IFR International Federation of Robotics

Positive Impact of Industrial Robots on Employment

Updated in January 2013 to take account of more recent data

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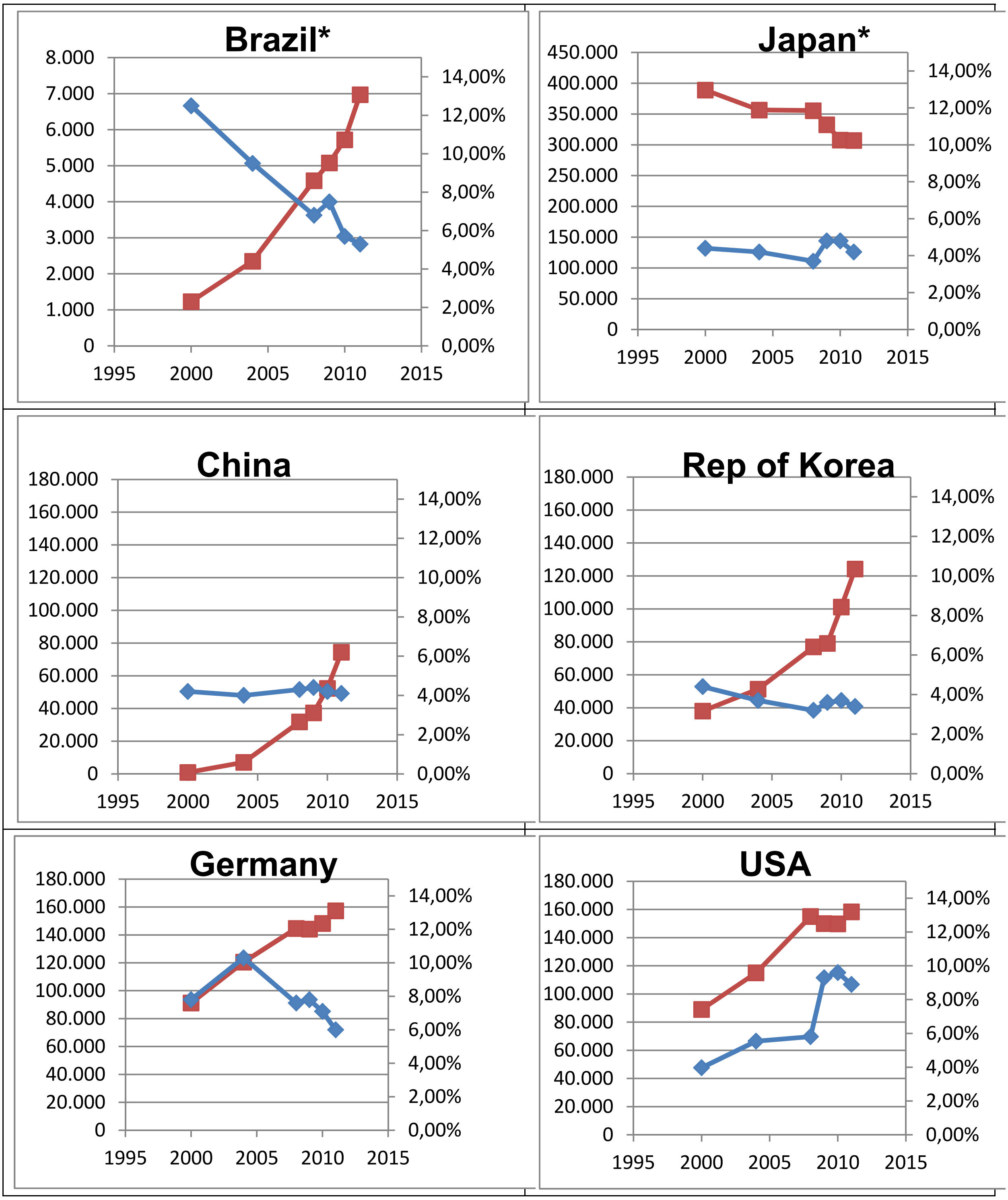
2011/2013

Rate of unemployment trend vs Numbers of robots in use.



♦ = UNEMPLOYMENT %

■ = Number of robots

*Note the different left hand scale for Brazil and Japan

1. SUMMARY

1.1 Overall rise in employment

Overall paid employment has risen in most countries. In the six considered here, only Japan has seen a decline.

This is driven by increasing participation of women, and increases in population, including immigration in some cases. It is also caused by the increasing demand for services, and the creation of completely new products and markets, often related to the application of electronics to communication.

The statistics mainly show reduction in employment in manufacturing in the developed countries, often a small reduction. It coincides with an increase in output and an increase in robotics use, except in the case of Japan.

The extra number that have gained employment in the years 2000 to 2011 is far greater than the small numbers losing their jobs in manufacturing.

The new jobs have been in:

1) distribution and services. Some of the distribution jobs are the result of manufacturers outsourcing their distribution. In the past these jobs would have been classified as part of manufacturing.

2) and also in new manufacturing applications, particularly using technology advances to create new consumer products [phones, computers, games etc].

In the industrialising countries, as could be expected, there has been a sharp rise in employment in manufacturing, as well as increase in output.

Productivity increases are not just caused by automation and robotics, but it is one of three main factors, along with increased size of manufacturing plants and the globalisation of sourcing. *Note: while the IFR numbers provide a clear basis from which to work, it has not always been possible to separate robotics from automation in our analyses.*

Individual countries differ greatly, manufacturing accounts for only 11% of employment in USA…but 24% in Germany and it is as high as 27% in more recently industrialising countries such as The Republic of Korea.

The level of robotics use has almost always doubled in all of the six countries [except Japan] in the eleven years covered by the study. **The proportion of the workforce that is *unemployed* has generally reduced except in the USA.**

The most recent figures show the short term effect of the economic crisis, and the apparent resumption of the general trend. *[see charts opposite and table overleaf].*

Six country comparison

	Change in population 2000 to 2012	Increase in total employment in the 11 yrs [millions]		Unemployment %			Actual employment in manufacturing [millions]					Annual rate of increase of industrial production %			Robots per 10,000 employed in Manufacturing [IFR]			
Year		#	%	2000	2008	2011	2000	2008	2010	2011	+-	2000	2008	2011	2000	2008	2011	2008 to 2011
Brazil	+16.5%	27	45%	13%	6.8%	5.3	7.7	9.7	*9.9*	*10.2***	+2.5	5.7	4.9	0.3	<1	5	7	40%
China	+6.3%	60	18%	4.2 %	4.3%	4.1	25 *80**	34 *104**	35.2	37e	+10 *+24**	11.0	13.4	13.9	<1	10	21	210%
Germany	=	2.1	5%	6.9 %	7.2%	6.0	6.2	6.1	5.9	6.0	-0.2	6.6	5.2	8	146	236	261	11%
Japan	=	-2.0	-3.0%	4.7 %	4.0%	4.2	11.8	10.3	9.3	9.1	-2.0	5.8	1.3	-3.5	337	344	339	-1%
Korea Rep	+4.2%	3.2	15%	4.4 %	3.4%	3.4	3.6	3.5	3.5	3.6	=	8.5	5.1	3.8	107	221	347	57%
USA	+12%	6.0	4.0%	4.0 %	5.8%	8.9	16.4	13.4	11.5	11.7	-4.7	5.6	-1.7	4.1	52	96	135	41%

Source: National Statistics, Laborstat[up to 2008], IMF and IFR

**Other sources suggest that the Chinese manufacturing industry may employ 100 million or more.*

***CEPR July 2011*

1.2 Changes since the 2011 study

Because the effects of the recession were hard to judge even in 2011, the base data in the original study was taken as 2008.

The update has focused on new employment resulting from robotics. The estimates show:

New jobs due to Robotics	***Total***
Up to and including 2008	***8 to 10 million***
2008 to 2011	***500,000 to 750,000***
2012 to 2016	***900,000 to 1.5 million***
2017 to 2020	***1 to 2 million***

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The update material also allows several important observations:

- That Chinese growth has not been stopped, but it has been restricted and this situation is likely to remain for several years. This reduces world growth by several percent.

- The three driving forces for using robotics, whether or not they generate new jobs, which will be mentioned again later, are:

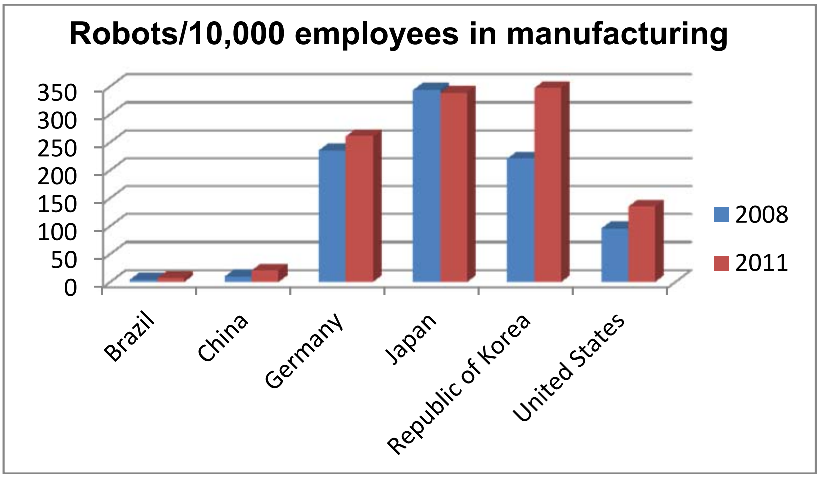
  I Where the product cannot be made to satisfactory precision, consistency and cost, without Robotics.
  This factor is expected to continue to grow in importance as technology advances.

  II Where the conditions under which the current work is done are unsatisfactory [may be illegal in the developed countries], but where a robot will operate.
  The recession has reduced attention on this factor.

  III Where [particularly] a developed country manufacturing unit with high labour costs is threatened by a unit in a low labour cost area.
  This is a critical factor in the re-balancing of the world manufacturing economies.

  China for example, is increasingly facing low cost competition and as Chinese employment costs rise, we can expect more use of robotics to maintain competitiveness.

- Korea has greatly increased its robot density over the past three years.



- Despite the rapid increase in the use of robots, USA has proportionately half the number of robots used by Germany. Germany itself [partly because of a different industry mix] is third, behind Japan and Korea.

- Two of the leading key robotics using countries, Japan and Germany, both face declining populations. They are well placed to maintain industry by using still more robotics to continue to lead in product quality.

- Skills shortages, have not been relieved by re-training during the recession and remain an important problem for industry. At least part of the solution is the application of robotics and automation.

  The concept of “Jobless recovery”, where an industry comes out of a recession leaner, needing fewer employees, is only short term. It is likely to lead to more job creation by the leaner, more competitive companies.
  At the same time, the service sector continues to absorb most of the displaced people. Some of these new service people owe their jobs to new robot driven industry.

The updated figures allow some revision of the previous report and allow the forecasts to look forward another two years.

Among the developing technologies which need robotics, there have been changes in the cost equation caused by the reduction in gas costs in USA as shale gas is exploited. This may lead to other shale gas activities in Europe, for example. The effect is to widen the gap between the cost of generating electricity by wind power and gas.

By contrast, for photovoltaic electricity generation, there is currently a large oversupply of solar panels. The result is almost certainly the survival of a smaller number of more efficient, even more automated producers. Current solar module prices range from about 70 to 90 cents per megawatt, less than half of the price three years ago. Module prices may go as low as 45 cents by 2015.

