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Industrial Robot Application Trend in World's Metal Industry

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Technological success implies technical solution improvement in automation domain of technological process and intelligent system application in different branches of industry, along with a metal industry. A huge number of robot applications exist today in metalworking industry. Their application is motivated with the technical and economical reasons like: quality improvement of the completed products (machine processing and other), fallout decrease (in the assembly process), rate enlargement of the homogeneity-constancy quality (in all process linked to robot application repeatability), security operation rate enlargement (in aggressive, burning, explosive and other areas, with the high rate of robot protection), decrease of necessary work force of routine and repeatability process, manufacture cost minimizing and overall maintenance, fulfilling of demands required by a competition and more rigorous quality standards.
Besides the technical advantages, which is carried out owing to the robot application, it is necessary to emphasize that rationality of the robot application in particular operations is principally conditioned with the manufacturing volume and the operation character which the robot (or more robots) needs to carry out.
This paper provides an analysis of the industrial robot applications in metal industry worldwide, with a detailed analysis according to years and manufacturing process. The analysis has been carried out on all four continents: Europe, Asia, America and Africa. The parallel analysis with the other industries has been given in addition to analysis of economic justification of robot application in manufacturing process.
The results of this research show increasing robot application in metal industry and in other industries, which was a primary goal of this research.
By using available data concerning installed robots worldwide, such as analyzing profitability and economic justification of robot implementation in manufacturing process, and as a result of this research, the trend of robot application in metal industry has increasing trend today.

Keywords*: industrial robot, robot application, metal, industry, robot application trend, profitability, of industrial robots, robot maintenance costs.*

Introduction

Metal industry, i.e. metalworking manufacturing implies the metal refinement process in order to obtain a final product, i.e. the semi-final product. In the metalworking industry the robots are applied (World Robotics 2006, 2008, 2010): as essential constituent element of new manufacturing lines which are projected at the high automation rate, with the flexibility characteristics. It is very hard to observe the robot here and its efficiency beyond the overall flexible manufacturing line with the activation in the existing manufacturing operations where robots highly increase the existing equipment efficiency, ensuring its economy. In this respect, the necessity for new or higher investments is reduced, considering that in certain conditions robot supply appeared as more economic than new machine supply. The robot system applications in metalworking industry, whether it is the full system automation or highly automatized manufacturing line, i.e. fixed automation or possible flexible manufacturing cell, is observed through: material transport and machine serving, processing operations, installation jobs and product control jobs.

In modern industrial operations of the metalworking industry the fixed automation still dominates. One of the characteristics of today's world's economic course is market expansion, i.e. the necessity for constant modification of the existing products with the new technological applications, in order to provide the competition at the rough market conditions. The robot significance is essential in conditions of the flexible metalworking manufacture (Isak *et al.,* 2011; Vlatko, 2008; Baksys, 2004; Rogic, 2001). Robot application in metalworking industry is very different. For some application fields there are special robots, while for others the robot elections based on the process demands and robot possibilities exists. Robot application is higher for economic and technologic advantages of the application. Therefore, in future the robot will be not only implemented in the industry, but also in other human activities.

The research problem is the analysis of the latest data concerning the installed robots in Europe, Africa, Asia/Australia and America (Isak *et al.,* 2011; Vlatko, 2005; Isak, 2005; Nof, 1999; Lung-When, 1999), in relation to a category of the manufacturing process, on the one hand, and analysis of the economic justification of robot application in industry, on the other hand.

The research object: Industrial robot application trend in world's metal industry.

The research goal is to show through the existing data concerning a number of the installed robots worldwide, the current trend of their application, and also by using available economic studies about the robot application economy in industry, to prove advantages of the automation of manufacturing process by using robots, i.e. the profitability of the industrial robot. To archive this aim, the following *research tasks are*:

- to search the latest data available concerning the number of installed robots in metal industry worldwide;
- to compare the obtained data with other industries;
- to analyze the economic justification of robot application;
- to show the industrial robot profitability in a particular example.

The research is formed by systemic and comparable literature analysis of scientific publications, using statistical data concerning the number of installed robots in the world, and publications from the internet.

Annual and total industrial robot application trend in the world

In order to analyze the industrial robot application in metal industry in the world, the annual and total industrial robot application trend by continents in the world needs to be analyzed. Statistical data for industrial robot application number has been taken from International Federation of Robotics (IFR), and Economic Committee data by UN for Europe (UNECE) and Organization for Economic Cooperation and Development (OECD) (Isak et al., 2011; World Robotics 2006, 2008, 2010).

The Figure 1, Figure 2 and Figure 3 show the industrial robot application worldwide and by continents at annual and total level.

