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Industrial Robots Worldwide Market Development: Robot Data and Robot Density Projection for the Year of 2030

Observing the markets over the last five decades it is obvious that robots, nowadays, have become a serial product for various industries. Many different manufacturers produce robots of different types, different sizes, different payload categories, and with hundreds of different abilities. There is already a global robot market which holds for every application the ideal robot. Looking at the next decades it can be easily predicted that the development of the robot market will keep on moving forward. In this paper estimations will be analysed in order to give a detailed projection on the development of the robot market and the robot density in the year 2030.
Keywords: industrial robots, robotic forecast, Industry4

Introduction

The very fast growing robot population together with the fast rising of the technical complexity of robots is a big challenge for engineers today and in the future. The latest publication of the International Federation of Robotics (IFR) shows that the era of robotics has just started. [1] A large increase of robot sales in all the industrial developed countries is observed, but there is also an almost explosive growth in the developing countries.

In this category of developing countries, China takes an extremely important role. With this situation today everybody will understand the upcoming challenge looking towards the immediate as well as the long-term future. In a global world of 2030 we have to expect robots working in every segment of the production, military, service and many other fields of life. The estimation for the numbers of engaged robots by this time is only possible with the use of the statistical data from the past.

These statistics show how the robot market reacted on different events and developments in the past and also show the influences of the price changes, quality demands or macroeconomic events. Only a few publications focus on the future robot market development with real figures. Most of the literature follows the future estimations in applications and branches such as the one of Martin Ford. [2] [23]

The IFR provides a unique global statistic for the robot markets and it is the main source of all published relevant market and branch-specific data. The statistics are based on consolidated world data reported by robot suppliers as well as on the statistics of the national robot associations of North America (RIA), China Robot Industry Alliance (CRIA), Japan (JARA), Denmark, (DTI), Finland (TBL), Germany (VDMA, R+A), Italy (SIRI), the Republic of Korea (KOMMA), Romania (Robcon), Spain (AER) and the United Kingdom (BARA). [1] The purpose of the authors is to predict trends in robot design and production for the decade of 2030 considering statistical data available for robot density prediction.

Industrial Robots

According to ISO 8373 the IFR classifies industrial robots as follows [3]: "An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes which may be either fixed in place or mobile for use in industrial automation applications".

This definition is the delimitation to special machines in automation. Other classifications of industrial robots are according to the mechanical structure or the robot type (Figure 1). IFR-statistics count according to this classification of mechanical robot structures. The delimitation is one of the big challenges in Robot Statistics. Especially in the field of electronic productions automation, the boarder between robots and special purpose machines is a very narrow path.

For many years this classification has represented the robot markets and showed steady impressive growths of this branch. Since the last few years the parallel or delta robot, as a fifths mechanical structure, has become more important and entered the statistics. This classification was formerly broader but some mechanisms became cumbersome and difficult to use.

These were left out of the scope (e.g.: spherical, cylindrical robots) while new ones were introduced. Even these days the classification is changing day by day. Some robot types steadily become less popular (e.g. the SCARA and Cartesian in some fields of manufacturing) and others widen in range. The articulated robots become more widely used and other versions of them are being developed such as the 7 and more axis, offset wrist robots, light robot versions, etc.

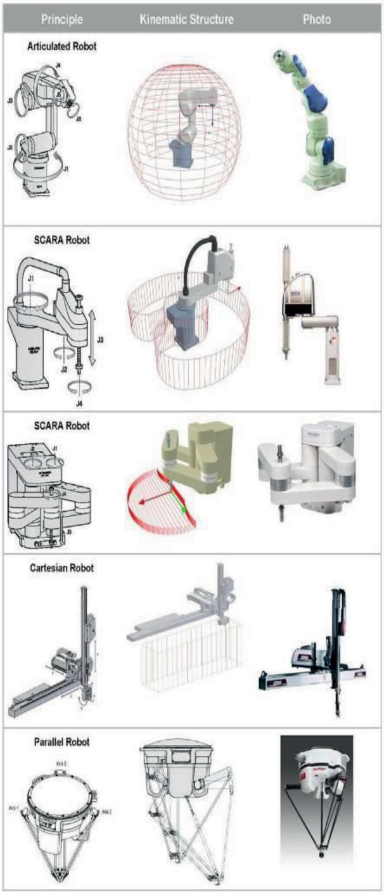

Figure 1. Classification of industrial robots according to their mechanism

The classification of industrial robots by industrial branches shows the wide range of usage for these multipurpose machines (Figure 2).