There is more caution about the speed of acceptance of electric vehicles than even two years ago.

1.3 Employment *directly* due to the use of robotics [World]

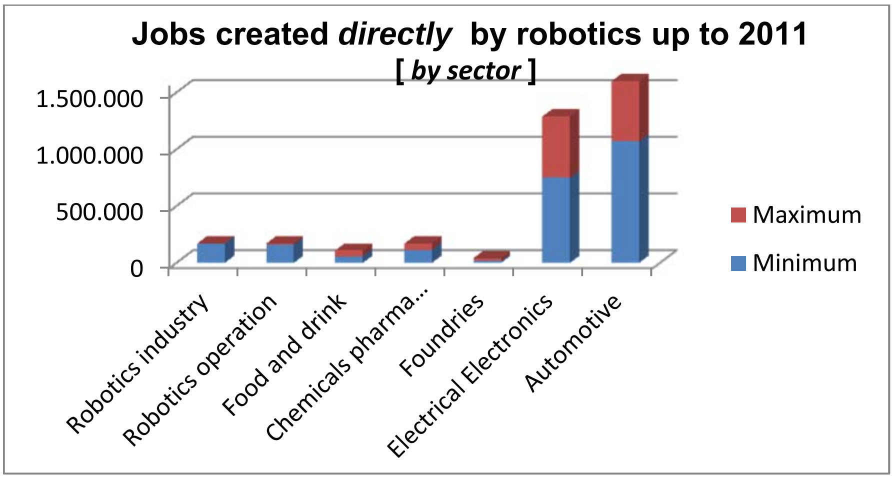
The robot industry itself generates 170,000 to 190,000 jobs worldwide, to which can be added the support staff and operators, another similar number of people.

As already mentioned, there are three other types of application where robotics create or preserve jobs. These are jobs which can only be done by robots.

I Where the product cannot be made to satisfactory precision, consistency and cost, without Robotics.

II Where the conditions under which the current work is done are unsatisfactory [may be illegal in the developed countries], but where a robot will operate.

III Where [particularly] a developed country manufacturing unit with high labour costs is threatened by a unit in a low labour cost area.



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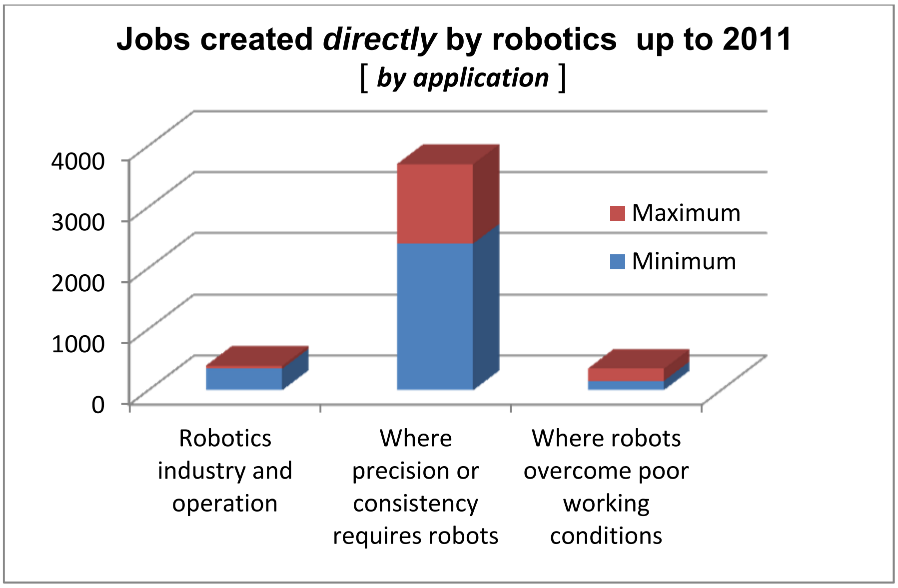

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1.4 Employment *indirectly* due to the use of robotics

A much larger source of employment, at least partly due to robotics, is the newly created downstream activity necessary to support manufacturing which can only be done by robots. We have been conservative in what we have chosen to include here. Some of the people we have spoken to, for example, would have liked us to have included large parts of the automotive sector sales and distribution employment. Our conclusion was that much of this infrastructure was in place before robots were widely used, and so not resulting from the use of robots.

The best example is the communication and leisure equipment business, from distribution to retailing. In the USA, this part of retailing is of the order of 1 million. In world terms this accounts for 3 to 5 million of jobs which would not exist if automation and robotics had not been developed to allow production of millions of electronic products, from Phones to Playstations to Tablets.

In world terms, these groups directly and indirectly generate jobs of the following order and in the country groups shown :

Total employment due to Robotics in 2008 [report first edition]

The period 2008 to 2011 was turbulent in economic terms, but using the same criteria as in 1.3 [above] to set up the above estimates, new employment generated in these three years due to robotics is calculated to be of the following order of magnitude.

Application type	Jobs created by robotics 2008	Areas where the jobs are created
Robotics industry and operation	300,000	Mainly industrialised countries
Where precision or consistency [sometimes within cost], requires robots	2 to 3 million	All countries with these industries
Where poor working conditions are overcome by the use of robots	150,000 to 300,000	Mainly industrialised countries
Where a sector which fails to use robots would be uncompetitive in world terms	2 to 3 million *[half of this at least overlaps with the above]*	Mainly industrialised countries
Downstream jobs created by new products and services	3 to 5 million	Countries where these products are sold.
Total	**8 to 10 million**	

By sector, numbers employed *directly as a result of robots* are of the order of:

Sector	**Total employment in the industry [world] 2008**	**Proportion of jobs which would not be there if robots were not used****	**Jobs created by robotics [world]** **to 2008**
Robotics industry	150,000	100%	150,000
Robotics operation	150,000	100%	150,000
Food and drink	15m to 20m	Well under 1%	50,000 to 100,000
Chemicals, pharma and plastics	12m to 15m *8m to 10m**	Under 1%	100,000 to 150,000
Foundries	1.5m to 2m	1 to 2%	15,000 to 40,000
Electrical and electronics	12m to 15m	5 to 10%	700,000 to 1.2 million
Automotive	10m to 12 m	10 to 15%	1 to 1.5 million
			2 to 3 million
Preservation of local industry [which overlaps with some of the above.]			***2 to 3 million***

And Indirectly

Plus…Downstream jobs in these sectors.		***3 to 5 million***
	Total	***8 to 10 million******

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**The Chinese figure is probably too large. If we reduce this, the total is more realistic.*

***This is the controversial column. It varies greatly between the industries [for example most of the food industry would survive without robots. [A lot of non robot automation and process control is used anyway, as well as low cost labour].*

By contrast, electronics or Automotive are high users of robots and without them parts of the industry could not survive even in the low cost countries. It also varies between countries, with higher proportions of robot dependent jobs in high cost countries such as Japan and Germany, and lower proportions in low cost countries such as China and India.

There are no agreed statistics on this, but we have discussed the estimates used here with the panel of robotics experts.

****We do not claim that these numbers are exact but they are likely to be of the right order of magnitude.*

Note that China now produces more cars than USA, but the number of robots used in vehicle manufacture in China is estimated at 40,000 compared with 65,000 in USA.

Robot density in a sector only provides a partial view of employment which is dependent on robotics. For example, use of robotics in the automotive sector does not cover all parts of the industry. However, large parts of the motor vehicle assembly sector would be lost to a country if it did not employ robotics. Probably not the components side, this is often highly automated but less likely to depend on robotics.

In the electronics sector some components could not be made without robotics, or could not be made at a cost which would sell, which would cause job losses not just in manufacture but downstream as well.

Apparent jobs created directly as a result of robots of the order of:

Sector	Increase in employment in the industry [world] 2008 to 2011	Proportion of jobs which would not be there if robots were not used**	Jobs created by robotics [world] 2008 to 2011
Robotics industry	150,000 +15 to 20%	100%	22,000 to 30,000
Robotics operation	150,000 +*8% to 15%	100%	Expansion in robots use. 12,000 to 22,000
Food and drink	1m to 1.2m	Well under 1%	8,000 to 10,000
Chemicals, pharma & plastics	*2m to 2.5m*	Under 1%	15,000 to 20,000
Foundries	small	1 to 2%	1,000 to 2,000
Electrical and electronics	1m to 1.3m	5 to 10%	50,000 to 80,000
Automotive	700,000	10 to 15%	70,000 to 100,000
			170,000 to 260,000

**2008 1m to 1.3m, 2011, 1.15m to 1.4m employed*

Plus…Downstream jobs in these sectors.		***300,000 to 500,000***
New jobs due to Robotics	***Total 2008 to 2011***	***500,000 to 750,000***

1.5 Potential for new job creation 2012 to 2016

There are five main areas where new jobs may be created in the next five years by the use of robotics.

I Continued development of new products based on the development of electronics and communication technology. One of the new areas identified, for example, is the manufacture of service robots. Another is the development and mass adoption of renewable energy technologies.

II. Expansion of existing economies and industries, notably automotive.

Sector increase due to sector expansion	Food & Drink	Elec Electronic	Automotive	Chemicals Rubber & Plastics	Total World
2012 to 2016	20%	30%	40%	30%	
New robot driven employment to 2016 *	9,600-12,000	65,000-110,000	100,000-140,000	20,000-26,000	200,000 To 300,000

**With continued improvement in robotics, and taking a conservative view, we have applied the lower growth figures to the mid point estimate of total robot driven employment in 2008 to arrive at a view on the expansion due to general economic expansion*

The same principle can be applied to estimate the growth in robotics using industries for the period up to 2020, although the confidence that can be placed on these figures reduces considerably

Sector increase due to sector expansion	Food & Drink	Elec Electronic	Automotive	Chemicals Rubber & Plastics	Total World
2016 to 2020	15 to 25%	25 to 30%	20 to 30%	20 to 25%	
New robot driven employment to 2020	11,000 to 15,000	80,000 to 140,000	120,000 to 200,000	23.000 to 32,000	250,000 to 400,000

III. Greater use of robotics in the SME sectors, particularly in the developed countries, to protect or win back manufacture from the low cost countries, or to win back production which had been seen as hazardous, but which had been taken up by the developing countries.

IV. Greater use of robotics in the food sector [where current use is low] as processed meals develop, to meet more stringent hygiene conditions.

V. Expansion of the robotics sector itself, to cope with the growth in demand. We have assumed an 8 to 15% growth which adds 15,000 to 30,000 in each four year period.

Potential *NEW* activity jobs because of robotics 2012 to 2016

	World **2012 to 2016**	**World** **2017 to 2020**
Food industry	60,000 to 80,000	*[extrapolated with increase]* 70,000 to 90,000
PhotoVoltaics	60,000 to 100,000	90,000 to 150,000
Wind power	5,000 to 10,000	15,000 to 30,000
Electric vehicles	40,000 to 50,000	80,000 to 150,000
New consumer electronics	Short term continuation of growth. *150,000 to 200,000*	*[extrapolated, with slow down]* 125,000 to 150,000
Manufacturing and selling Service Robots	Potentially much larger than manufacture of industrial robots. *50,000 to 100,000*	*[extrapolated with increase]* 60,000 to 120,000
More use by (S)ME* *[excluding those with less than 20 employees]	*10,000 to 50,000* dependent on advances in robot technology in the short term	*[extrapolated with increase]* *15,000 to 75,000*
Total for New Activity	*350,000 to 600,000*	*450,000 to 800,000*

Plus other jobs because of robotics

Due to current industry expansion	*200,000 to 300,000*	*250,000 to 400,000*
Downstream jobs	*400,000 to 600,000*	*500,000 to 800,000*

New jobs due to Robotics	***Total 2012 to 2016*** ***900,000 to 1.5 million***	***Total 2017 to 2020*** ***1 million to 2 million***

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The whole viability of companies today…as everybody is competing on a global basis you have to remain viable, and you don't want to be doing this with one hand tied behind your back. So, if you've got some technology out there that can help you compete, then you need to employ it. That's the way to protect jobs, and the way hopefully to create new ones." [Robot expert].