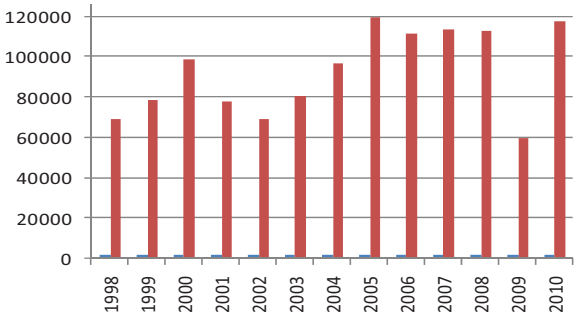


Figure 1. Annual industrial robot application in the world from 1998-2010

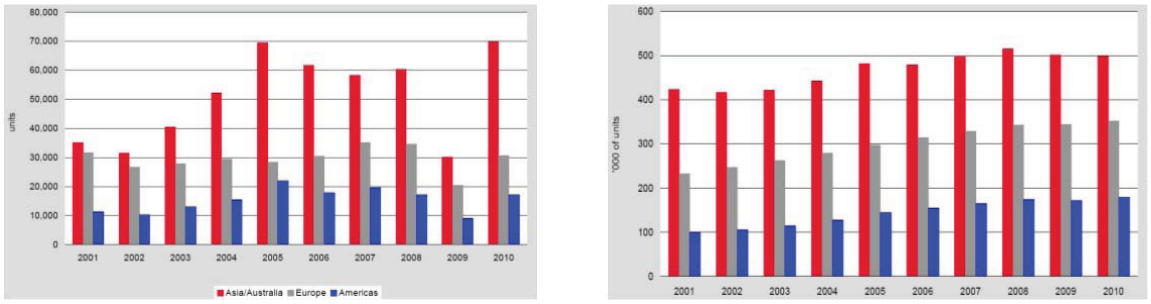


Figure 2. Annual industrial robot application by continents from 2001-2010

The annual trend of industrial robot application in the world from 1998-2010 has been shown at Figure 1 where the minimal robot application has been recorded in 1998, 2002 and 2009. From 1998-2000, robot application increased. Also from 2002-2005 the application trend has been increasing. From 2006-2010, the industrial robot application has been constant, unlike 2009, where the minimal industrial robot application has reached the number of 60.000 units. According to Figure 2, the first place in industrial robot application takes Asia/Australia with 69.833 units of applied robots in 2008, 30.117 units in 2009 and 60.294 units in 2010. The second place takes Europe with 30.630 units in 2008, 20.483 units in 2009 and 34.695 units in 2010.The third place takes America with 17.114 units in 2008, 8.992 units in 2009 and 17.192 units in 2010. The last place takes Africa with 256 units in 2008, 196 units in 2009 and 454 units of applied robots in 2010. On all four continents in 2009 the application was minimal due to the financial industrial crisis.

Total industrial robot application trend in the world has been followed by the annual robot application trend so that the first place takes Asia/Australia with 514.914 units, then Europe 343.329 units, the third place takes America with 173.977 units and the last place belongs to Africa with 1.777 units of applied robots in 2010.

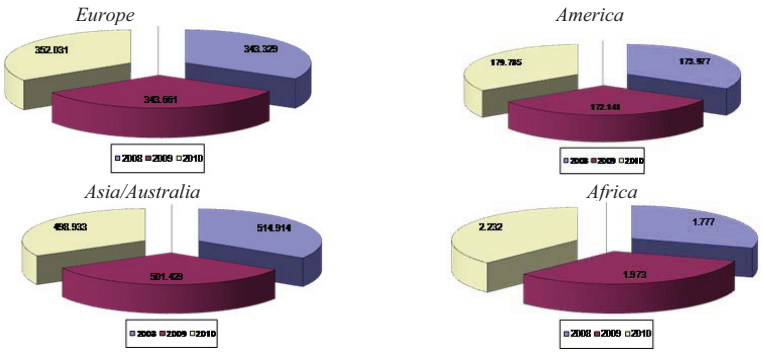


Figure 3. Total industrial robot application in Europe, America, Asia/Australia and Africa in 2008-2010

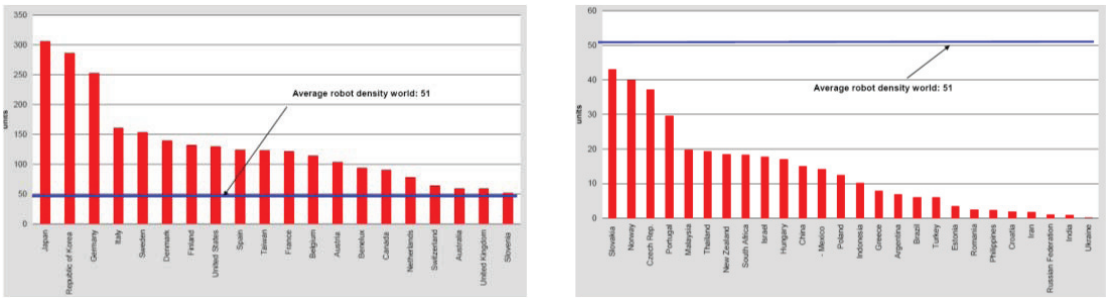


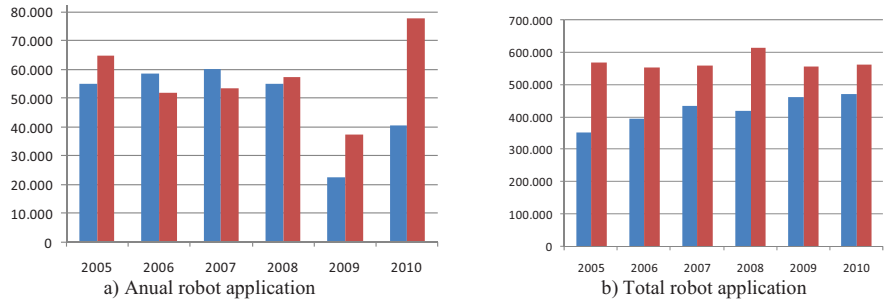
Figure 4. Industrial robot application number on 10.000 of employees in manufacturing industry
Source: World robotics, 2010.

