot manufacturer Kuka saw its life coming out of the Volkswagen automation department, while the Swedish/Swiss group ABB was created partly from Renault automation. Unimation Inc. is today active under the well-known brand name Staubli from Switzerland.

Following the first successes of Engelberger's invention, the automotive industry was going through the shock waves of the first oil crisis in the early '70s. They were quick to adapt; the automotive companies embraced robotics. As they were producing in mass volume with high labor content they could benefit directly from the labor saving and quality increase provided by robots. The steady growth of the use of robots coincides with the growth of the industrial output by the western countries on one side and the computing capacity on the other. CPU power has multiplied more than a 1000 fold over the past decades. Each 2-4 years the newly available CPU's were introduced also into industrial robots. Same goes for the necessary memory capacity. Robots in the '90s were still equipped with large and slow bubble memory or EEPROMS for the storage of its programs. This technology push allowed robots to work faster, communicate with each other and within networks, control peripherals and work with other technologies like vision systems.

For better understanding, the economic impact of robots over the past decades we first look at the position of the **P**roduct **L**ife **C**ycle (or PLC) of industrial robots as a group. Although the Product Life Cycle is a hypothetical approach, it serves to provide a good indication of what may happen in the future. The theoretical PLC is given in Figure 1.

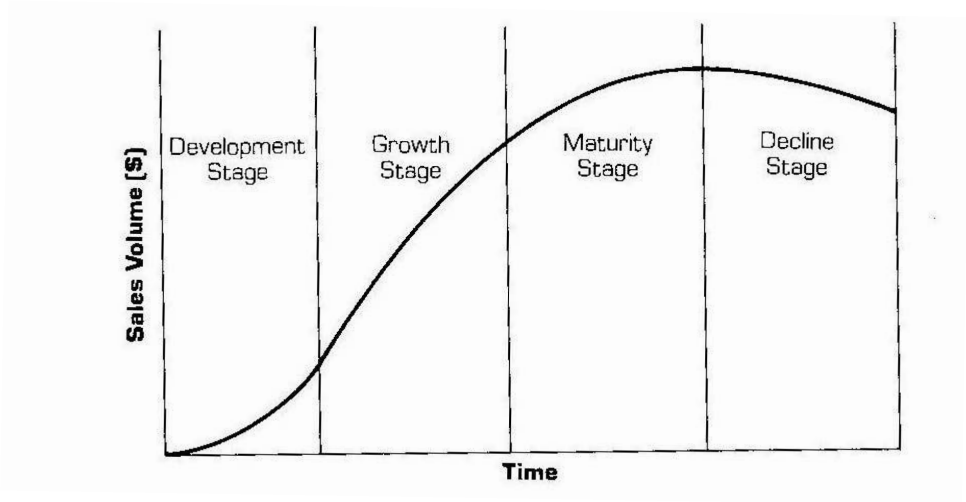

Figure 1. Theoretical Product Life Cycle.

The Product Life Cycle concept, assumes the stages of the life of a product/technology [2]. Where the start takes a long time for the product to become accepted, it is followed by a steady growth till it reaches adulthood and eventually fades out due to new technological solutions. Or in human terms birth, growth, maturity, decline and death [3]. In the early stages of the cycle, new products need high advertising and promotional expenditures, while later when these needs decline due to a decline in need of information prices typically fall and competition becomes fierce.

The cycles of i.e. typewriters, gramophone players, VHS video recorders all followed similar paths like displayed in figure 1. Following data obtained by the International Federation of Robotics (IFR), [3] has been estimated and displayed in figure 2. It is clear that the PLC for robots – nor any other product for that matter – does not follow exactly the bell shape of the theoretical model.

Today industrial robots are to be found growing steadily, entering the Maturity phase, while i.e. Service robots are clearly still in their development stage. It is predicted that after economic crisis the volume of industrial robots will continue to grow [4]. So the decline in sales volume due to the crisis does not conclude a decline in the life of robots. It has to be seen in the light of the unprecedented circumstances of the economic crisis.