2. INTRODUCTION

Study Aim

The study analyses the impact of the use of robots in the industrialized production of goods on employment. The study covers years 2000 to 2016. Revisions have been made at the end of 2012 to take account of more recent data.

Project scope

The sectors considered are:

1. The large automotive players as well as the component suppliers,
2. Electronics and its interface with specialist plastics [solar cells, photovoltaics etc or other advanced materials], particularly clean rooms [but not the very specialised microchip manufacturing application].
3. Food and beverage, [health, cleanliness and safety]
4. Plastics [and Rubber] Industry as such, not only in combination with Electronics, Chemicals and Pharmaceuticals,

Definitions of the industries are given in the appendix.

Other than the automotive sector, the brief specified that SMEs (Small and Medium Enterprises) up to 250 employees were specified as the target where possible. By agreement, this has been given less emphasis in the project as there is little available information on the use of robots specifically by smaller companies.

Industrial robots are the target.

Global markets are covered by the economic background data. The study then focused on six key countries. Brazil, China, Germany, Japan, Republic of Korea and USA.

Method

The project is based largely on analyses of economic data on the six selected countries. This has been combined with the data on Robot use provided by IFR. The current revisions add the latest information from IFR as well as updated or new information on the sectors.

Conclusions were drawn by the Metra Martech team for the base study, based on economic and industry knowledge. There are considerable gaps in the information available and the main quantifications show orders of magnitude rather than precise numbers. These conclusions have been tested on IFR members in the countries. The testing process involved a two stage set of questions which were responded to by eighteen of these experts. The first question set established the validity of the main assumptions made by Metra Martech; the second was a more detailed set of questions, sent by IFR to selected experts. The Metra team completed two discussions each in German, Chinese and French, and in English with participants in Scandinavia[3], USA[3].

Metra Martech is a long established specialist in industrial and economic analysis, clients are governments and international organisations.

Employment in manufacturing, Production output and use of Robots. [year 2000 =100]

Country	Employment Index	Production Index	Robots in use, Index
BRAZIL ‘00	100	100	100
‘04	116	106.2	191
‘08	**126**	**126.0**	**373**
‘11	**133 +2%pa**	**133 +2%pa**	**567 +15%pa**
China ‘00	100	100	100
‘04	120	176	750
‘08	**136**	**373**	**3,500**
‘11	**139 +1%pa**	**518 +12%pa**	**8,183 +33%pa**
Korea ‘00	100	100	100
‘04	102.5	119	134
‘08	**101**	**158**	**203**
‘11	**104 +1%pa**	**183 +5%pa**	**328 +17%pa**
Japan ‘00	100	100	100
‘04	92	92	92
‘08	**94**	**104**	**92**
‘11	**86 -3%pa**	**96 -2.5%pa**	**80 -4%pa**
Germany ‘00	100	100	100
‘04	95	104	133
‘08	**98.5**	**120**	**159**
‘11	**92 -2%pa**	**120 0%pa**	**173 +3%pa**
USA ‘00	100	100	100
‘04	83	100	129
‘08	**78**	**111**	**148**
‘11	**70 -3%pa**	**113 +1%pa**	**156 +1.5%pa**

3. THE ECONOMIC FACTORS

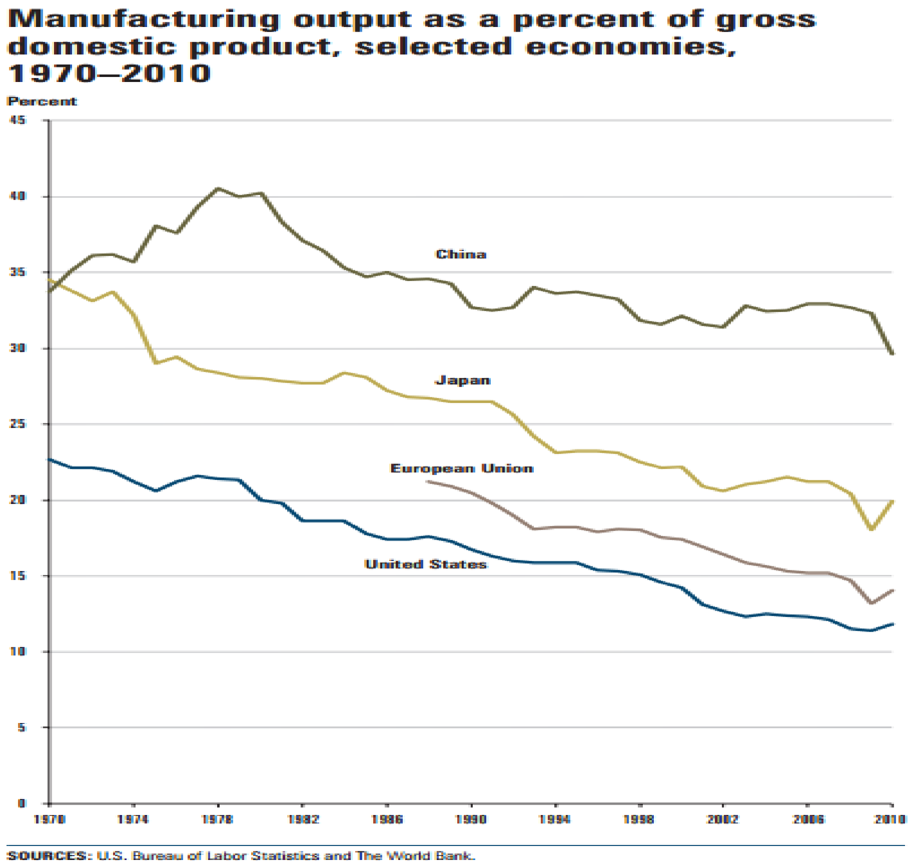
and their effect on the use of robotics.

3.1 Displacement and re-employment

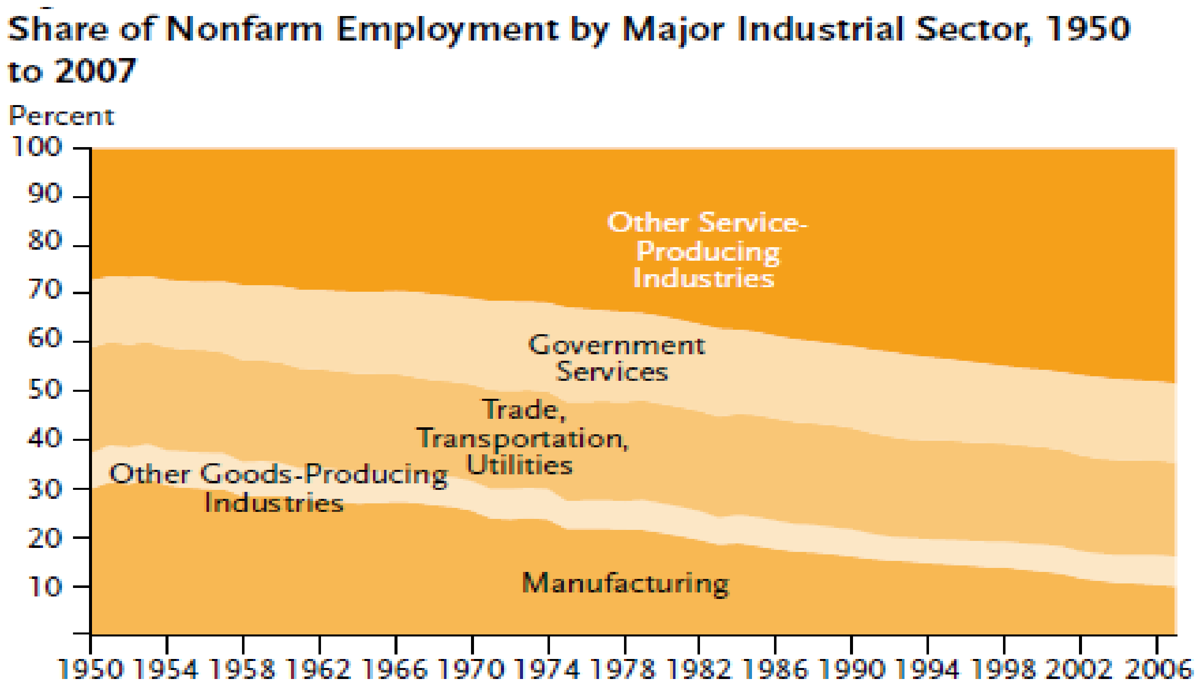
Where automation displaces people in manufacturing it almost always increases output [see table opposite]. In some cases it allows such an increase in production and related decrease in unit price, that it creates a whole new market and generates the need for downstream jobs to get the product to the consumer. It releases employees for other, often new jobs outside manufacturing. Historically, this has always been the case.

An alternative view is that this displacement in the future will be more difficult to place, as service robotics may take over some or many of the new job opportunities in human tasks such as in banking, fast food chains, and retailing petrol forecourts.

What is likely is that the growth of the production, marketing, selling and maintaining service robots will create the next wave of employment.



The USA has provided a good example [see chart below], where the total number of people in employment has grown, driven by increase in population, increased participation by women and increased immigrant labour.



Source: Bureau of Labor Statistics, Current Employment Statistics, 1950 to 2007 (March).

Manufacturing output has increased while employment in manufacturing has fallen in all of the six study countries except in Brazil and China where manufacturing increases have been so large that employment has risen too.

What is driving this trend to fewer employees in manufacturing is that manufacturers have steadily improved manufacturing productivity, largely by increasing the size of production units, automating tasks and sourcing components globally.

Doubling use of robots in the past ten years in USA has not affected the trend. By contrast, Germany, which has proportionately many more robots, also doubled the number of robots and has achieved slightly higher growth with almost no reduction in manufacturing employment.

Pressure to increase productivity in the *developed* countries, has been precipitated by greatly increased competition from overseas manufacturers, and passing of high labour content production to the low labour cost areas.

Pressure to use robotics in the *developing* countries has been that, despite availability of low cost labour, consistency and accuracy required to compete with or meet the requirements of the developed markets, can sometimes only be achieved by robotics.

Five other economic factors have to be considered:

- Globalisation
- Increasing speed of technology development
- Age and skills profiles
- Wage levels
- Health and safety legislation levels

3.2 Globalisation of the market

There has been very rapid growth of the very large developing markets of China and India.

These are low labour cost countries and while labour costs can be expected to level up around the world, these two countries are likely to be relatively low cost areas for at least 20 years. The markets are so large that they encourage the development of locally grown research and technology. This means the phase when China, for example, largely produced goods to western specifications is passing.