An average density of the industrial robot in the world amounts to 51 robots on 10.000 of the employees. Industrial robot application analysis on 10.000 of employees in the manufacturing industry has been shown on Figure 4. The countries with this average higher than 51 robots are: Japan, Republic of Korea, Germany, Italy, Sweden, Denmark, USA, Spain, Taiwan, France, Belgium, Austria, Benelux, Canada, Holland, Switzerland, Australia, England and Slovenia. Under this average, to 10 robots on 10.000 of employs the following countries belong: Slovakia, Norway, Czech Republic, Portugal, Malaysia, Thailand, New Zealand, Africa, Israel, Hungary, China, Mexico, Poland and Indonesia. The other countries are under the average of 10 robots on 10.000 of employees. In the countries with the average density higher than 51 robots, the manufacturing process are more automatized and modernized, with the developed automobile industry and with high robot applications. Year after year, some countries with the average lesser than 51 robots tend to increase an average, i.e. are carrying out the automation and modernization of the manufacturing process.

Industrial robot application in world's metal industry

This analysis comprehends industrial robot application in metal industry. The issues taken into consideration are: basic metals, metal refinement process, industrial machines, motor manufacturing, automobile part manufacturing and automobile manufacturing. The analysis has been shown at tables and figures below (Isak *et al.,* 2011; World robotics, 2008, 2010; Vlatko, 2005; Baksys, 2004; Rogic, 2001). Annual industrial robot application in metal industry from 2005-2008 moves from 50.000-60.000 units and application trend is constant. In 2009, the minimum robot application has been recorded with 22.513 units, due to the financial industrial crisis.

In 2010, robot application increased to 40.636 robot units. Total robot application in metal industry from 2005-2010 has the increasing trend.



a) Anual robot application b) Total robot application

Figure 5. Annual and total industrial robot application in metal industry in the world blue colour - metalworking industry; red colour - other industries

The analysis of Table 1 shows that industrial robot application in metal industry in the world is most abundant in motor and automobile manufacturing, but robot application in metal processing, basic metals and metal processing is decreasing.

Table 1

Annual and total industrial robot application in metal industry from 2008-2010

Application/Year		Annual application			Total application		
		2008	2009	2010	2008	2009	2010
Metal industry	Basic metals	592	421	603	5.504	5.669	5.898
	Metal processing	10.166	2.738	4.457	50.852	51.700	53.355
	Machine industry	4.018	2.094	2.874	42.159	40.876	38.174
	Motor industry	20.273	10.734	20.052	190.156	189.423	196.568
	Automobile industry	20.164	8.526	12.650	158.442	164.883	171.252
	Unspecified	-	-	-	15.187	10.546	5.403
	Total Σ	**55.213**	**22.513**	**40.636**	**421.300**	**463.097**	**470.650**

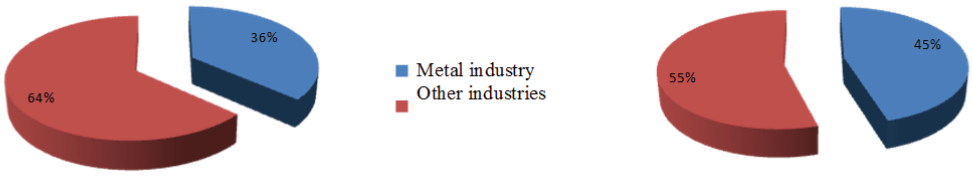
At the annual level, the least application has been recorded in 2009. The total robot application in metal industry from 2008-2010 has the increasing trend. Such industrial robot application trend in metal industry has been expected due to the automation and modernization of manufacturing process and market, due to the high competition of companies which are manufacturing motors and automobiles and needs to satisfy customer conditions.

Table 2

Total industrial robot application in the world, in metal and other industries from 2008-2010

Application/Year	Annual application			Total application		
	2008	2009	2010	2008	2009	2010
Metal industry	55.213	22.513	40.636	421.300	463.097	470.650
Other industries	57.659	37.505	77.701	614.011	557.634	564.364
Total Σ	**112.972**	**60.018**	**118.337**	**1.030.301**	**1.020.731**	**1.035.014**

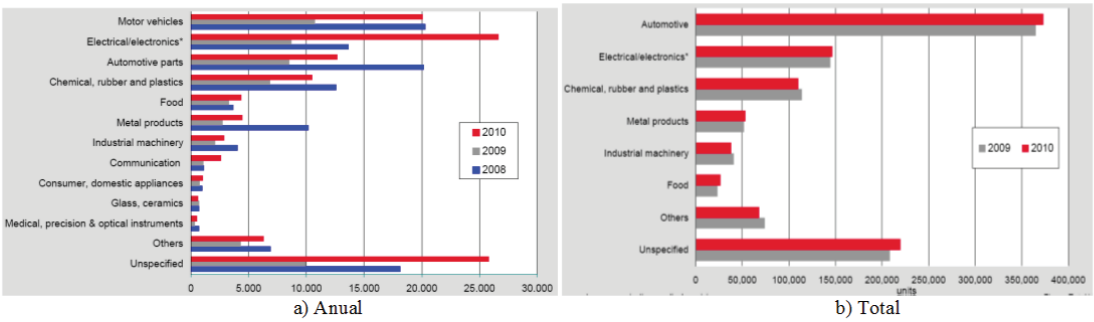
Source: Isak, et al., 2011; World robotics, 2008, 2010.



a) Anual b) Total

Figure 6. Annual and total percentage industrial robot application in the world, in metal industry and other industries in 2010
Source: World robotics, 2010.

Table 2 and Figure 6 shows that the industrial robot application in metal industry, at the annual and total level during the last three years in the world takes high place and moves from 40%-48%, in relation to total industrial robot application. In 2010, in metal industry at annual level 40.636 of robot units or 36 % have been applied. The other industries amounts 77.701 units or 64 % of the total annual application. At the total level, the percentage of the industrial robot application in metal industry is higher and amounts 45 %. In order to compare them, the next figure shows the annual and total industrial robot application in all industries in the world. According to Figure 7, the second place takes the electrical industry, then chemical industry and food industry, according to the industrial robot application, at annual and total level.

