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ROBOT PRODUCTION VOLUME DATA TRENDS AND ANALYSIS[⊗]

TRENDEK ÉS ADATANALÍZIS A ROBOTGYÁRTÁSBAN

Bob STRUIJK, BSc, MBA

General Manager, Vice President Europe
FANUC Robotics Magyarország Ltd.
ZM NDU, PhD Student
struijkb@fanucrobotics.es bob@fanucrobotics.hu

Abstract: *To determine how industrial robots has grown and how they will grow and to understand why it has grown in that way, a large number of factors can be investigated:*

- *The annual production volume of industrial robots.*
- *The type of application where the robots were used in*
- *The types of industries adapting robots over time*
- *The geographical markets that used robots over time*
- *Macro-economic data of the automotive industries of the regions involved*
- *The spread and use of industrial robots and UAV's in current society in industry, its effect on employment.*

The data analysis will highlight growth trends of the various regions and indicate sectors for growth.

Keywords: *robots, unmanned aerial vehicle UAV, robot applications, IFR, automobile industry, articulated , BRIC, robot density.*

Kivonat*: A szerző célja bemutatni, hogyan nőtt az iparban alkalmaztott robotok száma, és várhatóan hogyan fog tovább nőni. A szerző az alábbi tényezőket vizsgálja a cikkben:*

- *az előállított ipari robotok száma*
- *az ipari robotok alkalmazási területei*
- *az ipari robotok földrészenkénti alkalmazása*
- *a vizsgált régiók makroökonómiai adatainak vizsgálata az autóiparban*
- *az iapri robotok és az UAVk alkalmazása a modern társadalmakban, és a robotok alkalmazásának hatása*

A vizsgált adatok alapján a szerző következtetéseket állapít meg a robot alkalmazások növekedése, és a növekedés egyes területei között.

Kulcsszavak*: Robotok, Pilóta nélküli légijármű UAV, robot alkalmazások,IFR, autóipar,vizsgált, BRIC, robot-sűrűség*

I. RELATED WORKS

Robots have their roots in the ever present desire to automate, mechanize tedious labor tasks. The evolution of automata and robots and man's fascination are explored by McCloskey [1]. Szabolcsi and Mies [2] give a short brief upon history and future of modern robotics. Difficulties occur when handling non-conventional materials with robots (such as soft polyurethanes foam parts). The main problem is that the part changes its shape when handled with an impacting gripper.

A simple solution using ingressive (needle) gripper for handling these kind of materials was introduced in [7], and a method for designing such grasping method was given in [8], [9]. An example of a region suffering from the lack of investment in flexible automation is given in [10].

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Wang in [14] studies the development and trends of industrial and service robots in China, while Kemp in [16] analyzes the impacts of niche strategies in the automotive industries. In the service robotics field, the sector of air applications is highlighted.

The growing segment of Unmanned Aerial Vehicles is investigated by Frost and Sullivan in [17]. Pan in [18] surveyed the position of UAV's among the aerospace industry and forecasted its market for 2020. In [19] and [20] Szabolcsi dealt with special UAV applications both for military and non-military purposes. The basic mathematical modeling problem of the human operator/pilot is outlined in [21]. The environment in which air robots act is described in [22].

Identification of the UAV flight dynamics model is presented article [23]. Flight path preliminary design is shown in [24] and [25] to provide quasi-optimal behavior of the UAV.

The mathematical theoretical backgrounds are summarized in [26] by Pokorádi for analysis of dynamical systems.

II. INTRODUCTION

This paper will focus on the statistical data available on the evolution of robots in society. Automation using robots started in with the use of articulated robots in the automotive industry. Over time other industries followed. The first applications were to be found in material joining area: spot welding and arc welding in car factories.

With the spread of automation into other industries, robots were being used in different applications like machine loading and material handling. In the last decade industrial robots can be found in all industries.

New sectors are opening up for robots like aerospace and the medical sector. The author will determine in what way robots and their use will be used in the future based on current market information and trends. Cross section analysis on industries and prevailing regions will be applied. Model analysis needs to assist in determining trends. Robot density charts will identify the strength and growth areas.