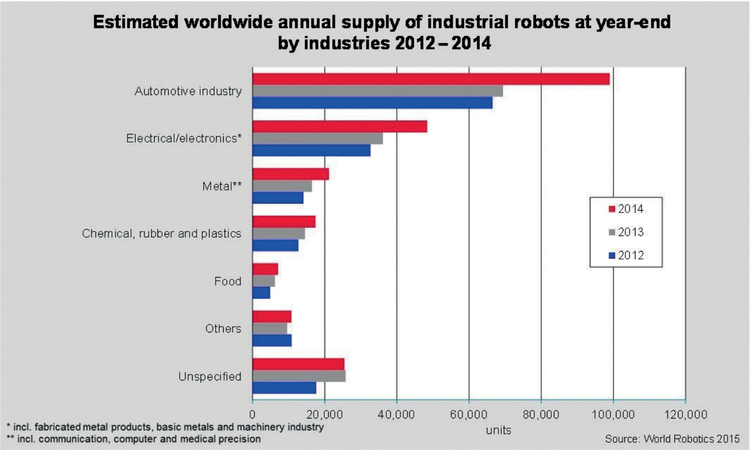

Figure 2. IFR Estimated worldwide annual supply of industrial robots by industries at the year-ends of 2012–2014 [4]

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The classification for industrial robots by industrial branches shows the wide range of usage for these multipurpose machines (Figure 3).

The classification by applications areas gives a good overview about the abilities and flexibility of industrial robots. The list below (see Table 1) shows the type of classification by application areas, which is used in the IFR yearly surveys. [5]

Table 1. Industrial robots broken down by application areas

Robotic operation	Operation details
Handling operations	• Metal casting (including handling operations for heat treatment); • Plastic moulding; • Stamping/forging/ bending; • Machine tools (loading/unloading); • Palletizing • Packaging, picking and placing
Measurement, inspection, testing;	• Geometrical Measuring inspection (e.g.: length measuring) • Fatigue testing • Operation evaluation
Machine tending	• Machine tending for other processes (handling for assembly) • Material handling n.e.c.
Welding and soldering (all materials)	• Arc welding; • Spot welding; • Laser welding; • other welding (incl. ultrasonic welding, gas welding, plasma welding); • Soldering
Dispensing	• Painting and enamelling; • Application of adhesive, sealing material or similar material; • Dispensing others/ Spraying others
Processing	• Laser cutting; • Water jet cutting; • Mechanical cutting/grinding/ deburring/ milling/polishing; • Other processing
Assembling and disassembling	• Fixing, press-fitting (including bonding); • Assembling/ mounting/ inserting; • Disassembling; • Other assembling
Others	• Cleanroom for FPD; • Cleanroom for semiconductors; • Cleanroom for others; • Others

The shares of these applications are summarized in Figure 3.

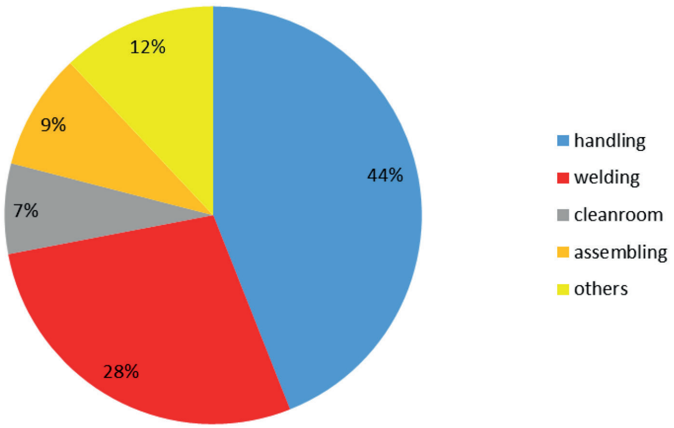

Figure 3. Shares of applications, industrial robots 2013 [Gerald Mies 2015]

The main difference between industrial robots and all other technical machines is that industrial robots can be built as multi-process-machines with no agreed application.