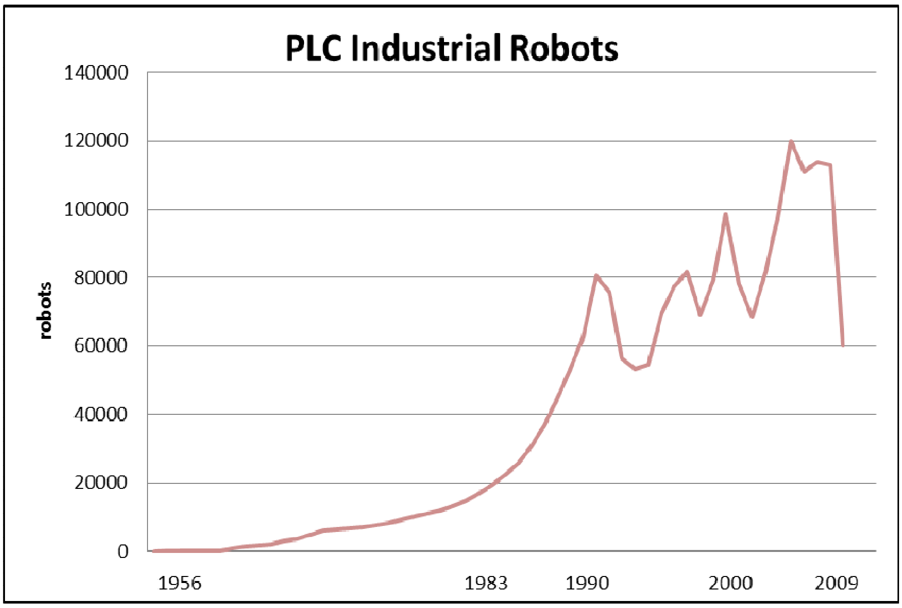

Figure 2. Estimated Product Life Cycle based on IFR data.

The adoption rate of robots in industry will grow and the need for skilled labor in the industrialized countries is evident. If the position of industrial robots is entering in its maturity phase, it supports the fact that industrial robots are being transformed into a commodity. Economies of scale dictate high barriers to entry for new comers into the industry. Prices of robots will continue to go downward based on their position in the PLC, again economies of scale being the force to cut product unit cost. It can be concluded from the Product Life Cycle model that industrial robots up to the crisis followed a normal path, they went through the stages of Development (Engelberger), Growth Phase (early adoption by the automobile manufacturers) and they are now experiencing further growth, entering in the Maturity Stage.

What is true for industrial robots is not true for other classes of robots in military applications. Most military robots in general are in still in their development phase. Exception is probably the UAVs, or **unmanned aerial vehicle**. First introduced in a thesis by the Serbian inventor Tesla in 1915, UAV's are experiencing a strong growth after a wide deployment in both gulf wars, the Afghanistan theatre and war on terror. Built as a reconnaissance plane they can now be fitted with antiarmor missiles and are used widely as an attack/deterrent weapon and for C3 missions. UAV's flew over 300 combat missions during Operation Desert Shield/Storm.

Currently there are more than 328 Army UAV deployed in theater, summing a total of more than one million hours of flight. The US Army will train 2100 operators in fiscal year 2012, a staggering 800 percent increase compared to 2003 [5]. Typical in line with the early Growth Stage within the Product Life Cycle. Extensive growth can be expected over the coming 20 years as show the industrial robot PLC example.

It can be concluded that robots for industrial use have followed a normal growth path and are entering its adult phase. This implies that for the next 10 to 20 years the volume used will continue to be large. Robots will continue to change the way products are manufactured and subsequently require full focus from managers, education and R&D platforms. Military robots are lagging behind. However the successes of UAV's clearly show military leaders the advantages over human operated devices. The steady growth will continue and will lead the way to acceptance of other military robotics.

Market position of industrial robots –concentration curve

While we have seen that the early manufacturers of robots were linked to the car manufacturers, in 2008 some 40+ manufacturers were active in the production of articulated, Cartesian and Scara robots. Starting 2007 a strong growth is noticed in new manufacturers of Delta type robots. This is an important point one has to mention. The enormous leap growth of delta robots over the recent years. What started as an academic research product, these robots were first introduced in the market by ABB worldwide, the so-called Flexpicker.