III. THE DOMINANCE OF ROBOTICS

Automation has deep roots, going back to the early days of mankind. Modern robotics is a logical result of the industrial revolution that started in the late 18th century in England. The Industrial Revolution de facto changed the economic scene as per-capita economic growth was realized in the western economies. It started the modern capitalist economies. A relevant fact as all historians is in agreement that the onset of the Industrial Revolution is the most important event in the history of humanity since the domestication of animals and plants [1].

One development worthwhile mentioning is that of machine tools. The textile industry which was at its heights in the late 18th century employed craftsmen from the watch and clock sector to develop machine tools to be able to produce parts necessary for the automation of textile machines. Machine tools enabled to produce machines made out of metal in an economic way, instead of using manual labor on wood and steel and thus became the stepping stone for modern engineering and flexible automation using robotics, as we will see later [2]. It was the automobile industry that embraced robotics in the mid-20th century. In 2010 more than 77 million cars were produced worldwide [3]. A staggering number indeed, providing the home for many industrial robots in applications like spot welding, arc welding and handling, among others.

In fact, many current well known industrial robot suppliers found their origin within one of the car manufactures' automation departments. The current biggest manufacturers of robots are 1, FANUC, that was emerged out of a merger between General Motors (GM) and FANUC Ltd, while 2, the German based robot manufacturer Kuka, grew out of the Volkswagen automation department and 3, Swedish/Swiss group ABB that was created partly from Renault automation. It may come as no surprise that the automobile industry is today still the largest user of industrial robots. According to the International federation of Robotics (IFR) the number of units sold worldwide almost doubled in 2010 vs. the crisis year of 2009. It demonstrates the acceptance of robots as means for flexible automation solutions. Even compared to 2008, which was a record year in itself, a growth rate of 5% was achieved

[4]. Figure 1 shows the estimated worldwide supply of industrial robots for the last 13 years.

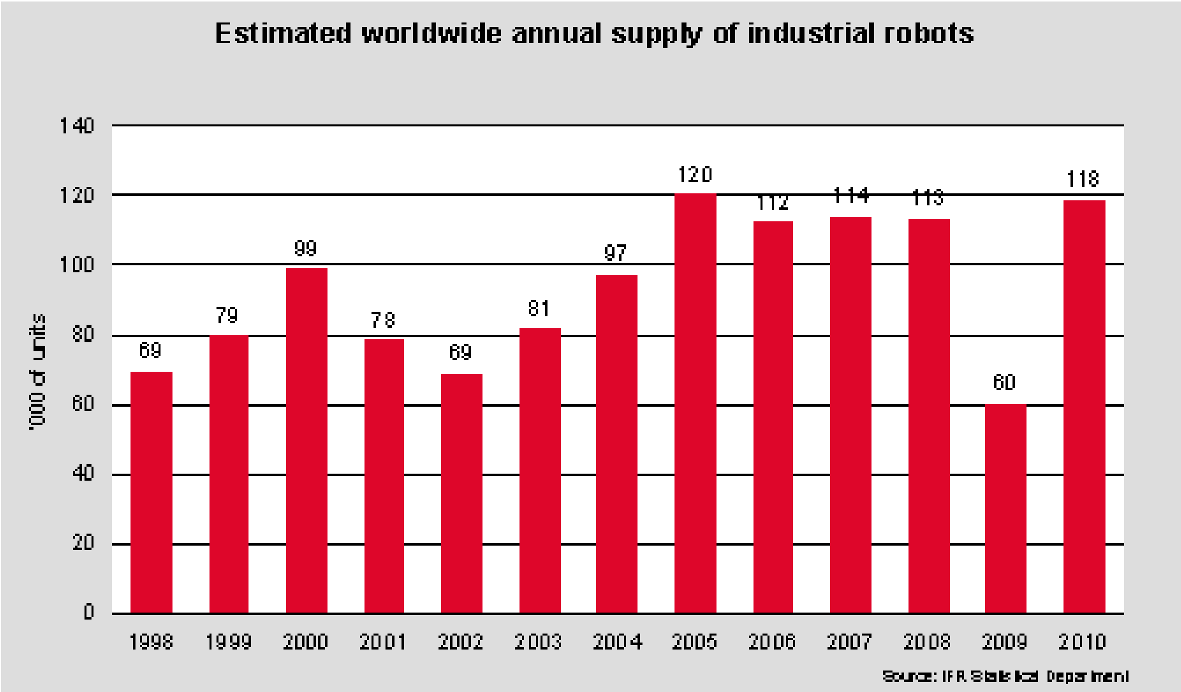

Figure 1. Total annual supply of industrial robots worldwide

Four immediate conclusions can be drawn from Figure 1.