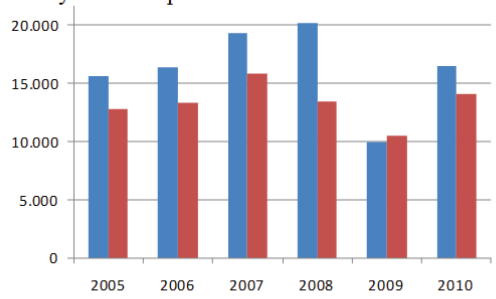


a) Anual b) Total

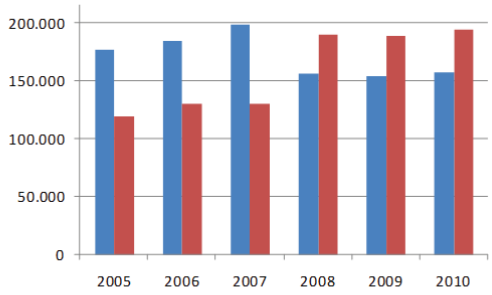
Figure 7. Annual and total industrial robot application in all industries in the world

Industrial robot application in metal industry in Europe

This analysis shows industrial robot application in metal industry in Europe. Statistical data for industrial robot application number has been taken from International Federation of Robotic (World robotics, 2006, 2008, 2010) and the analysis has been shown at tables and figures below.



a) Anual



b) Total

Figure 8. Annual and total industrial robot application in metal industry in Europe

According to Figure 8, industrial robot application in metal industry in Europe precedes and is higher than in other industries at annual level, and till 2007 at the total level also. In the last three years, the application in the metal industry is less at the total level. According to the Table 3 and Figure 9, in 2010 industrial robot application in metal industry in Europe amounts to 54 % and in other industries to 46 % of total robot application number in 2010.

Table 3

Total industrial robot application in metal and other industries in Europe from 2008-2010

Application/Year	Annual application			Total application		
	2008	**2009**	**2010**	**2008**	**2009**	**2010**
Metal industry	20.228	9.984	16.487	156.446	154.308	157.643
Other industries	13.467	10.499	14.143	186.883	189.353	194.388
Total Σ	**34.695**	**20.483**	**30.630**	**343.329**	**343.661**	**352.031**

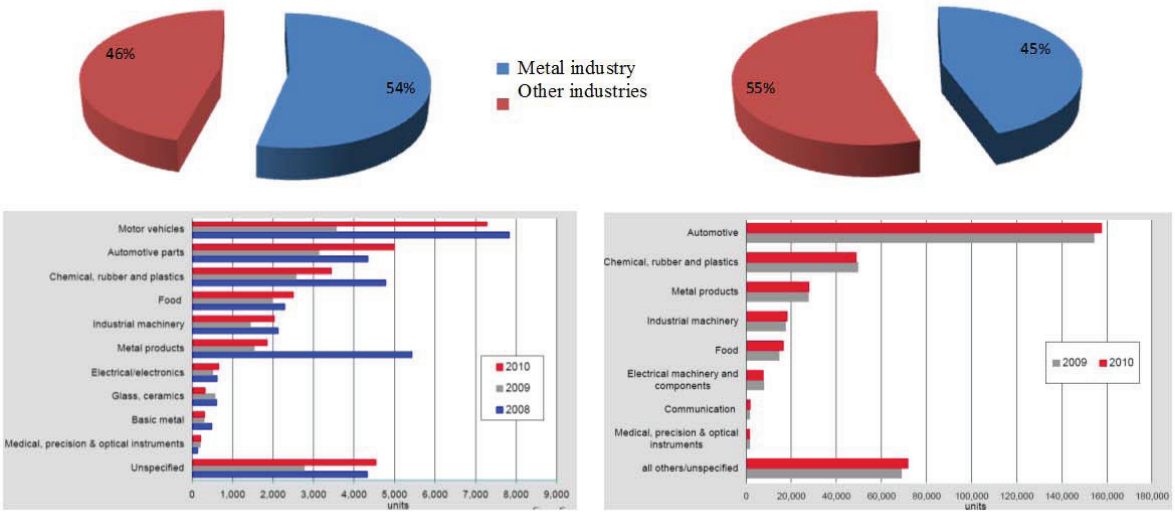


Figure 9. Annual and total industrial robot application in all industries in Europe
Source: Isak, et al., 2011.

At the total level this relation amounts to 45 % in metal industry, and in the other industries 55 %. After industrial robot applications in the metal industry goes chemical industry, food industry, and the third place is taken by the electrical industry.

Industrial robot application in metal industry in Asia

Industrial robot application analysis in metal industry in Asia has been shown at the tables and figures below.

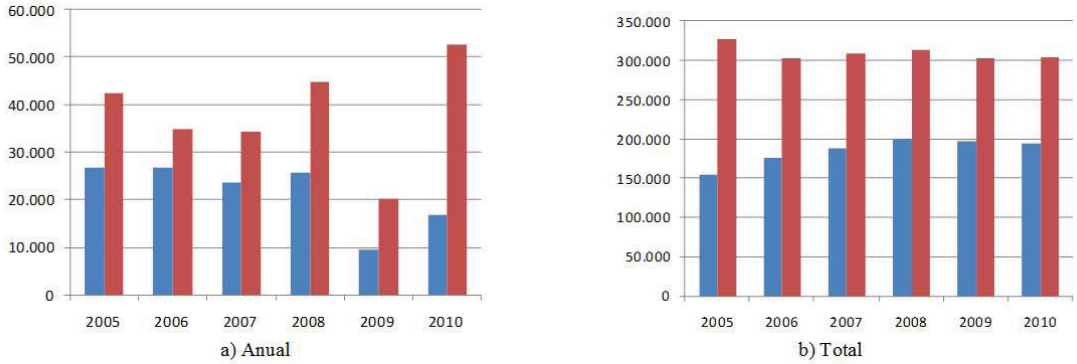


Figure 10. Annual and total industrial robot application in metal industry in Asia