With this flexibility as multi-process-machines, robots have a much lower threshold when investing in automation. Customers can invest in robotic automation, without having a risk with changeable requirements. Robots are the key instruments in production strategies of flexible automation.

Most of the robot suppliers design their robot types as multifunctional robots. That means one robot type with identical mechanical components and identical robot controller can become an arc welding robot, a paint robot, an assembly robot or a handling robot. Responsible for this multiple use is the application software of the robot, the so-called application tool. This is one of the most important characteristics of robots and a key for their economic success. The second unique feature is the flexibility during the process. Robots are able to change their tasks within the production cycle.

Service Robots

The definition of service robots is much more difficult than the definition of industrial robots. The wide range of possible usage of service robots makes the definition dependent on the application of the robot. Even industrial robots can also be regarded as service robots if they are installed in non-manufacturing operations.

Considering these aspects UNECE (United Nations Economic Commission for Europe) and IFR give the following definition for service robots:

- A *robot* is an actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment to perform intended tasks. Autonomy in this context means the ability to perform intended tasks based on current state and sensing, without human intervention.
- A *service robot* is a robot that performs useful tasks for humans or equipment excluding industrial automation application. Note that classification of a robot into industrial robot or service robot is done according to its intended application.
- A *personal service robot* or a service robot for personal use is a service robot used for a non-commercial task, usually by lay persons. Examples are domestic servant robot, automated wheelchair, and personal mobility assist robot.
- A *professional service robot* or a service robot for professional use is a service robot used for a commercial task, usually operated by a properly trained operator. Examples are cleaning robots for public places, delivery robots in offices or hospitals, fire-fighting robots, rehabilitation robots and surgery robots in hospitals. In this context, an operator is a person designated to start, monitor and stop the intended operation of a robot or a robot system.
- A *robot system* is a system comprising robot(s), end-effector(s) and any machinery, equipment, devices, or sensors supporting the robot performing its task.

Note of the Statistical Department: According to the definition, "a degree of autonomy" is required for service robots ranging from partial autonomy (including human-robot interaction) to full autonomy (without operational human-robot intervention). Therefore, in addition to fully autonomous systems, service robot statistics include systems which may also be based on some degree of human-robot interaction (physical or informational) or even full tele-operation. In this context, human-robot interaction means information and action exchanges between humans and robots to perform a task by means of a user interface. [6][7]

The complexity of the definition of the field of service robots shows that this part of robotics is still a new, multifunctional and unpredictable discipline.

Some examples of service robots are robots for domestic tasks like vacuuming or pool cleaning, handicap assistance with robotized wheelchairs or personal rehabilitation aides as well as professional service robots in fieldwork, professional cleaning, construction and demolition, and logistics. Additionally, military robots make up a big part of service robots looking at unmanned aerial vehicles, drones, demining devices, etc. [28][29][30][31][32][35]

Since professional and military service robots have a far bigger share than robots for personal and domestic uses, this paper will not consider the latter. Their numbers are much too small to be of major significance.

Data and Trends

Worldwide market development of industrial robots

After the financial crisis in 2009 the market of industrial robots recovered faster than expected. In 2010 the robot branch reports 118,333 shipments, [5] a plus of 97 percent compared to the data of the year of 2009. [5] The number of total installed industrial robots grew up to 1,035,000 units worldwide. [8][26][35]

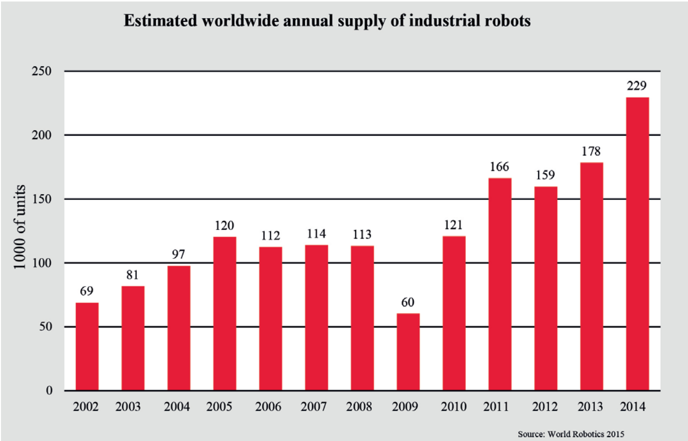

Figure 4. Estimated worldwide annual shipment of industrial robots 2002–2014 [5]

The diagram shows clearly that – excluding the years of weak economies (2002, and 2009) – the shipment of industrial robots continuously grows. No other branch in the field of engineering has a similar constant trend of growth.