1. The total number of industrial robots supplied in absolute value, 118.000 units in 2010, demonstrates the high degree of acceptance of robots as means for flexible automation.
2. The quick recovery from the impacts of the financial crisis 2009 to 2010 demonstrates that robots are linked to capital good investment and industrial output.
3. The crisis in 2009 plunged robot deliveries with -47% to a level equivalent of 1994. A significant drop, but nonetheless not cyclical nor trend related.
4. The annual compounded growth rate since 2002 till today amounts to 7%. A strong grow rate, which will continue for the future.

As Struijk [5] already showed, today position of industrial robots in the product Life Cycle is that of a Maturity Stage. New strong growth rates are to be expected from spin off technologies and technological developments on the base design. The maturity of the industry will become more clear when analysing the various industries.

If we add the two sectors that make up the Automobile sector, being Motor Vehicles and Automotive Parts, we see that this is still the largest user of industrial robots. In total some 32.700 units were used worldwide, close to 28% of the total. The Electronics sector, which includes TV, computers etc., is a good second driver of robots with approximately 31.000 units or 26% delivered. Interesting to establish is the fact that the Metal sector did not recover from the 2009 crisis as did most other sectors. Robots in the Metal sector are used for arc welding and some handling, often related to the construction markets.

The real estate sector is indeed still in a slump following the financial crisis of 2009 and the subsequent sovereign debt crisis in Europe and the US. Another noteworthy fact is that of the Food Industry. In 2010 they were good for 4350 units, a 4% share. Small compared to Automobile and Electronics, but its significance is growing fast. 58% of worldwide robot sales to this industry are done in Europe as we will see later. It is estimated that since the introduction of industrial robots (1960 onwards) the total number of units installed is approximately 2.1 million units. According to an

UNECE/IFR study [6], the average economical life of an industrial robot can be estimated at 15 years. This implies that the worldwide operational stock of industrial robots is approximately 1.3 million units! The economic value in 2010 can be estimated at US$5.7 billion.