Table 4

Total industrial robot application in metal and other industries in Asia form 2008-2010

Application/Year	Annual application			Total application		
	2008	**2009**	**2010**	**2008**	**2009**	**2010**
Metal industry	25.699	9.704	17.022	200.806	197.860	194.101
Other industries	45.000	20.413	52.811	314.108	303.564	304.832
Total Σ	**60.699**	**30.117**	**69.833**	**514.914**	**501.424**	**498.933**

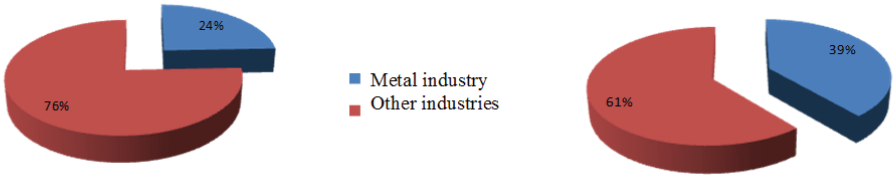


Figure 11. Percentage relation of industrial robot application in metal industry in Asia in 2010

According to Figure 10, industrial robot application in metal industry in Asia is different in relation to Europe. At the annual and total level the industrial robot application is lower in metal industry in relation to other industries in Asia. According to the Table 4 and Figure 11, in 2008-2010, industrial robot application at annual and total level is lesser than robot application in other industries. In 2010, the number of applications amounts to 24 % in metal industry, at annual level and 39 % at total level.

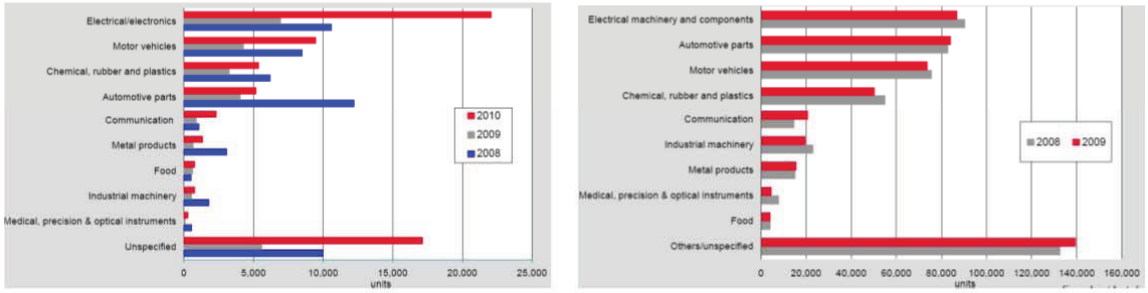


Figure 12. Annual and total industrial robot application in all industries in Asia
Source: World robotics, 2010.

The first place in industrial robot applications (Figure 12) is taken by the electrical industry, the second place goes for metal industry and the third place goes to chemical industry.

Industrial robot application in metal industry in America

Industrial robot application in metal industry in America has been shown at the tables and figures below.

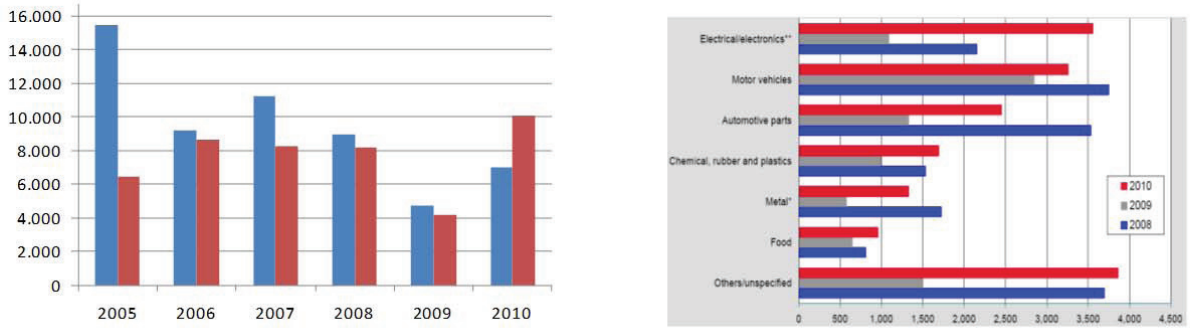


Figure 13. Annual industrial robot application in metal industry in America

Table 5

Annual industrial robot application trend in metal and other industries in America from 2005-2010

Application/Year	Annual industrial robot application					
	2005	**2006**	**2007**	**2008**	**2009**	**2010**
Metal industry	15.478	9.237	11.283	9.006	4.754	7.042
Other industries	6.508	8.683	8.299	8.186	4.238	10.072
TOTAL Σ	**21.986**	**17.910**	**19.582**	**17.192**	**8.992**	**17.114**

Source: World robotics, 2006, 2010.

Industrial robot application trend in metal industry in America in 2005-2009 is higher than robot application in all other industries. In 2010, the application in metal industry is lesser in relation to other industries. After robot applications in metal industry go electrical industry, then chemical industry and food industry. Annual industrial robot application in metal industry in America during the last four years is decreasing, unlike the increasing trend in other industries. The highest robot application in metal industry has been recorded in 2005, twice higher than in other industries.

In 2010, in metal industry in America, application of industrial robots amounts to 42% and in other industries 58%.