Two defences that the developed countries have to maintain their wealth creating production capacity [without putting up trade barriers] are:

1. To put more money into research and development. The success of the Fraunhofer Institutes in Germany, and the new 150bn Yen FIRST projects [Funding program for world leading Innovative R&D on Science and Technology] in Japan are examples of this.
2. To reduce dependence on high cost labour by introducing automation when it offers an economic alternative.

3.3 Increasing speed of technology development

This is about the pace of technological development, and the opportunity which this provides for those who can introduce the new technologies. It results in the shortening of product life cycles. Shorter cycles call for more flexible robotics. The product sectors which are the target for this report are not all affected to the same degree by shortening life cycles. Length of production run is an allied factor. Increasing customisation of products, and the flexibility needed by smaller companies are likely to be met by the next generation of robots

Sector	Comment
Food and drink	Formulations change, the process stays the same. Marketing initiatives re packaging may be very short lived
Rubber and plastics	The basic processes remain, the design, size and quantity changes with the electronic industry below.
Chemicals	Slow to change
Pharmaceuticals	Robots hardly used in manufacture, laboratory processes change slowly
Metal working	Slow to change
Electrical/electronic	Rapid design and technology changes
Automotive	Basic change is slow, detail changes are becoming increasingly rapid.

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3.4 Age and skills profiles

The ageing populations in, for example China, Japan and Germany are often cited as an added reason for adoption of robotics. USA is also affected but to a lesser degree.

A very significant ageing is forecast, but if we consider the workforce, within the timescale of the survey, only Japan is significantly affected, with a projected 5% loss of people of employable age. The German situation will become critical in the following years, but is projected to be less than 2% loss in workforce because of ageing, between now and 2016. Our discussions with robotics experts identify specific problems with ageing workforce in the aerospace sector in USA, but this is outside the scope of the present study.

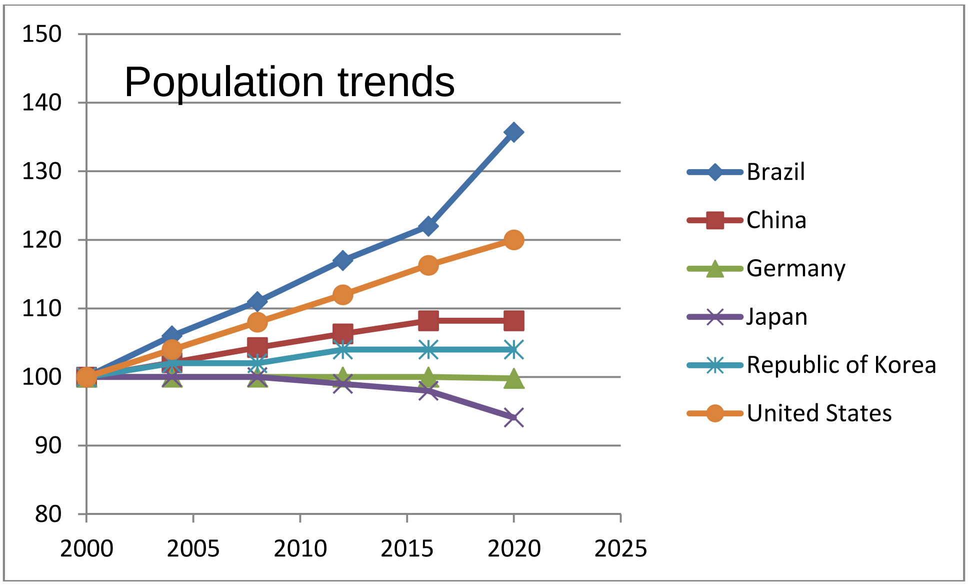
The existence of skills gaps is reported to be a problem, but this is more a question of education and training regimes than the effect of population ageing.

Several factors are involved in addition to age, the change in population as a whole, the change in people of [currently] employable age, the overall number of people employed and the success of skills training in the country.

Population in the 6 countries

Country	Population,				
Index [2000 = 100%]	**2012**	**2016**	**2020**	**08-16**	**12-20**
Brazil	116.5	121.6	135.7	+9%	**+16%**
United States	112.1	116.3	121.0	+8%	**+8%**
China	106.3	108.2	108.4	+4%	**+2%**
Republic of Korea	104.2	104.2	104.2	+2%	**=**
Germany	100	100	99.8	=	**=**
Japan	99.2	97.6	94.1	-2%	**-5%**

"There are sectors where it is increasingly difficult to find qualified personnel to work machines, e.g. turning. In part this is because fewer young people want to train in these areas and so when people retire they cannot easily be replaced. Robotisation is not the only solution. Companies get round the problem with flexible working hours (i.e. overtime) etc." [Robot expert]

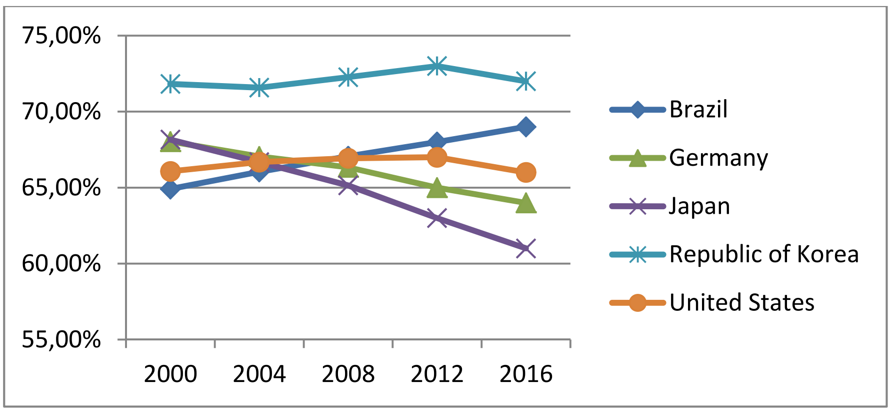


USA and particularly Brazil are forecast to have a significant increase in population. The rate of increase in the Asian countries is slowing, and the population in Japan is beginning to decline markedly.

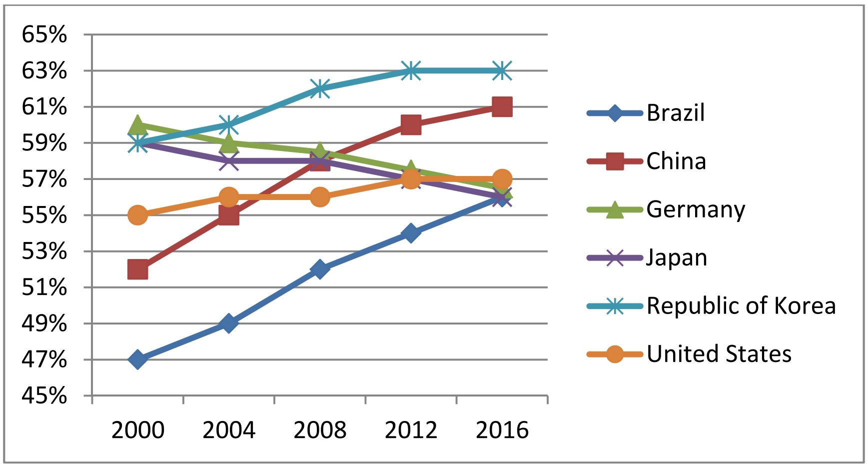
These changes in population are one of the key factors in the changes in actual numbers employed. In Germany and Japan, the change in population has been very small as has the numbers employed while Brazil, Republic of Korea and USA have all increased. Note that in the recession the US employment figure dropped from over 150million to less than 140 million. The Chinese figure dwarfs the other numbers. The employment figure there has grown from 729 million in 2000 to 784 million in 2008.

The employed age profile has two aspects, the number of employable age, and the number who can be expected to be more skilled [age 22 or more]. The figures for the six countries are shown in the charts below. Germany and Japan are the two countries losing potential workforce. The USA shows a different picture for the 22 to 64 age group, this almost certainly reflects the large numbers of mature immigrants entering the country.

Proportion of the population between 15 and 64



Proportion of population between 22 and 64
[the potentially skilled age group]



Skills gaps

Even with increasing levels of technology training around the world, reports on the subject show that skills gaps are occurring. The recession has accelerated this. The idea of a jobless recovery [see extract below] favours investment in productivity rather than people. There is another factor connected to this which is the much greater computer and electronic interface skills of the up and coming generation. They also have higher expectations about the type of work they would like to do. The problem is more of skills mismatch than overall skills availability. This is a structural training problem rather than a consequence of the ageing population.

- jobs are changing
- educational attainment is lagging.

ManpowerGroup surveyed nearly 40,000 employers across 41 countries and territories as part of its annual Talent Shortage Survey *[May 2012]*. Globally, 34 percent of employers say they are having difficulty filling positions, the three most challenging of which are Skilled Trades, Engineers and Sales Representatives. The reasons most often cited are lack of available applicants and lack of technical skills. Among the 41 countries and territories surveyed, employers are having the most difficulty finding the right people to fill jobs in Japan 81%, Brazil 71 % and USA 49%. *[8.]*

The American Society for training and development [ASTD] reports major skills gaps in USA. It also identifies the trend to a jobless recovery… one in which firms put off hiring new workers and achieve productivity gains with existing employees. Anthony Carnevale, director of the Center on Education and the Workforce at Georgetown University, notes that the last three recessions have been followed by jobless recoveries in which there was gross domestic product growth without job creation.“Recessions accelerate the trend to eliminate low-wage, low-skills jobs,” notes Carnevale, “and those jobs don’t come back.” Instead, companies create jobs requiring more education and skill. Growth of these jobs is slow in part because they require paying higher salaries and providing costly technological infrastructure for these workers. “Employers will hire cautiously to fill skill gaps that they couldn’t address by hiring during the recession,” *[ASTD]*

3.5 Wage costs and availability of low cost labour

One of the arguments against robots, contested by the suppliers, is that they are less flexible in operation and demand more up-front investment than the employment of low cost [often immigrant in the developed countries] labour.

The high labour cost sectors are more likely to use robots.

The differences between the countries are large too, although the interpretation of comparative data is often difficult.

Overall labour costs

Sector	Comparative Labour cost levels	Average weekly manufacturing wage USA [2012 *BLS*]
Automotive	High	$1,400 to ++
Robotics industry	High	
Robotics operation	High	
Other metal working industries	Medium/high	$750 to $1,000
Chemicals, pharma and plastics	Medium	$700 to $900
Foundries	Medium	
Electronics	Medium	
	Medium /low	$650 to $750
Food and drink	Low	$400 to $650

Metra Martech

Hourly labour costs in manufacturing, International comparisons

[USA costs are considered as 100]

Country	2000	2004	2008	2011
Brazil	17	13	26	33
China			10*	13
Germany	103	131	149	133
Japan	103	88	86	100
Republic of Korea	40	44	50	53
USA	100	100	100	100

Source BLS, except China which is Laborstat up to 2008, The China estimate is then based on 15% pa growth.*

Notes: The BLS definition of hourly compensation costs is not the same as the International Labor Office (ILO) definition of total labor costs. BLS hourly compensation costs do not include all items of labor costs.