The exclusive patent rights ended in the new millennium. Due to its relative easy drive and motion control structure starting 2007-2008 many local manufacturers of 3-4 armed delta robots could be found in Europe and USA. In Europe alone in 2005 some 500 units were sold, only to grow to more than 4000 in only 3 years [6]. In 2008 a total of some 40+ manufacturers can be identified, selling more than 100.000 robots in total.

A measure to better understand the current market position of industrial robots is the degree of concentration. In the so called Concentration Curve we measure the cumulative turnover or market performance versus the number of suppliers. Figure 3 shows the graph as calculated for 2008 supplier's market data. The diagonal line would indicate a complete absence of any concentration; all suppliers would have equal share of the market. The concentration curve shows the influence of the various suppliers.

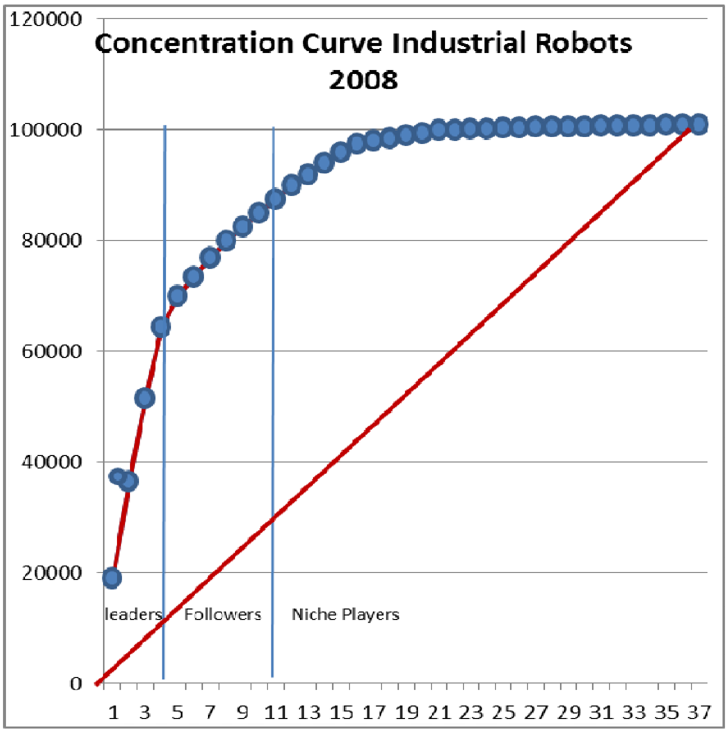

Figure 3. Concentration Curve — Industrial Robots 2008.

The Concentration Curve as shown in Figure 3 displays a clear high degree of market concentration. The market is dominated by few leaders. In fact, the first 4 producers (FANUC, Yaskawa, Kuka and ABB) of industrial robot arms make up close to 65% of the total market. Yet another clear sign of coming to maturity of the market in 2008. With high concentration the "barriers to entry" are also getting very high, it is difficult for newcomers (i.e. China has no robot manufacturing capability today) to enter due to the large market positions of the leaders. Leaders compete on price by their economies of scale. New comers or smaller producers – followers – have only chance of survival to focus on niche markets, where a relative higher margin can be achieved due to the added value or specific function offered. This is the case of the various small sized manufacturers of Delta robots. A concentrated market has also the typical inclination to increase the concentration going to high levels of concentration; small players are being swallowed-up by larger players. This can have far reaching consequences for the industry and its actors.

In terms of consequences for the military sector of robotics the conclusions are obvious: national manufacturers of military equipment wanting to apply robotized arms would need to seek cooperation instead of own research and development of this advanced technology. In example, it would be too costly for the Hungarian MoD to start today its own UAV development given the already steady growth and concentration of these kinds of robotic equipment.

A 2008 NATO finding [7] shows there appears to exist a gap between the ideas of the military on the use of ground robotics for their purposes and the technical possibilities offered by industry and research. In general the military work with the offer on hand from the robotics industry, however that does not meet the needs of the military. The gap has a twofold origin: the ideas that military have on the use of robots is still not uniform and on the other hand industry is developing robots without going into specific military needs and requirements.