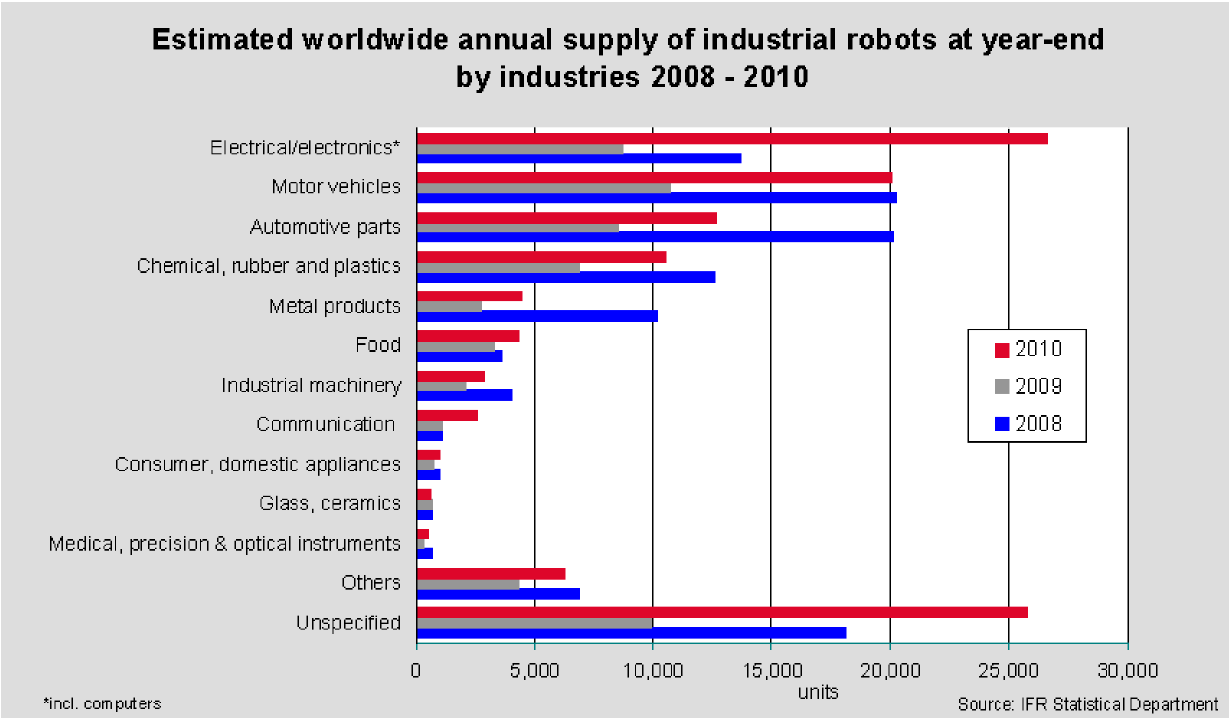

Figure 2. Worldwide supply of industrial robots by industry

The average value per unit for end customers is hence 48.000 US$. The value of a robotics system is of course much higher. A robotized work cell contains other costly hardware components like customized grippers, cell safety, interfacing of the robot with its peripherals etc. and various software components. In designing robot cells the main problem is that often parts can change form and shape when handled with a passive gripper. A simple solution using ingressive (needle) gripper for handling these kind of materials was introduced in [7], and a method for designing such grasping method was given in [8], [9]. So to estimate a value, we can not only consider the robot but must add these customized items like grippers and software.

An industry rule of thumb to estimate the value of a robot system is; system price is 3x the naked robot price. So the total market for robotics systems in 2010 is estimated at 3x 5.7 billion, or 17.5 billion US$. It is a large sector which has its own momentum, and will continue to grow.

III. GEOGRAPHICAL DATA ANALYSIS

With the value of the market established and the main industries identified, the next step is to analyse the various markets per economic region. As industrial robots are means of flexible automation, the geographical areas are split in three main areas: Asia (incl. Australia), Europe and America. Figure 3 shows the breakdown of annual sales to these regions.

From Figure 3 the following main conclusions can be drawn:

- Asia dominates with a 60% share, headed by South Korea and Japan
- China doubled its unit volume from 2008 to 2010, and has a total share of ~13%.
- Japan, as only Asian nation, did not recover from the 2009 crisis, realising in 2010 a unit volume well below 2008 levels, losing some of its previous competitiveness to emerging countries like China and Korea.

- While the Americas (read USA) recovered fully from the 2009 crisis, Europe did not, lagging behind. The 2010 absolute value in Europe (30.630 units) is still substantial higher than in the US (16.356 units).
- Germany, the economic motor of Europe is by far the largest user of robots, almost 50% of all European robots are destined for Germany. A part will be re-exported but this is not taken into account.
- The UK has lost its traditional manufacturing power, and is transformed into a service and banking industry. With less than 1.000 robots sold per year, its manufacturing weaknesses are surfacing. In a recent study it showed that UK companies, despite being innovators in product and process technology are falling significantly behind their European competitors in adopting automation [10].