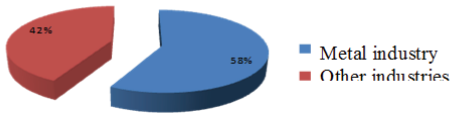
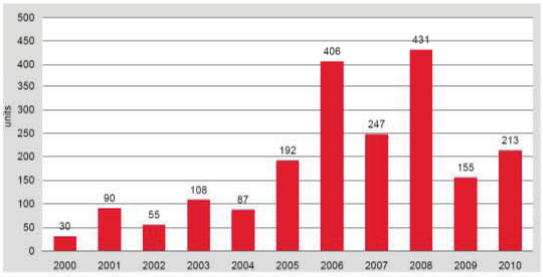
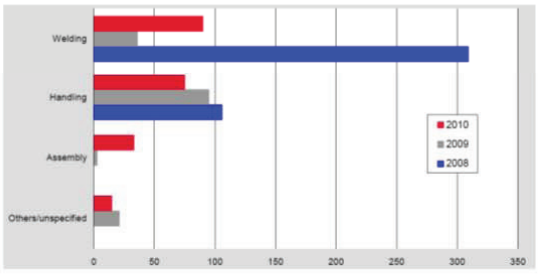


Figure 14. Percentage relation of industrial robot application in metal industry in America in 2010

Industrial robot application in metal industry in Africa

The industrial robot application in Africa has been given at the following figures.





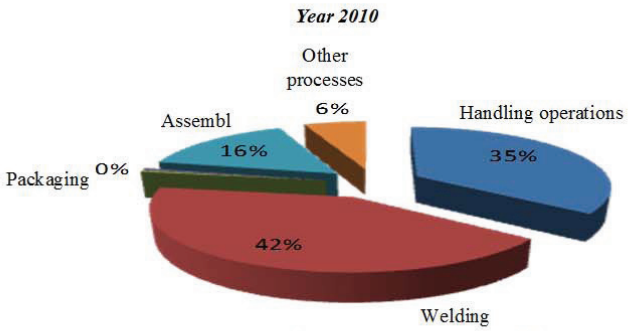


Figure 15. Industrial robot application in Africa
Source: World robotics, 2006, 2008, 2010.

In Africa, industrial robot application is neglected in relation to Europe, America and Asia/Australia, but is taken into consideration. The highest industrial robot application is in metal industry, over 90

The profitability of industrial robots and benefits of robot automation

Falling unit costs of robots (Figure 16), increasing labour compensation (Figure 17), and significantly improved robot system performances open up new automation solutions, many of which are outside the "classic" applications of industrial robots. Furthermore, robot manufacturers and systems integrators are increasingly supplying low-cost flexible work cells with standard configurations, which can be rapidly integrated into existing production systems for standard applications.

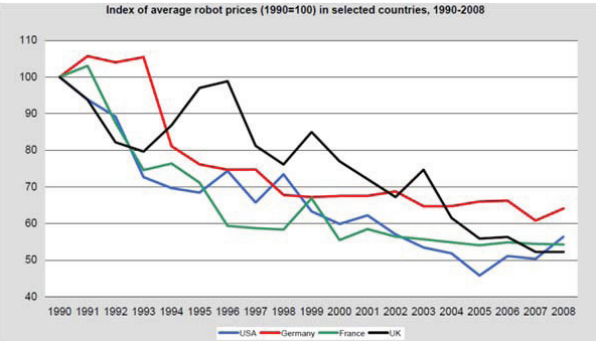


Figure 16. Index of average robot prices in selected countries, 1990-2008
Source: World robotics industrial robots, 2009

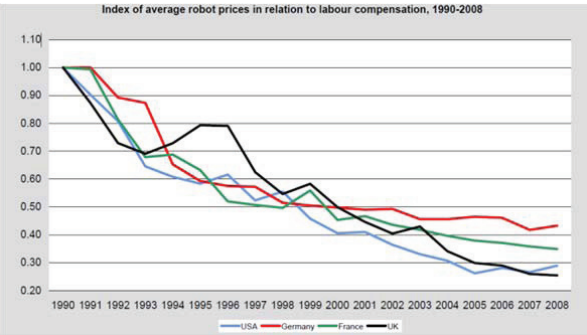


Figure 17. Index of average robot prices in relation to labour compensation, 1990-2008
Source: World robotics industrial robots, 2009

This implies that even small volume productions can be automated effectively in areas such as parts welding and cutting, flexible assembly and packaging and palletizing. It therefore seems that robot investment will become more and more profitable and hence become increasingly widespread within industry.

Besides the cost-effectiveness, there are several other factors which are important when a company is considering investing in a robot system, e.g. effect on parts quality, manufacturing productivity (faster cycle time), yield (less scrap), reduction in labour, improved worker safety and reduction of work-in-progress.

Surveys among robot users and prospective users have shown that the main motives for investing in industrial robots are: reduced labour costs, improved product quality/obtaining of more even quality, improved quality of work by eliminating hazardous, heavy and/or repetitive work cycles, increased output rate, increased product flexibility, reduced material waste, compliance with safety rules, reduced labour turnover/difficulty of recruiting workers, reduced capital costs-inventory, work-in-progress, floor space etc. (World robotics industrial robots, 2009).

In many cases robot investments have the reduction of labour costs as the main objective.

The best example for this purpose is data from one business study (Churchill Technologies 2011*, available at: http://www.churchill-tech.com*), where the costs of robot implementation in manufacture against the human work costs (manufacture without robot application) are analyzed, as follows:

How can robot be competitive in relation to the cost of human work?