The next two charts (Figure 5, Figure 6) give a reflection of where the markets of the largest increase are in the world.

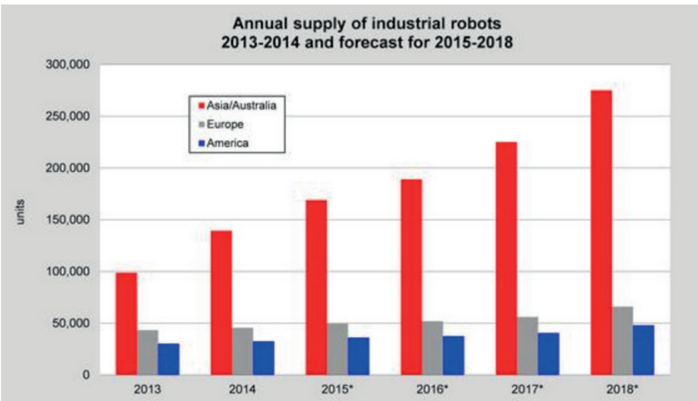

Figure 5. Industrial robot shipments according to years and regions [10]

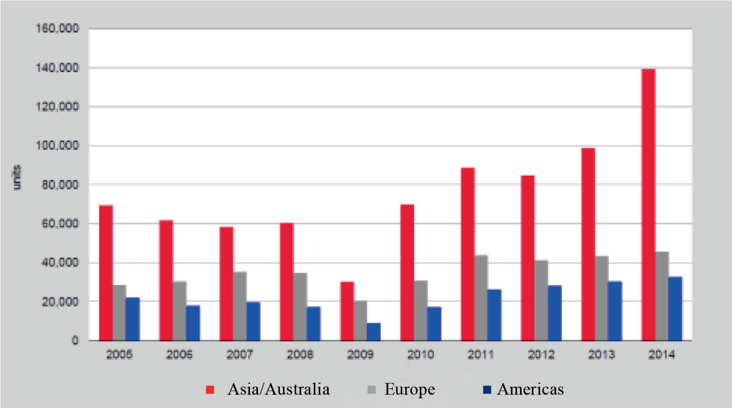

Figure 6. Industrial robot shipments according to years and regions [9]

The annual shipment of robots to Asia and Europe in 2001 and 2002 was nearly on the same level. The above shown figures indicate that the Asian robot markets have doubled the shipment-result of that of Europe since 2005. Behind the numbers of the Asian success, are two countries of significant increasing robot shipments: China and Korea.

The former strongest Asian robot market, the market of Japan, fell down from 43,932 shipments in 2005 to 29,297 shipments in 2014. This means that the Japanese domestic robot market shrinks. The reason for this change in Japan is not the change of production philosophies; it has the same production politics as in a global world. Japanese companies have also followed the large demanding markets and they started production plants in the countries of their customers. Japan is still by far the largest supplier of industrial robots with the second highest robot-density in production industry worldwide. [11]

According to IFR [12] [13] China and Korea are the large drivers of the Asian robot markets. Korea has nearly doubled its robot shipments and China has tripled the market from 2005 to 2014. However, also many other, smaller Asian markets have doubled or tripled their volume during the same time, just still at a lower level. [14]

This development in the Asian automation industry indicates for the future a clear change from classical low wage countries with manual production to countries with highly automated production facilities.