In conclusion it can be stated that the highly concentrated industrial robot market, dominated by a handful leaders, is making the situation only more complex. Research and development and other investments are focused on economic gain; industry is driven by economic (profit) factors, military in general operate on a different axis. The existing gap will only widen more.

Growth process of robots – adoption by industry

If the automotive industry, as an early adapter of robots in the product life cycle is the role model, then what is the underlying growth theory of adaptation of robots by the industry? How do robot and their use evolve? An attempt was made by the author in 2004 during an internal congress on industrial automation organized by the worldwide well known Dutch beer brewer Heineken to come up with a frame work [8]. This frame work is dubbed by the author "Heineken Growth Phases" model. This model describes the adoption rate of robots in industry, whether it being the beverage industry, food industry, medical, plastics, metal etc.

The adoption rate of robots by industry is typically following 4 phases: in the first phase a factory starts with robots, where a worker handling a machine is replaced by a robot. Or simply a one-to-one exchange of humans by robots. The benefits are present but not large. The company gains its first experience with the new high technology and tastes the possibilities of flexible automation. It has to be said that more often than not high barriers had to be overcome to get the robot accepted, hence the typical starting point at t=2 years. The volume of robots in phase one is typically small 1 to 3 units maximum. The first phase is all about opening up to technology and flexible automation as a driving force of the production platform. Economical benefits are quantified in labor cost saving mainly. Return on investment, depending on many factors, are typically benchmarked at a maximum of 2 years.

In the second phase, when time has passed and barriers to the new technology have been reduced and benefits – direct labor saving and increased production rate – are becoming more obvious more operators are being replaced by robots. Also the robots start to do more complex tasks than the operator did, in example the measuring of the output quality. Up to the economic crisis of 2008 most companies using industrial robots (articulated, Cartesian and/or delta) were – and probably today still are – positioned in phase 2. Often management decides for copying the success of the first flexible automation solution to multiple production lines, taking benefit of the economic advantages this phase brings, but holding short of the threshold of phase 3.

The next step, or third phase is characterized by a well accepted time frame of wide spread use of flexible automation using robots in production lines – the automotive role model. Robots typically handle products in its various sub-stages till finished product and packing and palletizing. The third level is reached by the early adopters of flexible automation. Most western and Japanese car manufacturers operate today in phase 3. In addition the modern beverage industry, due to its large volume and uniformity of its products are situated in this phase. Manufacturers of beers/soda's like Heineken and Coca Cola use their financial strengths to have their breweries and plants automated, with robots, from filling to packing and palletizing. The last phase is the ultimate phase: the highest level of flexible automation reachable.

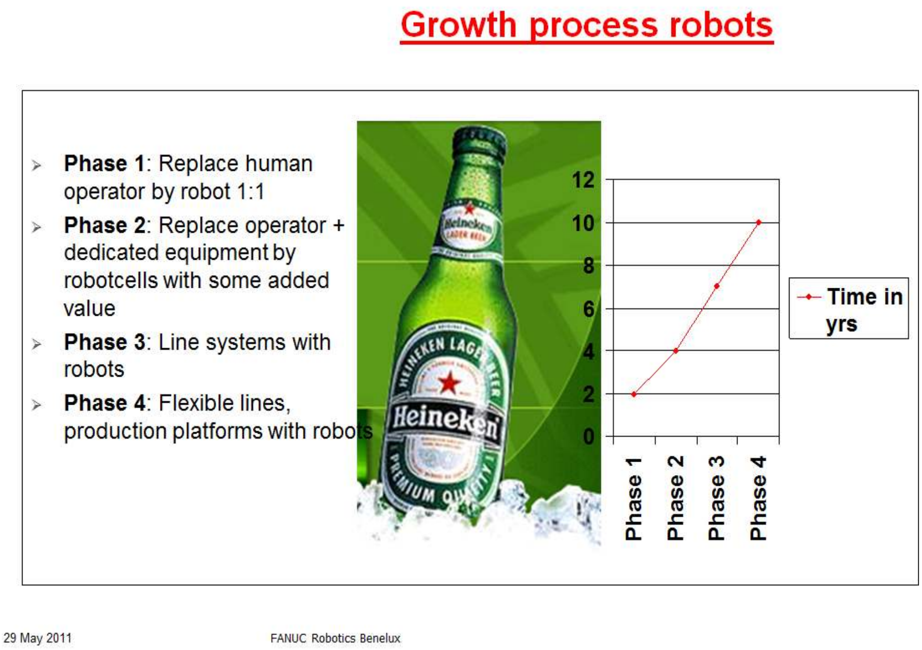

Figure 4. Growth process of Robots.