The robot can work 24 hours per day, 7 days a week, and 52 weeks a year, without the need for breaks, with no benefits or legacy cost. For analysis there was taken a medium size robot with 100 kg payload and 6 kWh power consumption (auto industry is the biggest user), with an average cost per hour to operate about 30 cents. At an average cost of $0.30 per hour (Churchill Technologies, 2011), robot costs are:

- for a one shift day, the average cost is $2.40;
- for a two shift day, the average cost is $4.80;
- for a three shift day, the average cost is $7.20;
- total average cost per year for three shifts, five days for 52 weeks is $1872.

How does this compare to human workers?

According to the article that in Forbes magazine is titled "Buy a Robot and Save America", (Robert 2006) the average wage for a U.S. warehouse or distribution worker is about $15 per hour plus benefits. The average wage for the same worker in China is about $3 per hour. The average wage for a skilled UAW U.S. auto worker is somewhere between $25 and $30 per hour, plus the staggering costs of health care coverage and retirement benefits.

Even if the cost of 30 cents per hour for robot labor were to double ($0.60), it is still 1/5 the cost per hour of a Chinese laborer! It's more like 1/50 as costly as a skilled UAW U.S. auto worker!

Maintenance costs

Cost of maintenance for manual workers:

- Lunch and breaks = lost production time;
- Vacations = no production;
- Lost time due to injuries = no production;
- Employee turnover: training and retraining;
- Protective clothing and safety devices;
- Locker rooms and supplies: lunch rooms and supplies;
- Parking lot;
- Insurance;
- Pensions;

- Worker's compensation;
- Inconsistent, unpredictable production.

Robot maintenance costs:

- Beyond the initial cost and small operating cost, there are some additional maintenance costs (example: typical application of two shift per day material handling robot);
- For the first 3-4 years, $500 per year in preventive maintenance (mainly lubrication);
- After the 4th year, $5,000 in preventive maintenance, mainly in replacement of wear items (I.e., internal wire harnesses);
- For the next 3-4 years, $500 per year in preventive maintenance (mainly lubrication);
- After 8-10 years (30,00 hours usage), refurbishment may be required at a cost of 50% of the asset value of the robot, depending on the duty cycle and environment of the robot.

From above mentioned we conclude that the costs for human maintenance are substantial and many times more than the maintenance cost for robots.

In Table 6, there is shown the initial purchase and installation cost of the robot that can usually be amortized in a few years, whereupon, the cash flow is impressive.

Table 6

Robot project payback analysis

Year (of use)	Robot system cost*	Manual labor costs**	Yearly cash flow	Cumulative
1	$200.000	$100.000	-$100.000	-$100.000
2	$500	$102.000	$101.500	$1.500
3	$500	$104.040	$103.540	$105.040
4	$500	$106.121	$105.621	$210.661
5	$5.000	$108.243	$103.243	$313.904
6	$500	$110.408	$109.908	$423.812
7	$500	$112.616	$112.116	$535.928
8	$500	$114.869	$114.369	$650.297
9	$500	$117.166	$116.666	$766.969
10	$30.000	$119.509	$$89.509	$856.472

** includes training and installation costs*
***$50.000/yr/man/2 shifts including benefits and 2% annual inflation.*
Source: http://www.churchill-tech.com/

Direct labor savings are many times used as the only justification for robotics project, because they are easy to quantify. There are many other benefits that are harder to quantify that are left out of the justification analysis, like:

- Increase in productivity Examples: arc welding and machine load/unload;
- Improved quality Examples: arc and spot welding;
- Material Savings Example: Paint and sealants;
- Reduced scrap and rework Example: Investment casting;
- Improved manufacturing flexibility (shorter product runs product life);
- Reduced work-in-process inventory (combined operations);
- Floor space savings Example: overhead mount and arc welding;
- Better utilization of capital equipment Example: machine tool load/unload
- Lower piece part cost (competitive advantage)
- More efficient production planning and scheduling (predictability)
- Better department efficiency
- Removal of personnel from hazardous or fatiguing tasks and their redeployment to other value-added jobs.

The above mentioned data show that robot costs are considerably lower in relation to human work. It also shows that the invested resources at the beginning of the robot implementation in manufacturing process are worthwhile. This and other robot advantages suggest that cost effectiveness of investing in robot systems in manufacturing is unmistakable.

Conclusions

Total industrial robot application trend in the world has been followed by annual robot application trend so that the first place takes Asia/Australia with 514.914 units, then Europe 343.329 units, the third place takes America with 173.977 units and the last place belongs to Africa with 1.777 units of applied robots in 2010.

Annual industrial robot application in metal industry from 2005-2008 moves from 50.000-60.000 units and the application trend is constant. In 2009, the minimum robot application has been recorded with 22.513 units, due to the financial industrial crisis. In 2010, robot application increased to 40.636 robot units. Total robot application in metal industry in 2005-2010 has the increasing trend.

Industrial robot application in metal industry worldwide is most abundant in motor and automobile manufacturing, while robot application in metal processing, basic metals and metal processing is in decrease. At the annual level, the least application has been recorded in 2009. Total robot application in metal industry in 2008-2010 has the increasing trend. Such industrial robot application trend in metal industry has been expected due to the automation and modernization of the manufacturing process and market, due to the high competition of companies which are manufacturing motors and automobiles and needs to satisfy customer conditions.

According to Figure 7, the second place is taken by electrical industry, then chemical industry and food industry, according to the industrial robot application, at annual and total level.

According to Figure 8, industrial robot application in metal industry in Europe precedes and is higher then in other industries at annual level, and till 2007 also at the total level. During the last three years, application in metal industry is less at total level.