Worldwide market development of professional service robots

Service robots for professional use are similar to industrial robots. They are defined as machines with a high technical level and predominantly with a high value. Figure 7 shows the 2013 market share of applications service robots for professional use. [15]

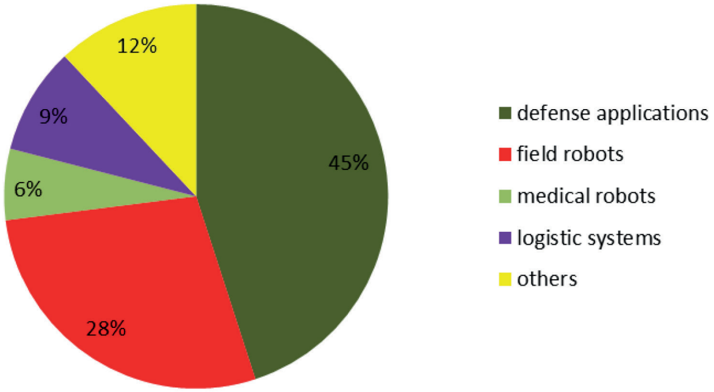

Figure 7. Shares of applications, professional service robots 2013, according to [16]

Defence applications are dominating in professional service robots with a part of 45 percent. With a strong rise of unmanned combat missions as a strategy against international terrorism, the demand for robotized military equipment is believed to keep rising. [33] Especially, since defence robots represent a group with a very high technical and price level. The unmanned aerial vehicles represent the largest military application. [28][30][34]

The rate of growth in units of service robots for professional use performs in a similar way than for industrial robots. The sales value on the other hand increases much more and reflects the strong influence of the military use.

Data projection for the year 2030

Long-term projections in robotics focus mostly on new branches of robot applications and new robot markets where countries enter into factory-automation. The future forecasts of IFR and VDMA are based on market facts with actual measurable variables. The validation period is up to three years and provides good results. A future projection up to 2030 cannot only be based on actual market data. In a long-term survey the market development of the past has to be considered as well, in order to give an indication of how fast these special markets are able to grow.

Future projections are dependent on many unknown indicators which are not reflected in statistics of the past. Upcoming new robot suppliers, new applications, new economical boundaries, new technical levels of robots or the increasing quality standards will influence all kinds of future estimations. [17][18]

Industrial robots in 2030

A future projection of the number of industrial robots can be made with the help of two methods. The first is based on the annual supply of the past years, the second considers the development of robot density. This density is one of the economic key figures that compare various countries with different size of manufacturing industries.

The International Standard Industrial Classification (ISIC) distinguishes two categories. The first is based on the whole manufacturing industry; the second is based on the automotive industry [19]. The separate analysis is motivated by the fact that in some countries more than 50 percent of the industrial robots are used in the automotive Industry. Today the automotive industry has a branch with the highest rate of automation. In some parts of the automotive body shops the automation rate even reaches higher than 99%.

Automotive production is still a unique industry out of the scope of robotics. But other industries with large scale series productions also have significant growth rates. In the electronic industry the producer of smart phones and tablet-PCs will catch up with their level of automation. It is to be expected that in the closer future smartphone manufacturers will have fully robotized productions, at least with their hot-seller products.

According to the ISIC revision part 4:10–33 [4] [27] there are two main definitions of robot density:

Definition 1: "Robot density: number of multipurpose industrial robots per 10,000 persons employed in manufacturing industry".

Definition 2: "Robot density: number of multipurpose industrial robots per 10,000 persons employed in automotive industry".

Both methods are predicting that in a global world of competition environment, quality and production-standards become more and more similar. Already, this trend is clearly recognizable in the global automotive industry. Even today's global quality and technical standards in the automotive industry, forces the supplier to use highly automated production machines.

This circumstance makes the future projection more accurate, because the production environment in today's highly developed countries anticipates the coming situations in the developing countries. The diagram in Figure 8 shows the worldwide annual supply of industrial robots from 2001 to 2014 and IFR- forecast from 2015 to 2018. [20]