The line production with robots are replaced by flexible lines, or island production where the manufacturing process of the product (beer, a television, a robot, anything really) is handled by various disconnected production groups of robots, producing to intermediate production warehouses. The disconnection of lines implies getting rid of the negative aspect of line production whilst maximizing the benefits of flexible automation, maximizing throughput and maximizing product quality while minimizing cost. The factories of FANUC Corp is a good example, as the world's largest robot manufacturer, FANUC has some 2000 robots employed , while having only approx 200 factory workers to maintain its production platforms.

A robot/worker ratio of 10:1, (density of 10.000) showing an enormous high degree of automation. Fanuc's capacity ranges to 5000 robots per month, 150.000 servo motors and 20000 CNC controllers. Today food industry can be characterized as being in phase 2. Solar industry and pharmaceutical industry are still in phase 1. Some automotive factories are moving into phase 4. Many metal transforming factories have been using arc welding robots – a typical phase 1 operation. Now they too are trying to move into phase 2 by automation of press brake tending, laser welding with robots.

The conclusion from this modeling is that most companies, and even the development of economies, follow the growth pattern of the "Heineken Growth Phases" – model. It is the underlying process of industrial automation and can be used to establish current position of companies/sectors and predict future steps and investments necessary. The model can guide management in determining the type of staff, education levels and required inputs and expected outputs of the various stages of flexible automation.

Economic impact of robotics up to 2008

As we have seen in the Product Life Cycle example, the number of installed robots and with an average life time span of 15 years, is growing. To understand the impact on a national scale however, the absolute numbers have to be seen in a relative approach. In example, in an under-developed country even a relative small number of installed robots results in a high degree of automation. Phase 1 of the Growth model explains the substitution of workers by robot.

It is therefore a good measure to better understand the economic impact of robotics to calculate the so called robot *density*. The density is calculated by matching the number of robots with the number of workers employed (per 10.000) in manufacturing industry. Figure 5 shows the density chart of industrial robots per industrial sector.

It comes as no surprise that the automotive sector has worldwide the highest density today, ranging up to 400 robots per 10.000 workers. Other traditional sectors like Food and Beverage are still on the low range of robot density, but with large potential. New sectors like Solar Panel Manufacturing are emerging. According to IFR [9] the estimated average robot density in the total manufacturing industry in the world has a robot density of between 50 and 100.