Expenditures on the maintenance and repair of facilities related to company-provided services-such as cafeterias, daycares, private medical clinics, and recreational facilities- are excluded because they are overhead costs not directly linked to the level of employment or payroll. Recruitment and vocational training costs and reimbursements of business expenses are not included because the concepts used, and thus the measurement of these items, are not consistent across countries. The above labor costs items not included account for no more than 2 percent of total labor costs in most countries for which the data are available. Production workers generally include those employees who are engaged in fabricating, assembly, and related activities; material handling, warehousing, and shipping; maintenance and repair; janitorial and guard services; auxiliary production (for example, power plants); and other services closely related to the above activities. Working supervisors are generally included; apprentices and other trainees are generally excluded. All employees include production workers as well as all others employed full or part time in an establishment during a specified payroll period. Temporary employees are included. Persons are considered employed if they receive pay for any part of the specified pay period. Self-employed, unpaid family workers, contract workers, and workers in private households are excluded.

Hourly Compensation Costs consist of:

Hourly Direct Pay
Pay for Time Worked
Basic wages
Piece rate
Overtime premiums
Shift, holiday, or night work premiums.
Cost-of-living adjustments
Bonuses and premiums paid each pay period
Other Direct Pay
Pay for time not worked (vacations, holidays, and other leave, except sick leave)
Seasonal and irregular bonuses
Allowances for family events, commuting expenses, etc.
The cash value of payments in kind
Severance pay (where explicitly not linked to a collective agreement)

Employer Social Insurance Expenditures (both legally required and contractual and private) and
Labor-related Taxes
Retirement and disability pensions
Health insurance
Income guarantee insurance and sick leave
Life and accident insurance
Occupational injury and illness compensation
Unemployment insurance
Severance pay (where linked to a collective agreement)
Other social insurance expenditure
Taxes (or subsidies) on payrolls or employment

Low cost labour

China, and to some extent Brazil, have had access to low cost indigenous labour.

Japan and to a lesser extent Korea have restricted the incoming movement of workers.

USA and parts of Europe have until recently allowed this inflow, and both areas have used fewer robots proportionately as a partial result of this, with the exception of Germany. The table shows very large differences in immigration.

Immigration

2008	**Brazil**	**China**	**Germany**	**Japan**	**Korea Rep.**	**USA**
Immigrant Population (million)	0.6	3.9	10.1	2.0	0.6	38.3
Immigrants as % of population	0.3%	0.3%	**12.3%**	1.6%	1.2%	**12.8%**

http://www.nationmaster.com/graph/imm_imm_pop_imm_as_per_of_sta_pop-immigrant-population-immigrants-percentage-state *2012* *[All CIA World Factbooks 18 December 2003 to 18 December 2008]*

The figures for 2011 are very similar.

3.6 Health, safety [H&S] and environment

The increasing attention to these factors adds impetus to the employment of robotics in hazardous environments, or those involving great monotony. In the developed countries, H&S is a steadily advancing area; in the developing countries, progress is very sporadic.

According to the International Labor Organization (ILO), 270 million workers fall victim to occupational injuries and illnesses, leading to 2.3 million deaths annually, showing that the problem is significant.[2005]

There is pressure from consumer groups to force manufactures in developing countries to look after their workers to a standard approaching that achieved by the developed world manufacturers, but progress is slow.

However, no specific new initiatives have been identified in the study so far, which would cause a ***step change*** in the current trend to gradual improvement of health and safety practices in the six countries being studied.

Looking at the six countries, the current and planned changes are broadly as follows. The local enquiries and the views of the experts contacted suggest that there is likely to be continued improvement rather than a step change in all of the six countries.

Country	**Current status**	**Impending changes**	**General effect**
Brazil	Heavily regulated labour markets. 30 health and safety norms, but fast growth has results in gaps in enforcement	New regulations on personal protective equipment etc, working form platforms and shipbuilding in 2010	Continued improvement, no step change.
China	Far behind, but developing awareness		
Germany	Well advanced within the EU legislation framework.		
Japan	Well advanced		
S Korea	Increasing scope of KOSHA activities		
USA	Well advanced	Increased budget for enforcement Jan 2010	

Metra Martech

There is more background on the countries in the appendix of the 2010 report.

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4. NOTES ON THE SECTORS AS ROBOT USERS

The paragraphs below provide orders of magnitude for the applications to put them into a world perspective.

4.1 The robotics industry itself

The numbers employed in ***manufacturing*** robot systems are of the order of 150,000 [2008] and 175,000 [2011], worldwide. Almost all robot suppliers increased capacities in the period and some have built new production sites. This can be compared with almost zero employment thirty years ago.

The second group is the skilled ***systems integrator*** and the in-house skilled technicians of the robot systems. IFR figures show 1 to 1.3 million robots in use. If a car plant has 500 robots this could require say 50 skilled technicians for the robots. This is 1 job gained per 10 robots

The automotive industry has at least 415,000 [and possibly up to 550,000] robots [IFR report 2011] so divided by 10 = around 50,000 dedicated staff.

Non automotive, typically smaller robot installations, could gain proportionately twice as many dedicated staff per 10 robots installed. A stock of 740,000 robots in 2011 robots divided by 5 or 6 = 120,000 to 150,000 dedicated staff.

The total of the two groups both autoimotive and non-automotive, is 170,000 to 190,000 people. Adding the numbers employed in manufacturing robot systems, gives a **total for the industry of 320,000 to 350,000**

[These proportions have been agreed as the right order of magnitude by a selection of the IFR members.]

4.2 Where the product cannot be made to satisfactory precision or consistency without the use of robotics.

These are typically new industries made possible by robotics, where accuracy and consistency cannot be achieved without robotics, but parts of traditional industry, notably motor vehicle manufacture, require robots to achieve international standards.

The newer applications:

Parts of medical and biosciences, [not quantified*]
The next generation of consumer electronics
Renewable energy and “green” products.

Sector	World employment [2008] million	World employment **[2011]** million
Electrical and electronic [electronic]	12 to 15m [7 to 10*m]	16 to 21m [9 to 14*m]
Renewables [wind and PV]	700,000	1m
Metal foundries [remove work hazard]	0.5 to 0.75 m	0.5 to 0.75m
Automotive	11 m	12 m

*excluding Electrical machinery etc. [see below]

Electrical and Electronics Sector as a whole

The electronics and consumer sector is part of the IFR Electrical/Electronics sector. It is the first of the two groups in the table below. And it is where very large volumes of sophisticated and often small sized products are made.

Employment [2008]	Computer, communication and electronic products and components	Electrical machinery & equipment	Total [2008]	Total [2011]
Brazil	267,000	122,000	389,000	405,000
China	6.8 million		6.8m	7.7m
Germany	648,000	331,000	979,000	1m
Japan	1,280,000	770,000	2m	1.8m
Rep of Korea	413,000	139,000	552,000	620,000
USA	1,010,000	409,000	1.4m	1.2m
World 2008	7 to 10 million	5 to 8 million	12 to 18 million	
World 2011	9 to 14 million	7 to 11 million	-	16 to 25 million

[ILO Laborstat, except Republic of Korea and China for which we have used National Statistics]

Renewables

World employment in wind and solar generation is of the order of 600,000 to 700,000. Fuel cells, batteries for electric vehicles and storage account for another **20,000 to 30,000.** [see later analysis, section 7.6]

Pharmaceuticals

World employment in pharmaceuticals is 1.2 to 1.5 million. European employment [2010] was 660,000 and USA, 416,000. 75% of this is concerned with manufacturing.

Extract from World Robotics.

*The **pharmaceutical industry** is continuously improving quality and increasing quantity of their products. The worldwide R&D expenditures are very high, about 10% of the total turnover. The demographic shift will result in an over ageing society**. Health care systems are set up in more and more countries. The worldwide demand for pharmaceutical products is on the rise. The pharmaceutical industry was hardly affected by the economic crisis. Thus, investments in robots only slightly decreased in 2009. Similar trends can also be observed in the **medical devices** industry. In both industries robot installations will gain momentum in the coming years."

**Metra note: Service robots are likely to be very important in this area.

Fuel cells

Forecasts in this area are varied, the general position seems that the future is heavily dependent on further research, and also on the cost of the Lithium or Platinum components. A great deal of research money is being spent on the subject for military as well as transport applications. The general position appears to be that of the order of 75,000 units were shipped in 2009 [world], but very high growth rates are expected. One forecast expects the growth to be 75% a year for the next few years. Another expects output to double by 2014. This is still small compared to the potential market of tens of millions. Raw materials are a prime cost, but reduction of production costs is clearly important and when the breakthrough occurs, recent R&D activities related to fuel cell have developed platinum free fuel cells which are expected to significantly reduce the cost of fuel cell in the coming years. Robotics and the employment which goes with it will be significant. [see later analysis, sec.7.7]

Automotive

Germany[720,000], Japan[787,000] and USA [717,000] each, China 2.9 million [may be as high as 5 million], rest of world two to three million. **In world terms, employment in the automotive industry is of the order of 12 million [2011]**.

4.3 Areas where Health and Safety may cause a change to Robots

Sector	World employment 2008 2011
Food and beverage [remove work hazard]	15 to 20 million 16 to 22 million
Chemicals, Rubber and plastics	20 to 40 million 21 to 41 million
Metal foundries [remove work hazard]	0.5 to 0.75 million Small change
Metal fabrication	7 to 12 million Not estimated
Paint application [remove work hazard]	20 to 30 million Not estimated
Many welding applications	Not estimated

The food industry is certainly one such area, where large numbers of employees are said to be at risk. It is a sector where wages tend to be low, and robotics has so far been viable only in higher added value products such as picking and sorting vegetables for fresh or frozen applications. Process control is widely used in bulk food preparation, but is outside the scope of the present study.

> ***Work environment.*** Many production jobs in food manufacturing involve repetitive, physically demanding work. Food manufacturing workers are highly susceptible to repetitive-strain injuries to their hands, wrists, and elbows. This type of injury is especially common in meat- and poultry-processing plants. Production workers often stand for long periods and may be required to lift heavy objects or use cutting, slicing, grinding, and other dangerous tools and machines. To deal with difficult working conditions and comply with safety regulations, companies have initiated ergonomic programs to cut down on work-related accidents and injuries.
>
> In 2007, rates of work-related injury or illness for full-time food manufacturing workers were higher than the rates for all of manufacturing and for the private sector as a whole.
>
> *[US Bureau of Labor]*

Food and beverage,

Current employment, USA 1.7 million, Japan 1.4 million, Brazil 1.6 million, China 3 million+, Germany 0.9 million, Spain 0.5 million…

15 to 20 million in the world

Chemical, [including plastics and rubber]

The chemical sector itself, does not have large use of robotics, but sub sectors do, notably the plastics sector:

Employment 2008	Chemicals	Rubber and plastics	Total
Brazil	840,000	400,000	1,240,000
China	4,296,000	3,530,000	7,830,000
Germany	558,000	354,000	910,000
Japan	580,000	630,000	1,210,000
Rep of Korea	125,000	172,000	300,000
USA	850,000	734,000	1,580,000
World			12 to 15 Million

[ILO Laborstat, except Republic of Korea and China for which we have used National Statistics]

Metal Foundries

US steel foundry employment of the order of 30,000

Non ferrous foundries maybe 20,000

Germany a similar or greater number. Foundries which specialise in the automotive sector [at least 50% of German foundry output] are sophisticated. The rest of the industry employs more people and is less sophisticated.

Outside China, the total employment in foundries is of the order of **250,000**

The Chinese industry is as expected remarkable in size and scope. An extract from a 2008 report shows:

The foundry industry in China is very large, estimated to produce about 28 million tonnes of castings. This makes it the largest in the world in volume terms, but significantly lower in value terms when compared with the 14 million tonnes produced in USA and 5 to 6 million tonnes in the German foundry industry.