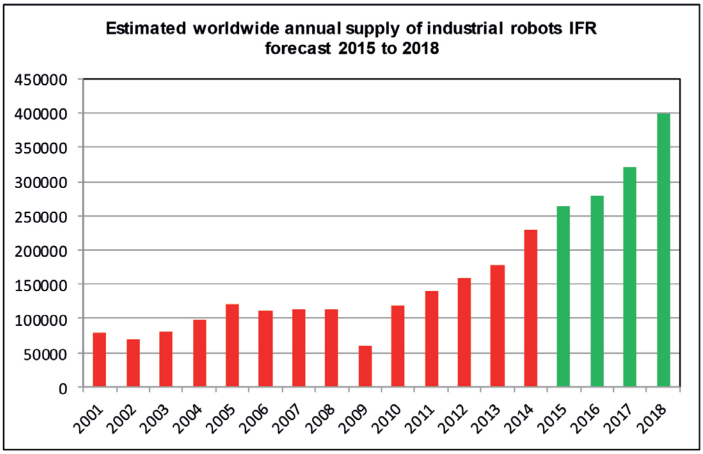

Figure 8. Worldwide annual supply of industrial robots from 2001 to 2014 (source IFR). IFR- forecast from 2015 to 2018. (Gerald Mies 2016 [20])

The average annual growth from 2001 to 2018 is 18 percent. This figure can be used to calculate the future projection up to 2030 (Figure 9).

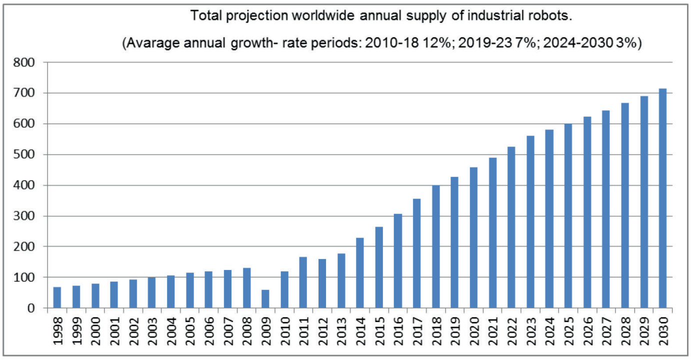

Figure 9. Total projection worldwide of the annual supply of industrial robots from 1998 to 2030 [21] [Gerald Mies 2016]

According to this calculation (eq. 1.) the estimated annual supply of industrial robots in 2030 is 965,759 units.

The calculation is based in three growth periods, period 1: 2010 till 2018, period 2: 2019 till 2023 and period 3: 2024 till 2030. This distinction in three growing periods was made to the effects of the exceptional growth rate in the Chinese market to consider. The average growth-rate p is calculated to each growth-period with the formula given below:

$$p = \left(\left(\sqrt[n]{\frac{q_n}{q_0}} \right) - 1 \right) \cdot 100 \qquad (1)$$

where p is the average growth rate, q_0 is the value of the initial growth factor; q_n is the end value of the growth factor over the period of n years. n is the number of years taken into consideration.

With the result of the numbers of the annual supply, the operational stock for 2030 can be calculated. The operational stock of industrial robots is defined as the accumulated robot sales of the last 12 years. 12 years is the actual average service lifetime of industrial robots. [4][16] In a future projection, not only the service lifetime responsible for the intended period of use has to be considered, it is also the commercial and technical reasons for the replacements of robots. In consideration of this fact the average time of use is on the assumption of 10 years.

Under these conditions the Operating-Stock q_n has been calculated for each period using the following formula:

$$q_n = \left(q_0 \cdot \left(1 + \frac{p}{100} \right)^n \right) - \left(q_0 \cdot \left(1 + \frac{p}{100} \right)^{n-10} \right) \tag{2}$$

where: q_0 is the value of the initial growth factor; q_n is the end value of the growth factor over the period of n years. n is the number of years taken into consideration and p is the annual growth rate.

Calculating the number of installed robots in 2030 by using this first method adds up to 6,241,474 units.

For the second method the IFR gives average robot-densities of 815 units per 10,000 employees in the automotive industry and 106 units in the general industry respectively. The present growth-rate in automotive industry for robot density is 1.5 percent per annum.

The small growth of robot-density in the top 10 automated countries between 2005 and 2010 and even the decrease in Japan indicate that there is a possible saturation level on the degree of robot-density.

In this context, the growth-rate in robot-density in a future projection should be limited to an average of 0.5 percent per annum. With this rate the average robot-density in 2030 for the automotive industry will be 1500 units per 10,000 employees and for the general industry 420 units in countries with a high amount of manufacturing industry and 250 units with an average amount of manufacturing industry.