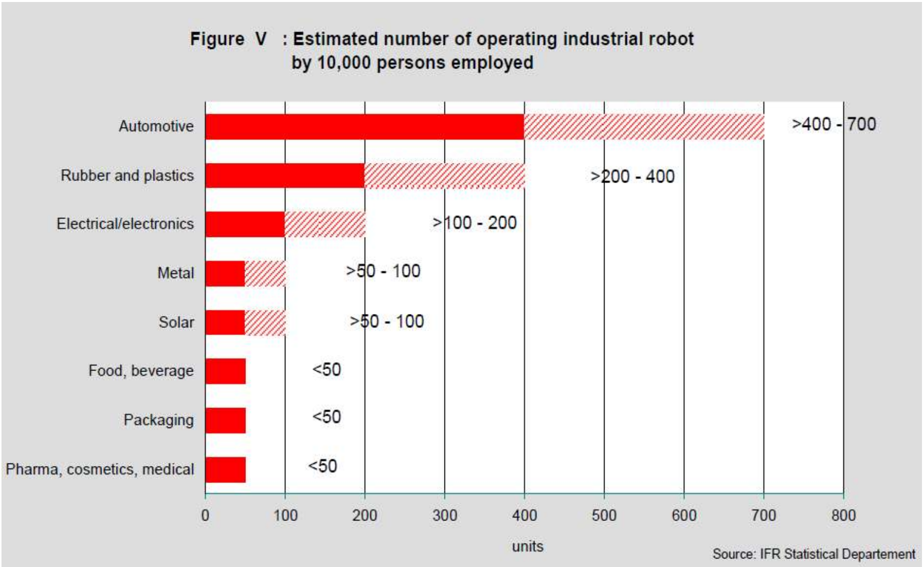

Figure 5. Robot density per industrial sector

In order to increase this density to about 200, (like current status of the Plastics industry, still way below Automotive), it would take between 1.2 million and 1.5 million new robots to be installed. The Growth Phase model already positioned markets like pharmaceutical & medical in phase 1, the density chart underscores this with hard data and clearly shows the enormous potential for robotics in this sector.

If we look at the same date but organized per country, the leading role of Japan in robotics becomes clear. Japan has by far the highest density in the world. The US only comes at a mere 5th position with close to 150 robots per 10000 workers. Hungary scores far less, with a density of up to 20-25 robots per 10.000 workers. Europe as a collective scores average (110-120), still below US and far from Japan.

The density analysis shows that future growth expectation for industrial sectors like food & beverage, pharmaceutical and medical are huge. They are still far away from the current level of automation in the car industry. The so-called BRICs, emerging economic powers Brazil, Russia, India and China do not yet appear on the 2009 chart. These 4 countries represent a vast economic (and military) power. It is only a matter of time before they too embrace flexible automation using robotics as mean to shift the power balance.

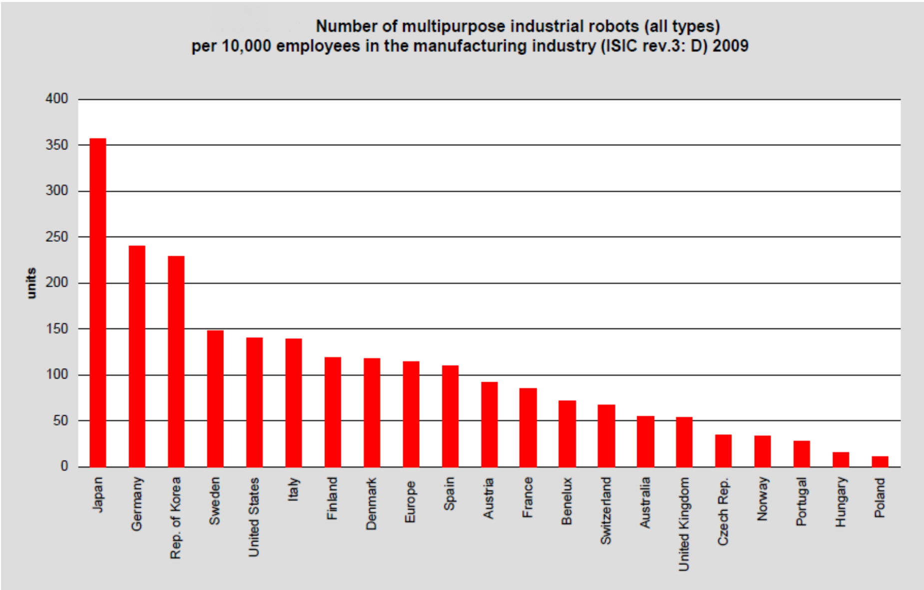

Figure 6. Robot Density per country.

CONCLUSIONS

Robotics as a sector is here to stay for quite some time. Started in the mid ‘50s they grew steadily in many developed countries and industries. Today the industrial robots are coming in a more mature life phase. Most developed countries show a high degree of robot density, but there is an enormous potential for growth, like pharmaceutical, food & beverage and medical industries. The emerging markets, or BRIC countries, will enjoy even faster growth given their current poor density.

Both robot density and growth phase stages show that the peak has not been reached. Industrial robots are commodities, as concluded via the PLC analysis, making the barriers to acceptance of military robots and service robots disappear. Most Military Robotics is still in their Development Stage. Exceptions that must be mentioned are the UAVs [10], [12]-[17].