China exports about 10% of its output in the form of rough and machined castings. Currently there are more than 20,000 foundry plants. These are spread across state owned captive units, regionally owned enterprises and those which are foreign owned.

With China, the world total employment in foundries is of the order of half to three quarters of a million.

If we extend this to fabricated metal products, **the world employment rises to 7 to 10 million**

Other industries also have hazardous situations, but these are hard to quantify.

Paint shops. A recent British Coatings Federation report broke the market into paint types, in order of size. It showed:

General industrial paints	45%
Industrial powder	23%
Automotive and vehicle	23%
Marine and high performance	9%

The proportion of the main types of industrial paint will vary from country to country.

In 1998 in USA there were 150,000 people working as paint and coating operators, in a variety of industries including automotive. Discussions with the robotics industry tell us that the industry has consolidated considerably since then, but the majority of these are not using industrial robots. As many as 80% are in the repair sector. There may be as many as 20 to 30 million paint and coating operators in world markets.

"I don't see safety as a big driver. It was a driver when you look at dirty and dangerous jobs like paint booths and welding that they took people out of and put robots into. But, when you look at the future then I think robots working more closely with people, fences coming down and intrinsically safe robots is more likely to drive the greater use of robots and at the same time, hopefully because of the increased productivity that is occurring, it will lead to more human jobs."[Robot expert]

4.4 Making [or maintaining] manufacturing viability, situations where employment would be wiped out if manufacturing costs were not reduced [i.e. saving rather than adding to employment]. This is a western industry problem, caused in the past twenty years by the growth of industries in the low cost countries, particularly China and India.

Sectors affected are those which have high labour costs. In the terms of the current study, this means the Automotive sector, parts of Electronics and parts of the Metal industry.

The numbers of jobs saved could be tens of millions but it has not been possible in this survey to analyse which applications these come from.

No doubt, **Japan, Germany and now Republic of Korea have invested more, and have lost fewer jobs in manufacturing in the period covered by the study**.

“Automation is not likely to enable industries that have already gone offshore (e.g.consumer electronics) to return but can help to stop others from having to go offshore. In the consumer electronics sector, France can no longer hope to compete with Chinese companies such as Foxconn, which have built facilities employing hundreds of thousands of people. A more likely development is that over time, companies like Foxconn decide to set up in Europe in order to be closer to the marketplace, but they are more likely to set up in Romania or Hungary than Germany or France. Over time it won’t be possible for everything to be done from China. The cost of living will rise there and the cost base will change.” [Robot expert]

“I agree with inclusion of downstream employment beyond the actual manufacture. However, it is hard to assign all associated jobs with the cell phone example. Could you also assign all jobs in the automotive industry including selling cars and servicing cars?

I believe that most viable products would be produced in some manner with or without robots and cell phones fall into this category. Automation may very well be part of the acceleration of the products success.”[Robot expert]

5. HOW MUCH EMPLOYMENT IS DEPENDENT ON ROBOTICS ?

5.1 Background

The tables which follow are based on the fact that only part of the workforce is there because of robotics. The rest of the jobs in the sector, to do with design, distribution etc, could be fed from a manufacturing plant elsewhere**.**

The factors that go to make up the estimated proportion are not easily quantified, but we have identified several which help to derive the overall view for a sector. The proportions shown are an indication only, but they have been refined as a result of the discussions with robotics experts during this survey

The proportion of the industry which uses robotics,
For example, this is low in the food industry, high in the automobile assembly subsector, but less evident in the automotive components sector [part of which may be heavily automated, but not robot users].

The sophistication of the manufacturing operation, or its special needs,
For example the need for cleanrooms in the electronics component sector, but not necessarily in assembly. Or the need to meet health and safety requirements in the more developed countries.

The cost of labour,
For example, the cost of labour is relatively low throughout the world in the food sector, which results in lower use of robotics. In China where the cost of labour is low, there is a much greater likelihood of employing large teams for assembly work in any industry, rather than robots

5.2 Precision, Consistency and Cost. Sectors which require robotics.

A very important element here is the role of automation in allowing large volumes of often complex products to be produced at a quality that is not otherwise achievable and at a cost which is affordable in the consumer market. In the days of manually assembled cars, they were expensive and the numbers purchased were relatively few. From the Ford Model T to the present day, mass production and then automation has brought the cost to an affordable level for most families in the developed world. Mobile/cell phones, computers etc have a very similar pattern of growth, except this has happened over a period of ten years and is now dependent on Robots**.**

Electrical and Electronics sector relationship with robots.

Description of the electronics sector structure in USA, [provided by the Bureau of Labor Statistics, BLS] suggests that about 22% *[10 to 15% if we consider the whole electrical electronics sector]* of the employment in the sector is actually or potentially could be connected to robotics. Hypothetically, if robots were removed, some products would become unviable, while others would move to the low cost countries and be assembled by hand. Feedback from the Chinese answers is that many tasks carried out in this sector, particularly by SME are still done by hand, but the Foxconn example below shows that the situation is changing in China. The loss of jobs would thus be greater in the developed countries, and the gain in jobs greater in the lower cost industrialising countries. There are no statistics on this type of dependence and we have made broad estimates based on the above and the number of robots in use in the country in the sector.

The need for robotics in this industry, to achieve accuracy in large volume output and alleviate the worker stress caused by repetitive work under pressure is illustrated by recent Foxconn announcements.

Taiwan-registered Hon Hai Precision Industry Co (Foxconn) has announced plans to build large numbers of robots for its own purposes. It has been reported in the press that about 10,000 units of these robots are already installed. They are less sophisticated than the ISO defined “Industrial Robot”, but the project is expected to create around 2,000 jobs in Taiwan, and initial indications from other news sources that the robots would replace the jobs of many Chinese workers have now been clarified. **The robots are intended to assist in overcoming Foxconn's well-documented workforce problems, not by replacing those workers with robots, but by supplementing those workers. T**he company states that it **intends to maintain its workforce and train existing workers for more important tasks.** The robots will enable the company to solve its hiring problems while improving output and workforce morale.

Foxconn robot

Foxconn is best known as the largest exporter in China, the assembler/manufacturer of Apple's iPad and iPhone . The company has

thirteen factories in China (including the massive industrial complex in Shenzen, plus manufacturing facilities in India, Mexico, Brazil, Slovakia, Poland and the Czech Republic, where it is the country's second largest exporter.

Robots per 10,000 employees Electric/electronic	Brazil	China	Germany	Japan	Rep of Korea	USA
2008	4	5	240	1,180	1,000	200
2011	6	11*	255	1,200	1,450	280
Change ’08 to ‘11	+50%	+120%	+6%	+2%	45%	40%

**And note the Foxconn plan to greatly increase its use of robotics in the next few years.*

Electrical and Electronics

Country	Numbers employed [1,000] 2008 2011	Proportion depending* on Robotics*	Number employed depending** on Robotics	Apparent new employment dependent on robotics 2008 to 2011
Brazil	390 405	2 to 5%	7,800 to 19,500 8,100 to 20,025	300 to 500
China	6,800 7,700	2 to 5% 3 to 6%*	150,000 to 350,000 250,000 to 450,000	100,000
Germany	980 1,010	5 to 10%	49,000 to 98,000 50,000 to 100,000	1,000 to 2,000
Japan	2,050 1,770	12 to 15%	246,000 to 307,500 212,400 to 265,500	-34,000 to -42,000
Rep of Korea	552 620	10 to 15% 11 to 16%	55,200 to 82,800 65,000 to 100,000	10,000 to 20,000
USA	1,420 1,220	10 to 15%	142000 to 213,000 122,000 to 183,000	-20,000 to -30,000
Total above	12 million 12.7 million		650,000 to 1million 650,000 to 1.2 million	**50,000 to 60,000**
World	15 to 20 million 16 to 21	5 to 10%	750,000 to 2 million 800,000 to 2.1million	**50,000 to 100,000**

Metra Martech

**The proportions were derived in the 2010 project note particularly the estimated increase in China.*

***If there were no robotics, the job would not exist or would not be sustainable as manufacturing and employment practices change..*

**** Continued growth of other South East Asian production*

Automotive sector relationship with robotics

Manufacture is very dependent on the precision and consistency needed to obtain quality at competitive production costs. The sector structure in USA [BLS again] suggests that about 37% of the employment in the sector is actually or potentially could be connected to robotics. This is reinforced by comments from the experts that there is still plenty of opportunity to expand the use of robots in the automotive sector.

> *"Automation and robotics will enter new areas of the car making process, essentially the assembly area, and this will drive growth in both the industrialised and the industrialising markets.*
>
> *The reasons this has not been possible so far are technical but as technological improvements resulting in more intelligent robot systems with better sensors enable closer interaction between human workers and robots, it will become a reality. This will drive automation into new areas and provide additional growth even in areas that appear saturated already.*
>
> *Every new production line built for the automotive industry results in orders for more robots and these orders are augmented by the new assembly activities that are becoming robotised." [Robot expert]*

Robots are mainly used in the body shop where welding, painting and material handling applications take place. The final assembly is a different segment of the plant, and that's where robots have not penetrated so much. There are a lot of people doing final assembly where robots cannot currently be used because they need to be working side by side with the people, but legislation says they have to be fenced off. GM have a joint research with NASA to produce a robot system with spatial awareness that is safe to work alongside, in the final assembly area. The component sector is also a user of robotics, but the nature of the components allows more automation rather than robotics.

The number of people who depend on robotics varies broadly with the wage level of the country. In China, where there are many low cost workers, larger teams are involved with the robotic work.

> *"In Germany, the number of robots that are used to make a car is among the highest in the world. So VW for example uses a lot of robots in its German plants or its Spanish plants but vastly fewer in its Chinese plants, to make the same model (e.g Jetta). If you visit a plant in China you see that the robots are being used in only a few areas, mainly spot welding, and even so, they continue to weld by hand as well. You don't see robots inserting window-panes or assembling components." [Robot expert]*
>
> *But the application of robots is growing as production grows [Metra]*

Robots per 10,000 employees Automotive	Brazil	China	Germany	Japan	Rep of Korea	USA
2008	45	63	1,082	1,606	554	1,000
2011	69	141	1,176	1,584	895	1,104
Change ’08 to ‘11	+53%	+114%	+9%	-1%	+62%	+10%

[IFR]

In a more expensive manufacturing region there are more robots, but fewer people involved with them. We have represented this by the percentage ratios in column three below. They are not exact figures, but they have been refined during our discussions with robotics experts.