Figure 10 shows the potential in operating stock for the most important countries in robotics. Based on today's market view, the sum of the potential stock gives an estimated market size in consideration of the actual automation industry. Country specific characteristic benchmarks as well as special market situations have been taken into account to work out the best results. According to this calculation there is a potential future robot market of 4,401,958.

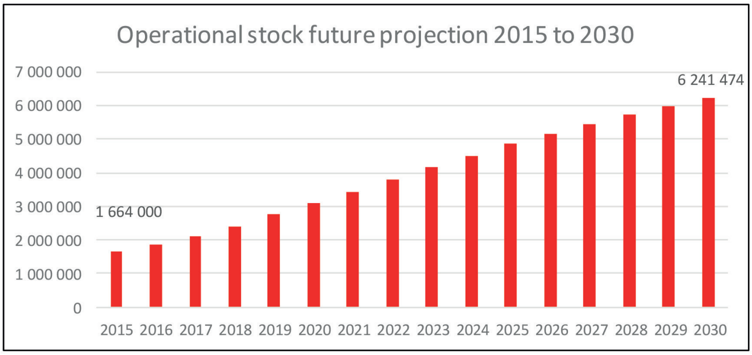

Figure 10. Operational stock future projection for 2030 of industrial robots (assuming robot lifetime to be 10 years) (Gerald Mies 2016 [22])

The sum of the operating stock *(qt)* is the amount of potential operating stock automotive *(qpa)*, plus the amount of potential operating stock general industry *(qpgi)*.

The potential operating stock automotive *(qpa)* is operating stock automotive *(qa)* divided by the robot density automotive actual *(daa)* and multiplied by robot potential robot density automotive *(dap)*.

The potential operating stock general industry *(qpgi)* is operating stock general industry *(qgi)* divided by the robot density general industry actual *(dgia)* and multiplied by robot potential robot density general industry *(dgip)* (Figure 11).

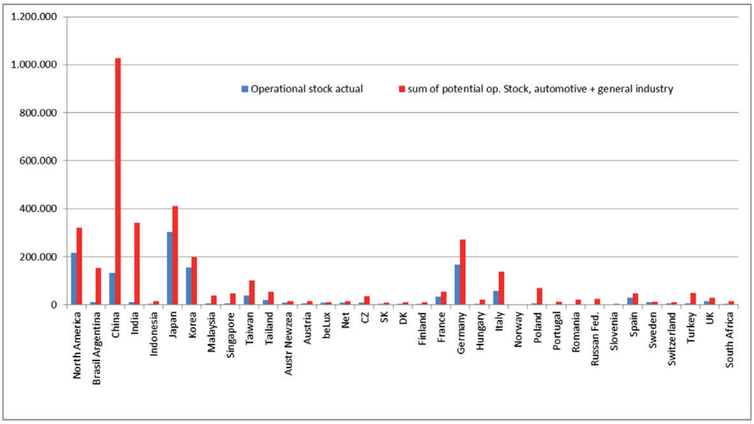

Figure 11. Operating stock actual and sum of potential operating stock (automotive and general Industry) [Gerald Mies 2016]

In comparing the results of the future projection on databases of 2015, using the actual market growth rates (6,469,920 units) or using the marked potentials (4,401,958 units), the results deviates more than expected.

If the same calculation is executed over the database of 2011 the results of the two calculation methods are very similar (3,329,694 and 3,036,774 units). On the other hand, there is a strong indicator that this projection is of high quality. This also implies that in 2030 the number of robots working in production is at least the double of today's numbers.

The background for the different results is due to several factors. Certainly, one of the key factors are the extraordinary growth rates in the Robotic in China and other Asian countries. Here the robot industry will be held above average growth in a short time period [24]. Another factor is the sharp increase in automation and thus the Robotics in the electronics industry. Here especially the growth Communication – Electronics-Industry has left its marks in the statistics.

The automotive industry was in the past measure for the degree of automation, now a second industry could establish with similar expectations in quality and price and effect a strong demand for automation (Figure 12, Figure 13).