Estimated annual shipments of multipurpose industrial robots in selected countries. Number of units

Country	2008	2009	2010	2011*	2014*
America	**17,192**	**8,992**	**17,114**	**22,450**	**26,700**
North America (Canada, Mexico, USA)	16,242	8,417	16,356	21,000	24,000
Central and South America	950	575	758	1,450	2,700
Asia/Australia	**60,294**	**30,117**	**69,833**	**81,200**	**100,000**
China	**7,879**	**5,525**	**14,978**	**19,500**	**32,000**
India	883	363	776	1,000	3,000
Japan	33,138	12,767	21,903	26,000	30,000
Republic of Korea	11,572	7,839	23,508	24,500	21,000
Taiwan	3,359	1,474	3,290	3,700	4,500
Thailand	1,585	774	2,450	3,100	5,000
Other Asia/Australia	1,878	1,375	2,928	3,400	4,500
Europe	**34,695**	**20,483**	**30,630**	**34,700**	**38,900**
France	2,605	1,450	2,049	2,400	2,800
Germany	15,088	8,507	14,000	15,500	16,500
Italy	4,793	2,883	4,517	4,600	4,900
Spain	2,296	1,348	1,897	2,100	2,400
United Kingdom	856	635	878	950	1,100
Central and Eastern Europe	2,603	1,448	2,507	3,700	5,100
other Europe	6,454	4,212	4,782	5,450	6,100
Africa	**454**	**196**	**259**	**400**	**500**
Total**	**112,972**	**60,018**	**118,337**	**139,300**	**166,700**

Sources: IFR, national robot associations.

*forecast

Figure 3. Annual industrial robot sales per region.

In 2010 China has enjoyed a 171% growth over 2009 and has become the fourth largest worldwide robot market. This growth is due to two factors. First, is the need to increase its production capacities, steering more away from the traditional manual labour to flexible automation. And second, the need to produce at higher quality levels. Flexible automation using robots yields higher production consistency and quality, and hence reduces costs for rework and scrap.

The forecasts made by IFR for the year 2014 show that the annual shipment for China will surpass the sales volume of Japan, reaching to a level of an estimated 32.000 units (Japan 30.000): it is a shocking prediction that will displace Japan from its undisputed leader position. The number of installed robots will keep Japan in the driver seat for quite some years, but the threat is clear.

In order to compare the regions and the use of robots as mean of flexible automation and thus manufacturing power, it is better to analyse the so called ‘robot density’ than just comparing absolute figures of robot sales and robot stock. The official definition of robot density is the number of multipurpose industrial robots per 10.000 persons employed in the manufacturing industry. A variant exist with reference to density but only related to employees of the Automotive Industry. [11] The world’s average robot density is 51 robots per 10.000 employees. Of course this changes dramatically when looking at the various countries. Figure 4 shows the robot density for 2010. Here we can derive various distinctive groups.

The first is the top 3; Japan, Korea and Germany with densities of 306, 287, 253 respectively. We can consider these three countries as the most automated in the world. A second group with still a high rate of robot density, which includes the US (with a robot density of 130) clearly underlines the gap between the top and followers. The US, Italy, Sweden, Denmark, Finland, USA, Spain, France and Taiwan all have similar densities and are considered strong industrialized nations.

But the gap is large and in the case of Korea and Japan even widening. Densities in the second group have risen in 2010, but not so much thanks to the high increase of robot stock but more debit to the rising unemployment rates. It might come as a surprise that none of the BRIC countries are represented in the chart. They have a density of 20 or lower. But it reveals the high potential of these regions for flexible automation.

The economies of the BRIC countries grow faster than that of the traditional industrialized countries. Both India and Russia have a robot density of 1 in 2010, while Brazil does not score much better with a mere 6 robots per 10,000 workers. If we look at the trends we find clearly a decline in Japan’s strength, its density dropping from 2006 (338) to 2010 (306) while Korea increased from 193 to 287.