China’s robotics investment is still heavily dependent on the automotive industry with 59 percent of demand, relative to electronics at 17 percent. *[Robotics Businiess review Dec 2012],*

Automotive

Country 2008 2011	Numbers employed	*Change in employment*	Total Vehicle Production *[OICA]*	*Number of robots [IFR]*	Employees depending* on Robotics *[Metra]*	Number employed depending on Rob'ts	Apparent new employment dependent on robotics
Brazil	507,000** 542,000**	*35,000*	3.2m 3.4m	*2,300 3,700*	1 to 4% 2 to 5%***	5,700 to 20,000 10,000 to 25,000	5,000
China	2.7million 2.9million	*200,000*	9.3m 18.4m	*17,000 40,000*	2 to 5% 4 to 10%***	54,000 to 135,000 116,000 to 290,000	60,000 - 150,000
Germany	757,000 719,535	*-37,000*	6.0m 6.3m	*82,000 85,000*	20 to 30%	150,000 to 230,000 145,000 to 215,000	-5,000 -15,000
Japan	895,000 787,000	*-108,000*	11.6m 8.4m	*144,000 124,000*	20 to 30%	180,000 to 270,000 150,000 to 240,000	-30,000
Rep of Korea	509,210 485,554	*-23,600*	3.8m 4.7m	*28,000 43,000*	15 to 20% 18 to 25%***	76,000 to 100,000 87,500 to 120,000	10,000 to 20,000
USA	875,500 716,900	*-158,000*	8.7m 8.6m	*64,000 79,145*	15 to 20% 16 to 21%***	130,000 to 180,000 115,000 to 150,000	-15,000 to -30,000
Total of the above		*-92,000*	42.6m 50m	*360,800 374,845*		600,000 to 900,000 650,000 to 1,030,000	75,000 -175,000
World	11.2m 11.9m	700,000	70.5m 80.0m		10 to 15%	1 to 1.5 million 1.1 to 1.6 million	120,000 to 240,000

Metra Martech, *the number of robots and the employment figures are from IFR except for Brazil, see note below.*

**If there were no robotics, the job would not exist at that location.*

*** IFR's employment figures for Brazil have been increased to allow an increase estimated by Metra. The proportion dependent on robotics in Brazil has been reduced for both years to take more account of the comparatively small numbers of robots in use there.*

**** Growth in use of robots/employee 2008/2012 in automotive [see table above]. .The percentage increase in column 5 is an indication of the likely change rather than an exact number.*

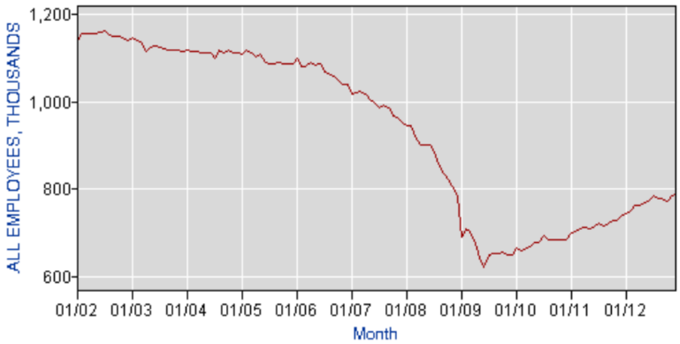
The figures show a loss of employment in the study countries of 92,000. This is more than offset by the increase in employment due to robotics 75,000 to 175,000. Brazil, China and Republic of Korea have gained, the other countries have lost employment.

"Executives' confidence is in line with data from the U.S. Bureau of Labor Statistics, which shows steady growth in auto industry employment over the last three years. Industry employment plummeted from 2006 to mid-2009, and has yet to recover to the levels of the early 2000s. However, since June 2009, employment in motor vehicle and parts manufacturing has grown from 624,400 jobs to 774,600 jobs, a 24.1 percent increase."
[KPMG report August 2012]

Data extracted on: January 6, 2013 (3:05:38 PM)

Employment, Hours, and Earnings from the Current Employment Statistics survey (National)

Series Id: CES3133600101
Seasonally Adjusted
Super Sector: Durable Goods
Industry: Motor vehicles and parts
NAICS Code: 3361,2,3
Data Type: ALL EMPLOYEES, THOUSANDS



[US Bureau of Labor Statistics]

5.3 Unsatisfactory working conditions, where robotics have replaced humans.

Food and Drink

The USA sector structure suggests that about 30% of the employment in the Food and Drink sector is actually or potentially could be connected to robotics. In fact the use of robots is relatively low. This is a sector with below average wage costs and often need for only minimum skills.

"The food industry as a whole is probably the next largest sector but it is very diverse. Robots are currently mainly being used here in downstream packaging, palletising and logistics and not very much in processes upstream of packaging. There is great potential to use robots in future for handling and processing tasks, such as cutting, positioning, inspection. It is already being done but much less than it could be." [robot expert]

Food is highlighted by the US Bureau of Labor as dangerous, but the big companies, and those making liquid ingredients use process control rather than robotics. Packaging and despatch are areas with potential, as are new products around the processed ready meal. The number of people in this industry dependent on robotics is a very small percentage of the total.

Robots per 10,000 employees Food & Drink	Brazil	China	Germany	Japan	Rep of Korea	USA
2008	<1	3	55	25	13	40
2011	<1	7	57	23	21	50
Change	-	130%	4%	-8%	62%	25%

Food and Drink

Country 2008 2011	**Numbers employed**	**Proportion depending* on Robotics**	**Number of employees depending on Robotics**	**Apparent new employment dependent on robotics 2008 to 2011**
Brazil	1.6 million 1.8 million	<<1%	1,000 to 2,000	100 to 200
China	2.7 million 3.1million	<<1%	10,000 to 20,000	1,100
Germany	858,000 895,000	<1%	4,000 to 5,000	400 to 500
Japan	1.42 million 1.36million	<1%	5,000 to 8,000	-500 to -800
Rep of Korea	261,000 263,000	<1%	1,000 to 1,500	100 to 150
USA	1.66 million 1.64million	<1.5%	10,000 to 12,000	-150
Total	8.5 million 9 million		30,000 to 50,000	1,000
World	15 to 20million 16 to 22million	<1%	50,000 to 60,000	1,500

Metra Martech

**If there were no robotics, the job would not exist at that location.*

Foundries are an obvious application, a robot could perform more effectively as well as relieving the operator from difficult working conditions, but the numbers are relatively small. Robots per 10,000 employed, in metalwork [including foundries]**,** are >50 to 100, or ½ to 1%. This may be explained by the different range of vehicles produced.

> The reasons for metalcasters to adopt robots are not new, but the technologies available to them are presenting a range of capabilities that make the investment more than a labor saving or labor environment strategy. The progress of robotic technology and the emergence of new functions make these installations even more consequential for the metalcasters that adopt them.
>
> Cycle time is one consideration, so higher throughput is a goal, metalcasters are trying to increase the throughput in their existing operations."
>
> Quality is another reason, especially for finishing. The consistency and quality of finishing with a robot is typically much better than it is for a manual operation: deburring, degating, grinding, sawing, etc.
>
> Pouring is very labor-intensive and slow, and it can be done more quickly and accurately with a robot than manually.
>
> Robots will soon be able to monitor process parameters such as metal temperatures and volumes, or mold or die temperatures, all of which may require an adjustment in a metalcasting production process, *[Foundry Magazine]*

Foundries

Country 2008 2011	**Numbers employed**	**Proportion depending* on Robotics**	**Number of employees depending on Robotics**	**Apparent new employment dependent on robotics 2008 to 2011**
Brazil		**1%**		
China	750,000 900,000	0.5%	3,000 3,500 to 4,000	
Germany	50,000	5%	2,500	
Japan	50,000	5%	2,500	
Rep of Korea		5%		
USA	50,000	5%	2,500	
World	1.5 to 2 million	1 to 2%	15,000 to 40,000	1,000 to 2,000

Metra Martech

**If there were no robotics, the job would not exist at that location.*

Chemicals, Rubber and Plastics, and Pharmaceuticals

The USA industry structure in this sector shows that maybe 10% of employment is potentially suitable for robotics. However, most of the processes are automated. Many are hazardous.

Plastic moulding, chemical dosing, filling etc are robotics areas. Current use is mainly in the plastics sector, and in pharmaceuticals.

Robots per 10,000 employees 2008 2011	Brazil	China	Germany	Japan	Rep of Korea	USA
Chemical (less Plastics & Rubber)	<1 <1	10 20	100 105	165 150	20 25	50 65
Plastics & Rubber	22 33	16 35	400 440	630 580	300 400	375 450

Chemicals etc.

Country 2008 2011	**Numbers employed**	**Proportion depending* on Robotics**	**Number of employees depending on Robotics**	**Apparent new employment dependent on robotics 2008 to 2011**
Brazil	1,240,000 1,350,000	<1%	2,000 to 3,000 2,200 to 3,250	200 to 250
China	*[7.8 million]* 8.6million	<<1%	5,000 to 10,000 5,500 to 11,000	500 to 1,000
Germany	910,000 890,000	1 to 2%	5,000 to 10,000	-
Japan	1,200,000 1,140,000	1 to 2%	10,000 to 20,000 -	-
Rep of Korea	300,000 360,000	1%	3,000 3,600	600
USA	1,580,000 1,420,000	1 to 2%	15,000 to 25,000 -	
Total for the six countries	10 to 15 m 11 to 16m		37,000 to 70,000 38,000 to 72,000	1,300 to 2,000
World	20 to 40m	<1 %	100,000	3,000 to 5,000

Metra Martech

**If there were no robotics, the job would not exist at that location.*
Most of the robotics occurs in the plastics manufacturing sector.

5.4 Supporting employment of local industry

We have already counted the automotive sector as one which cannot now be made to satisfactory standards *in any country* without robotics although in the industrialising countries more jobs are still done manually. There is a second reason too why the automotive sector is hard to analyse in terms of supporting local employment. It is possible to make many components on automated lines in low cost countries. Once it gets to the bodyshell, the cost of transporting bodies for final fitting in the high cost country, other factors being equal, becomes too costly. The industry is saved by the transportation cost. The third factor is the exchange rate and tax situation. This has led to US made Hondas and Toyotas being shipped from USA to Korea rather than sourcing them from Japan.

The choice is then to use more robots to produce better quality, [Germany, Japan, and increasingly Korea] or to find a lower cost region in which to make the cars. Examples of these are the Southern states in USA and East Europe for the Europeans.

The electronics sector has already conceded much electronics manufacture to the low cost areas. There they increasingly use robots when necessary to get the quality/volume equation right.

The opportunity for supporting local manufacturing employment appears to lie in situations where:

- The total cost of producing locally can be kept equal to or below the lower cost overseas manufacture plus the added transport cost.
- The benefits of having local service and support almost outweigh the lower cost overseas manufacture plus the added transport cost but there would be a clear advantage if cost could be lowered.
- A company cannot get enough production in the local market to be viable, but with robotics could increase production, lower cost and sell internationally.

Calculation of the size of this opportunity for re-generating local manufacturing employment is outside the scope of this study, but it could be very large, particularly in USA where the use of robotics has lagged behind that of Germany and Japan.

The jobs impact in USA of trade with China

Most of the jobs lost or displaced by trade with China between 2001 and 2011 were in manufacturing industries (more than 2.1 million jobs, or 76.9 percent).

Within manufacturing, rapidly growing imports of computer and electronic products (including computers, parts, semiconductors, and audio-video equipment) accounted for 54.9 percent of the $217.5 billion increase in the U.S. trade deficit with China between 2001 and 2011. The growth of this deficit contributed to the elimination of 1,064,800 U.S. jobs in computer and electronic products in this period. Indeed, in 2011, the total U.S. trade deficit with China was $301.6 billion—$139.3 billion of which was in computer and electronic products.

[The China Toll, Robert E Scott, Economic Policy Institute August 2012]

Country 2008 2011	No. of robots per 10,000 employees in manufacturing *[IFR]*	Growth %	Comparative Index, Germany = 100
Brazil	5 7	40%	3
China	10 21	210%	8
Germany	236 261	11%	100
Japan	344 339	-1%	130
Republic of Korea	221 347	57%	133
United States	96 135	41%	52

Reasons for the comparatively low uptake of robots in USA are no doubt complex, but include: the greater availability of low cost labour, and less stringent employment laws, and the different mix of industry. The rapid rise in use of robotics in the 2008 to 2011 period still leaves the US at half the level of robot use compared with the market leaders.