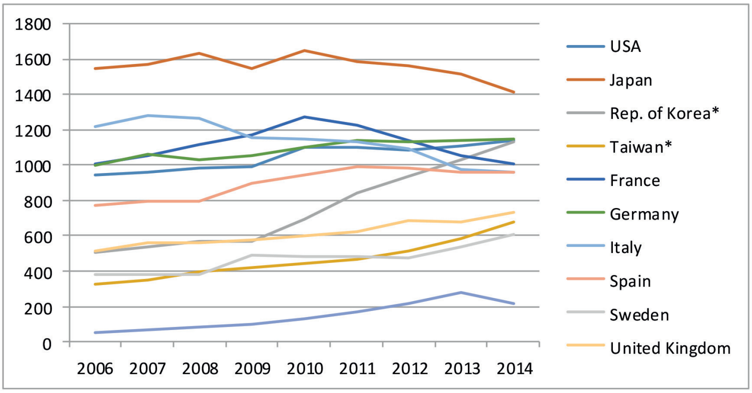

Figure 12. Development of robot-density in automotive industry for selected countries (Gerald Mies 2016)

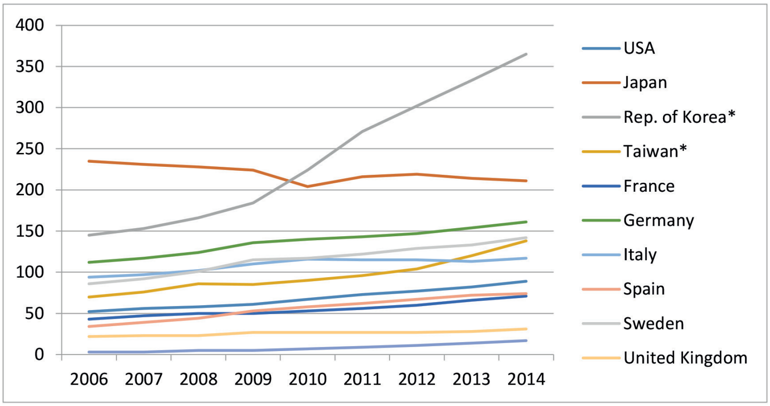

Figure 13. Development of robot-density in general industry for selected countries [Gerald Mies 2016]

Korea's growth in the areas of picking, packing, palletizing is 48% between 2013 and 2014 that is an increase of more than 5000 units in one year.

"The predominant customers for these robots are the semiconductor and the display industries as well as the automotive electronic parts suppliers. All other handling operations had a share of 14% of the total supply in 2014" says the IFR report. Here maybe the global success of the Korean electronic industry is the responsible one.

The increase of total units in numbers is high but it can be taken for an average compared with other industrial countries. The fact of the extraordinary growth in the handling applications were the automation which mostly imply a replacement of human labour; this might be the explanation of the extraordinary growth of robot density in production in the general industry. [7]

Conclusions

Comparing industrial and service robots, we might say that service robots are only compared to professional service robots to establish comparability. Professional service robots' sales are units of 24,207 in the year of 2014.

Industrial robots' sales were 229,261 units in the year of 2014. This number shows that the industrial robots are dominating by far the robot markets.

The great economic importance of industrial robots today is confirmed by the fact, that China [25] included the industrial robots as one of the 10 key industries in its future program "2025". The industrial robots will have in the upcoming decades an exceptional growth.

Especially in terms of production the given data proves this tendency. They even give a quite accurate number of more than 4 million installed industrial robots in 2030 compared to roughly 1,480,000 nowadays.

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Ipari robotok világpiacának fejlődése: robotadatok és robotsűrűség-becslés a 2030. évre

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Az ipari robotokról az elmúlt ötven évük tükrében elmondható, hogy mára számos területen sorozatgyártott eszközök. Sok gyártó állít elő különféle rendeltetéssel, különféle teherbírással, különféle céllal ipari robotot. Ezek globális világpiacán a megrendelő a számára leginkább megfelelő robothoz is hozzáfér. A következő évtizedekre előretekintve könnyen belátható, hogy a robotok piacán folytatódik majd a fejlődés. A cikkben a szerzők megpróbálják megbecsülni az ipari robotok piacán 2030-ban várható igényeket.

Kulcsszavak: ipari robotok, robot előrejelzés, Ipar4