According to Figure 10, industrial robot application in metal industry in Asia is different in relation to Europe. At the annual and total level industrial robot application is lower in metal industry in relation to other industries in Asia. Industrial robot application trend in metal industry in America in 2005-2009 is higher than robot application in all other industries. In 2010, the application in metal industry is lesser in relation to other industries. After robot applications in metal industry go electrical industry, then chemical industry and food industry.

In Africa, industrial robot application is neglected in relation to Europe, America and Asia/Australia, but is taken into consideration.

The highest industrial robot application is in metal industry, over 90 %, with tendency of application increase. Then, through the trend analysis of robot buying price, and with a certain robot characteristics providing a certain advantages in relation to hand work, and by using the study data concerning economics and profitability of robot system in manufacturing process, in relation to the cost of human work. All this proves a thesis that robot application will have an increasing trend in the future, in metal industry and in other industries.

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Pramoninių robotų pritaikymo kryptys pasaulinėje metalo pramonėje

Santrumpa

Be technikos privalumų, kurie atsirado pradėjus naudoti robotus, būtina pabrėžti, kad robotų pritaikymo konkrečioms operacijoms racionalumas yra susijęs daugiausiai su gamybos apimtimi ir operacijomis, kurias turi atlikti robotas (arba keli robotai) pobūdžiu. Technologinė sėkmė reiškia techninių sprendimų patobulinimą technologinių procesų automatizacijos srityje ir tinkamą sistemos pritaikymą skirtingose pramonės šakose, kartu įskaitant ir metalo pramonę. Šiuo metu egzistuoja daugybė robotų pritaikymo būdų metalo apdirbimo pramonėje. Jų taikymas yra nulemtas techninių ir ekonominių priežasčių, tokių kaip: baigtų gaminių kokybės gerinimas (mašininis apdirbimas ir kt.), šalutinių rezultatų sumažinimas (surinkimo procese), kokybės vienodumo-pastovumo normos padidinimas (visuose procesuose susietuose su robotų pritaikymo kartotinumu), apsaugos operacijų normos padidinimas (degiose, sprogiose ir kitose srityse, turinčiose aukštą robotų apsaugos normą), būtinos darbo jėgos kasdieniams ir pakartotiniams procesams sumažinimas, gamybos kaštų minimizavimas ir bendra priežiūra, konkurencijos keliamų reikalavimų ir daugybės griežtų kokybės standartų įvykdymas.

Pasaulyje pramoninių robotų taikymas metalo pramonėje gausiausias yra gaminant variklius ir automobilius. Metalo apdirbimo pramonėje robotų panaudojimas apdoroti sunkiuosius metalus, mažėja. Vertinant robotų panaudojimą per metus, mažiausias jų taikymas buvo užfiksuotas 2009 metais, nors bendras robotų taikymas metalo pramonėje 2008-2010 metais didėjo. Tokios pramoninių robotų pritaikymo krypties metalo pramonėje buvo tikimasi dėl gamybos procesų ir rinkos automatizavimo ir modernizacijos, dėl didelio variklių ir automobilių kompanijų konkurencingumo ir poreikio patenkinti vartotojų keliamas sąlygas. Pagal pramoninių robotų naudojimą per metus lyginant su kitomis pramonės šakomis*(žr. 7 pav.*), antrą vietą užima elektros pramonė, po to chemijos pramonė ir maisto pramonė. Aptariant 8 paveikslėlį, matyti, kad pramoninių robotų pritaikymas metalo pramonėje Europoje pirmauja ir yra didesnis negu kitose pramonės šakose per metus. Per pastaruosius trejus metus robotų pritaikymas metalo pramonėje yra mažesnis lyginant su kitomis šakomis. Jeigu palyginsime pramoninių robotų pritaikymą metalo pramonėje *(žr. 10 pav.)*, matysime, kad Azijoje jis skiriasi lyginant su Europa. Metiniu ir bendru lygiu pramoninių robotų pritaikymas yra mažesnis metalo pramonėje lyginant su kitomis pramonės šakomis Azijoje. Pramoninių robotų pritaikymas metalo pramonėje Amerikoje 2005-2009 metais yra didesnis už robotų pritaikymą kitose pramonės šakose.

2010 metais, pritaikymas metalo pramonėje yra mažesnis lyginant su kitomis pramonės šakomis. Po metalo pramonės robotų pritaikymo eina elektros pramonė, po to chemijos pramonė ir maisto pramonė. Afrikoje pramoninių robotų pritaikymas yra apleistas lyginant su Europa, Amerika ir Azija/ Australija, tačiau į jį atsižvelgiama. Didžiausias pramoninių robotų pritaikymas yra metalo pramonėje, daugiau kaip 90 %.

Šiame darbe pateikiama pramoninių robotų pritaikymo metalo pramonėje (visame pasaulyje) analizė, išskaidant ją atskirai pagal metus ir gamybos procesus. Analizė buvo atlikta visų keturių žemynų: Europos, Azijos, Amerikos ir Afrikos. Pateikta lygiagreti kitų pramonės šakų analizė. Pateiktos robotų pirkimo kainos, taip pat tam tikrų roboto savybių, suteikiančių tam tikrus privalumus lyginant su rankų darbu analizė. Panaudojant tyrimo duomenis, išsamiai atskleidžiamas robotų sistemos ekonomiškumas ir rentabilumas gamybos procese, lyginant su žmogaus darbo kaštais. Atliktas tyrimas leidžia daryti prielaidą, kad ateityje robotų panaudojimas metalo pramonėje ir kitose pramonės šakose didės.

Raktažodžiai*: pramoninis robotas, robotų pritaikymas, metalo pramonė, robotų pritaikymo kryptis, pramoninių robotų rentabilumas, roboto išlaikymo kaštai.*

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