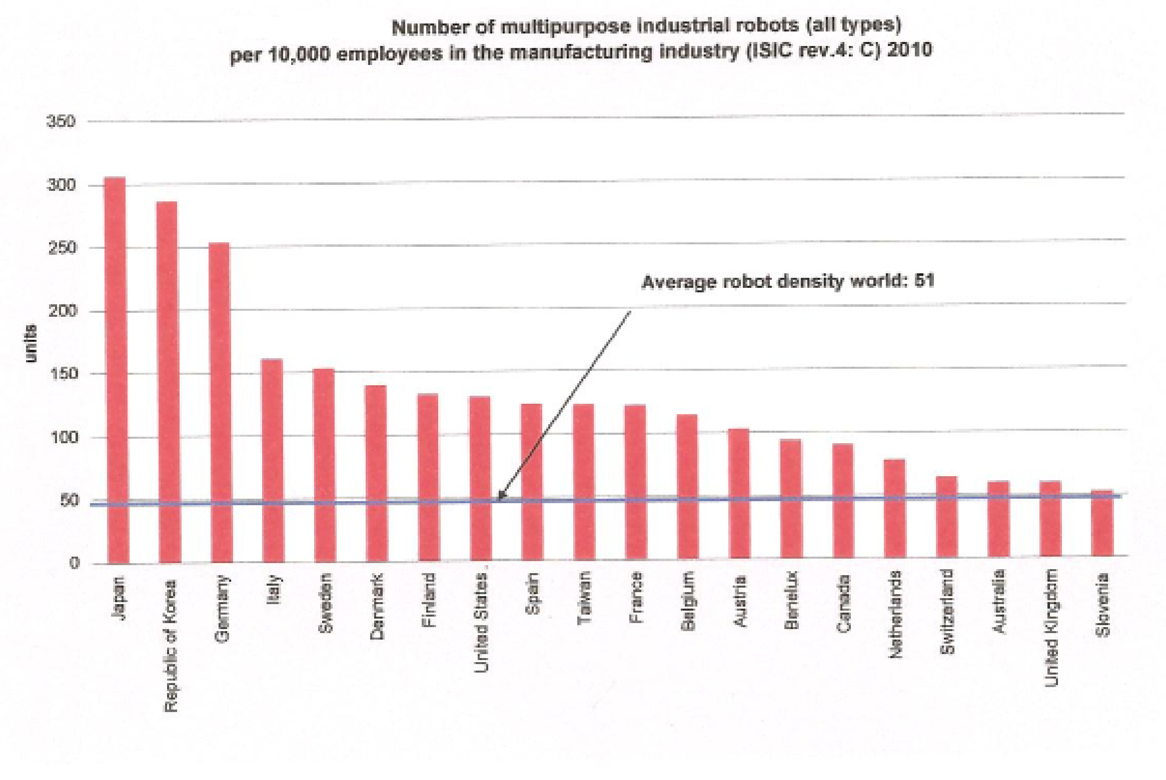

Figure 4. Robot density per country.

In the same period China grew from 5 to 15 robots per 10,000 workers. Still a midget compared to the other countries when it comes to the density parameter, but with its vast expansion and economic power I predict this number to grow sharply over the coming years. An example can be found by recent announcement of the Taiwanese manufacturer Foxconn that it will need 1 million robots over the next three years to replace manual labour [12]. Even though these numbers are not realistic, it does underline the enormous potential for the region.

It should be noted that China does not produce its own industrial robots, although some foreign manufacturers like the Japanese group Yaskawa and the Swiss/Swedish conglomerate ABB do produce locally in China, mainly to profit from the low labour rates [13] and have a local face. Local industrial groups like SIASUN and Boshi, with support from the Chinese government are growing fast, according to a recent study of Wang [14].

It is only a matter of time they will jump from the prototyping phase to the industrialisation of their own industrial robots and UAV's. A Chinese UAV prototype already made successful flights for south polar research in 2007.

IV. THE AUTOMOTIVE LINK

If we take the 2008 manufacturing figures for worldwide automobile [15] and cross this with Figure 3, we arrive at Figure 5.

					Robots		Robot	
Country	Cars	commercial	Total		Sold		Stock	
America	9,134,500	7,622,288	16,756,788	24%	17,192	15%	173,977	17%
Asia/Australia	23,703,965	6,367,579	30,071,544	42%	60,294	54%	514,914	50%
Europe	18,796,213	3,380,758	22,176,971	31%	34,695	31%	343,779	33%
Africa	1,334,479	394,698	1,729,177	2%	454	0%	1777	0%
Total	53,329,917	17,932,381	71,262,298	100%	112,635	100%	1,034,447	100%

Figure 5. 2008 Automobile production and robot installations

Although Figure 5 takes all robots installed in a region into account, the relative values would remain equal. The table clearly shows the dominance of the Asian (Japanese) car manufactures over the US. For years the US, with 'Detroit' being the center of automotive manufacturing, has had a leading edge over its worldwide competitors. As Kemp argues in [16], most US car manufacturers have chosen the 'Cost Leadership' production strategy. Although they did invest in robots and flexible automation to achieve cost-down, they failed to follow the market trends of smaller and fuel economic models.