They experienced a high growth and acceptance rate during their successes of the recent decade in the war on terror. This will only lead to a wider acceptance of other types of military robotics. The highly concentrated industrial robot market however, with clear economic objectives, is not concerned with military robots today. A gap that exists will remain.

References

1. Joseph F. Engelberger Awards Fact Sheet, http://www.robotics.org
2. Buzzel, R. D. "Competitive Behavior and Product Life cycles" Proceedings of the 1966 World Congress, American Marketing Association.
3. Day, G. (1981) The product life cycle: Analysis and applications issues, Journal of Marketing, vol 45, Autumn 1981, pp 60–67.
4. International Federation Robots, Gudrun Litzenberger, IFR General Secretary, press release 07/04/2011.
5. Maj. Gen. James O. Barclay III, Eyes of the US Army - US Army Roadmap for UAS 2010-2035, p1.
6. IFR, World Robotics 2010, Statistical Department, Table Europe. APP-2, ISBN 978-3-8163-0599-6
7. Schneider, F. E. Bridging the Gap in Military Robotics, NATO Research and Technology Organization, November 2008, ISBN 978-92-837-0044-9.
8. http://www.heineken.com
9. IFR, World Robotics 2010, Statistical Department, p15, ISBN 978-3-8163-0599-6
10. Szabolcsi, R. Stochastic Noises Affecting Dynamic Performances of the Automatic Flight Control Systems, Review of the Air Force Academy, No. 1/2009, pp (23–30), ISSN 1842-9238, Brasov, Romania.
11. Szabolcsi, R. – Mies, G. Robotics in Nutshell – Past and Future, CD-ROM Proceedings of the VIth International Conference "New Challenges in the Field of Military Sciences, ISBN 978-963-87706-4-6, 18–19 November 2009, Budapest, Hungary.

12. Szabolcsi, R. Conceptual Design of the Unmanned Aerial Vehicle Systems Used for Military Applications, Scientific Bulletin of "Henri Coanda" Air Force Academy, No. 1/2009., ISSN 2067-0850, pp (61-68), Brasov, Romania.

13. Szabolcsi, R. Identification of the UAV Mathematical Models, CD-ROM Proceedings of the VI[th] International Conference „New Challenges in the Field of Military Sciences, ISBN 978-963-87706-4-6, 18-19 November 2009, Budapest, Hungary.

14. Szabolcsi, R. Extra-Cheap Solutions Applied for Non-Reusable Unmanned Aerial Vehicle Technologies, CD-ROM Proceedings of the VII[th] International Conference „New Challenges in the Field of Military Sciences 2010", ISBN 978–963–87706–6–0, 28-30 September 2010, Budapest, Hungary.

15. Szabolcsi, R. UAV Flight Path Conceptual Design., Proceedings of the 16[th] International Conference "The Knowledge-Based Organization – Applied Technical Sciences and Advanced Military Technology", ISSN 1843–6722, pp(519–524), 25-27 November 2010, Sibiu, Romania.

16. Szabolcsi, R. Conceptual Design of the Unmanned Aerial Vehicle Systems for the Firefighter Applications, CD-ROM Proceedings of the 12[th] International Conference „AFASES 2010", ISBN 978–973–8415–76–8, p4, 27–29 May 2010, Brasov, Romania

17. Szabolcsi, R. Conceptual Design of the Unmanned Aerial Vehicle Systems for the Police Applications, CD-ROM Proceedings of the 12[th] International Conference „AFASES 2010", ISBN 978–973–8415–76–8, p4, 27–29 May 2010, Brasov, Romania.

Sources of figures used above

Figure 1. Theoretical Product life Cycle Derek F. Hall Strategic Market Planning, P.60, ISBN 0-13-851049-0 01.

Figure 2. Industrial robot PLC, based on data from IFR, World Robotics 2010,IFR Statistical Department.

Figure 3. Concentration Curve Industrial Robots 2008, FANUC Robotics Magyarország Kft Statistics

Figure 4. Heineken Growth Phases of Robots, 2005, B. Struijk, FANUC Robotics Benelux.

Figure 5. Robot density per industrial sector, IFR, World Robotics 2010, IFR Statistical Department.

Figure 6. Robot density per country, IFR, World Robotics 2010, IFR Statistical Department.