Today Asia (with Japan and China as production leaders) has an output more than double that of the US. It may come as no surprise that the robot stock in this region is triple to that of the US. Asia now produces 42% of all vehicles and possesses more than 54% of all robots worldwide. Where Europeans hit average on both sides, the US is clearly underperforming. The robot stock in Europe is almost double that of the US. The competitive advantage of the Japanese car manufacturers both in quality and pricing over their US counterparts was already well known.

The situation becomes even clearer when the robot density per 10.000 employees in the automotive industry is analyzed. Here Japan, the most automated country in the world, scores with 1.436 robots per 10.000 auto-workers the highest (other industry 191), compared to the number two Germany with 1.130 (other industry density 134). While the electronics sector is highly automated in Japan, in Germany robots are more widespread in their industry. The US follows Germany with 1.12 industrial robots per 10.000 employees (only 69 in other industries). The gap with Japan is clear. As seen before the UK lags behind, with 'only' 600 robots per 10.000 auto-workers, an unsustainable position for the mid-term. Already most original UK brands like Jaguar and Mini have been taken over. The BRIC's automotive density score low is as well, (Brazil 56, India 29, China 105) but are growing steadily. With their growing population and economies the market for industrial robots is enormous. The density figure also outlines the fact that growth in non-automotive sectors like Food & beverage, Medical and Plastics is emerging.

V. UAV & DEFENSE ROBOTS

When we look at defense related robotics, there is one sector worth mentioning. The Unmanned Aerial Vehicles (UAV) take up 45% of all service robots in defense applications in 2010. The value of defense robots is estimated at US$700 million, still far lower than the market penetration of industrial robots. The forecast for 2020 is that this industry will grow to a staggering 20 billion US$.

Research conducted by Frost & Sullivan [17] for the European union has indicated that between 2004 and 2008, the number of UAVs deployed globally on operations has increased from around 1,000 to 5,000 systems. Leading countries are the US, Israel, France, Germany and the UK.

According to Pan [18] UAV's have reached a level of maturity that put these robots on the forefront of international aerospace manufacturing. Although the early UAV's were mere drones, radio remote controlled vehicles by human operators, the latest generations UAV include built in guidance and control systems and advanced vision and weaponry systems. Although mainly military, in Japan there is a development of UAV use for civil applications [27].

VI. CONCLUSIONS

Robots are not changing the industrial landscape but also the competitiveness of countries and regions. Japan is by far the most automated country in the world with a robot density 6 times that of the world's average. But new markets are emerging quickly, especially in Asia where Korea and China are growing in a fast pace. It is predicted that China will overtake Japan in annual robot installations as early as 2014.

The data suggests that the rise of a national Chinese robot manufacturer can be expected. Other traditional industrial regions will struggle, like the US and Europe, with the UK in particular, unless they are able to revive investments in R&D and flexible automation. Germany makes up 50% of the European market and plays a crucial role in the old continent.

The amount of robots in operation in absolute values is growing faster each year. Robots are to be found in many industrial sectors, with high shares in Electronics and Automotive industry, and growing numbers in new sectors like Food and Medical. Similar to industrial robots, the market for UAV's is expanding at an increasing rate. As these types of robots are mainly military we see a continuing dominance of the US and to a lesser extent European countries.

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SOURCES OF FIGURES USED ABOVE

Figure 1. Graph of 'Worldwide annual supply of industrial robots'. Source: IFR Statistical Department
Figure 2. Graph of 'Worldwide supply of industrial robots by industry'. Source: IFR Statistical Department
Figure 3. Chart of ' Annual industrial robot sales per region'. Source: IFR and national associations
Figure 4. Chart of 'Robot density per country'. Source: IFR Statistical Department
Figure 5. Table by author of '2008 Automobile production and robot installations'. Source: IFR and International Organization Motor Vehicles Manufacturers.