Automotive, the largest robot user

In the current growth phase of the Chinese market, Western manufacturers are passing on their skills, including the use of robotics, and the chance to be supportive of home industry is greatly reduced by this. Part of the Chinese market is supplied by plants set up by long established western car makers and part by new Chinese companies. The Chinese companies are busy supplying fast growing local needs, but several have announced plans to export cars within two to three years.

Chinese car production is still so low cost, that there are reports of GM and others importing direct from their plants in China or Korea.

The “simple” solution of more automation to protect industry is thus only a part of the story. An analysis of production shows a complex picture.

The German and Japanese manufacturers who have invested heavily in automation and robots have maintained a lead in the quality market.

The Koreans appear to produce more vehicles per employee, and with fewer robots.

The USA figure shows US producing more vehicles per employee than Germany, with a lower proportion of robots.

Country 2008 2011 Automotive	**Total Vehicle Production**	**Number of robots**	**All vehicles per robot pa**	**Employees [1,000]**	**All vehicles per employee pa**
Brazil	3.2m 3.4m	2,300 3,500	540 975	507 555	6.3 6.1
China	9.3m 18.4m	17,500 41,000	310 450	2.7m 2.9m	3.4 6.3
Germany	6.0m 6.3m	78,300 85,000	79 74	757 720	7.9 8.8
Japan	11.6m 8.4m	139,000 125,000	85 67	895 787	13 10.7
Rep of Korea	3.8m 4.7m	27,000 43,000	135 108	509 485	7.5 10
USA	8.7m 8.6m	64,300 79,200	135 110	876 717	10 12
Total for the six countries	42.6m 49.8m	328,400 380,000		6.25m 6.16m	
World	70.5m 80.0m			11.0m 12.0m	
	[OICA 2008]				

………………..

The Chinese reporting leaves many robots not allocated to a sector. On advice from one of the experts, we have examined the Chinese figures for spot welding, most of which is for the Automotive sector. The result is that the Chinese automotive figure may be twice as large as the figure shown here. If that is the case, the number of vehicles per robot would come down to 150+ [2008] and 225 [2011]

We believe that some vehicle makers' purchases are allocated to their home country rather than the implant country. If this is the case the Brazil figure could be as high as 6,000 for 2008. This would bring the cars per robot down to a similar 120 +. The effect on the home country calculations is relatively small.

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6. THE POSITION OF SME

6.1 Profile of SME

In general, companies with less than 20 employees are very numerous and will not be buying robots. They distort the figures, therefore we have excluded them in the discussion about SME below. We show figures for year 2000 and 2007 here.

National statistics do not always report using the same size bands for industry. Where possible we have used 20 to 249 as the definition for SME with the potential to buy robots. In some cases this has meant estimating the break point in the available statistics.

The left hand set of tables below, show that the proportion of these small companies varies in the different countries, with Japan and USA having a lower proportion. They also show small movements in the proportions between 2000 and 2007.

The most notable of these is the trend in Japan to larger companies. The Chinese figures are for 2004, and exclude those with a turnover of less than €1/2 million. [and according to The Peoples' Daily in 2007 there were 42 million SME accounting for 99% of all companies].

The right hand set of tables shows the proportion of employees in each size band and shows that when the very small companies are removed, the 20 to 49 employee companies are of a similar size as overall employers, as the larger companies.

% of all manufacturing COMPANIES, with the following numbers of employees

http://www.swivel.com/workbooks/20027-Number-of-Enterprises-in-Manufacturing-by-Number-of-Employees?start_row=2400

2000	**0-19**	**20 to 49**	**50 to 249**	**250+**
China [2004]	25%		49% [50 to 200]	25.7% [200+]
Germany	82.8%	7.7%	7.5%	2.0%
Japan	73.6%	16.5%	8.1%	1.8%
Rep of Korea	73.3%	20.4%	6.3%	
USA	74.3%	26%		

http://stats.oecd.org/Index.aspx?DatasetCode=CSP2010

2007	**0-19**	**20 to 49**	**50 to 249**	**250+**
Germany	81.7%	7.8%	8.4%	2.1%
Japan	69.6%	18.4%	10.2%	1.8%
Rep of Korea	76.1%	20.9%	3.0%	
USA	76.8%	16.0%	4.3%	2.9%

% of EMPLOYEES in manufacturing excluding the very small ones

http://stats.oecd.org/Index.aspx?DataSetCode=CSP2008

2000	**0-19**	**20 to 49**	**50 to 249**	**250+**
China [2004]	3.3%		22% [50 to 200]	74% [200+]
Germany	14.2%	7.4%	23.2%	55.3%
Japan	21.5%	17.8%	30.1%	30.6%
Rep of Korea	22.3%	20.4%	57.3%	
USA	8.5%	9.0%	17%	65.5%

http://stats.oecd.org/Index.aspx?DatasetCode=CSP2010

2007	**0-19**	**20 to 49**	**50 to 249**	**250+**
Germany	13.0%	7.5%	25.3%	54.3%
Japan	19.2%	17.6%	31.0%	32.2%
Rep of Korea	25.8%	20.9%	53.3%	
USA	9%	9.5%	18%	63.5%

6.2 SME and use of robots

Evidence from this and previous reports shows that SME are much less likely to use robots than the larger companies. We have found that the main barriers are the perception that robots are inflexible and are expensive to use for small runs, and that they need *enough* special skills to avoid costly stoppages if things do not work out to plan, which the organisation is not large enough to support.

"For SMEs the choice is not so clear, especially for smaller ones (<100 employees). They need to be convinced that it makes sense for them. They are apprehensive about automation and robotisation, fearing it could be a can of worms with hidden costs for training etc.

Nevertheless use of robots in SMEs, particularly in the developed countries is growing for several reasons:

to increase efficiency (better quality, less wastage),
reduce wastage and
increase competitiveness so as to
avoid relocation to low cost countries.

Another factor, related to the last of these is

to reduce the risk of absenteeism due to repetitive strain injury (RSI), which can be a big drain on productivity.

So automation can be a way to obtain orders or preserve production. As an example, a typical SME application is medical devices. Typically the same product is manufactured for years, so robotisation makes sense for consistent quality.

SMEs making car parts are most likely to automate because the demands of the OEMs more or less demand it." *[Robot expert]*

"There is a huge potential for everyone. We recently visited XXX in Germany, the leading logistics company and they told us that 85% of installations nowadays, even within large companies, are very small scale. This trend towards smaller installations means that they are becoming more suitable for SMEs too.

If suppliers can come up with solutions that are both easier to install and affordable there is huge potential for the market to grow among SMEs on the one hand and on the other hand the SMEs will remain competitive in a global market. I think that this is already happening and will be increasingly the case in the next 5 years.

There is a joint initiative led by the robot manufacturers in Germany to address the needs of SMEs. We ourselves are trying to offer solutions that reduce the cost of installations. So I think that the suppliers have realised that it is an interesting market, but that in order to approach it they needed to develop solutions that are competitive although small scale, and the SMEs themselves are looking for ways to remain competitive vis-à-vis imports and larger competitors." [Robot expert]

There is no accepted measure for the likelihood of SME to use robots. We have tried various combinations to allow for the different industries, but for simplicity have adopted the hypothesis that the small companies are 20 times less likely to use a robot as the larger companies. For China, which has such a large pool of low cost labour, we have used the figure of 200 times less likely. Because the numbers of robots used by SME is small, the effect of changing the ratio is not critical in the context of the current study.

In a later project it should be possible to test these hypotheses.

The number of robots in use in each sector is based on IFR figures where they are available. Where they are not, we have made an analysis of shipment data provided by IFR.

The effect on employment is likely to be to give these companies advantage over those who have not adopted robotics.

The potential is large, but as there are many more companies to sell to than for the larger companies, penetration is likely to be slower.

Use of robots by (S)ME* [estimates 2008]

Numbers of robots in use	Food / Drink	Automotive	Electrical/ Electronic	Plastics/ Chemicals	Total
Brazil	-	100 to 200	-	40 to 50	150 to 250
China	V few	<50	V few	V few	50 to 100
Germany	200 to 250	650 to 750	130 to 160	300 to 400	1,250 to 1,600
Japan	50 to 100	1,100 to 1,400	1,250 to 1,500	550 to 625	3,000 to 3,700
Rep of Korea	<50	500 to 800	800 to 1,000	170 to 210	1,500 to 2,000
USA	80 to 100	400 to 500	200 to 400	150 to 250	800 to 1,200
Total	450 to 550	2,800 to 4,000	2,600 to 3,200	1,300 to 1,500	7,000 to 10,000
Total (S)ME employment*					39 million 13m excl China
Robots per 10,000					2 per 10,000 [6 per 10,000 excl China]

Metra Martech

**SME without the very small ones [generally those with less than 20 employees].*

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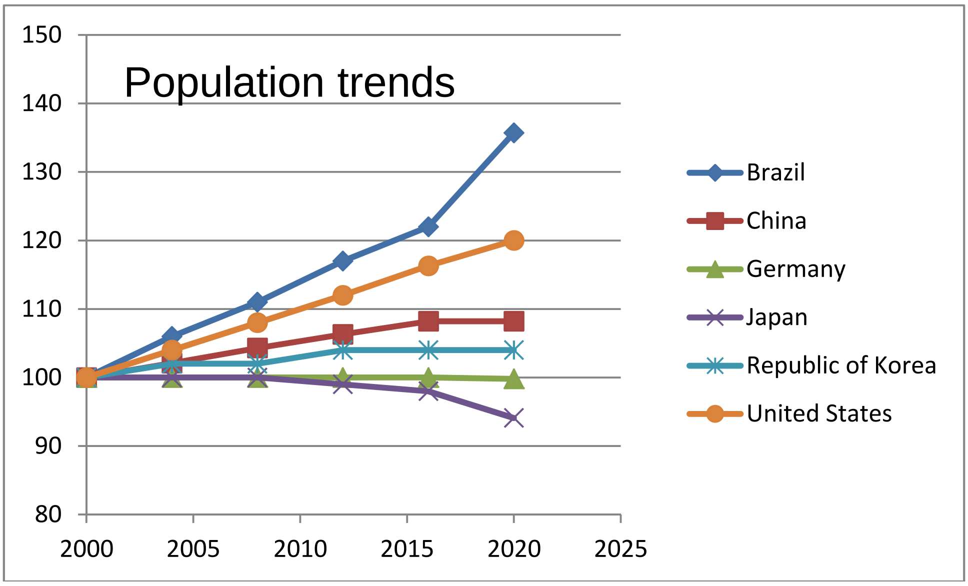
7. EXPECTATIONS UP TO 2020

7.1 The economic factors

Population in the 6 countries

Country	Population,				
Index [2000 = 100%]	2012	2016	2020	08-16	12-20
Brazil	116.5	121.6	135.7	+9%	**+16%**
United States	112.1	116.3	121.0	+8%	**+8%**
China	106.3	108.2	108.4	+4%	**+2%**
Republic of Korea	104.2	104.2	104.2	+2%	**=**
Germany	100	100	99.8	=	**=**
Japan	99.2	97.6	94.1	-2%	**-5%**

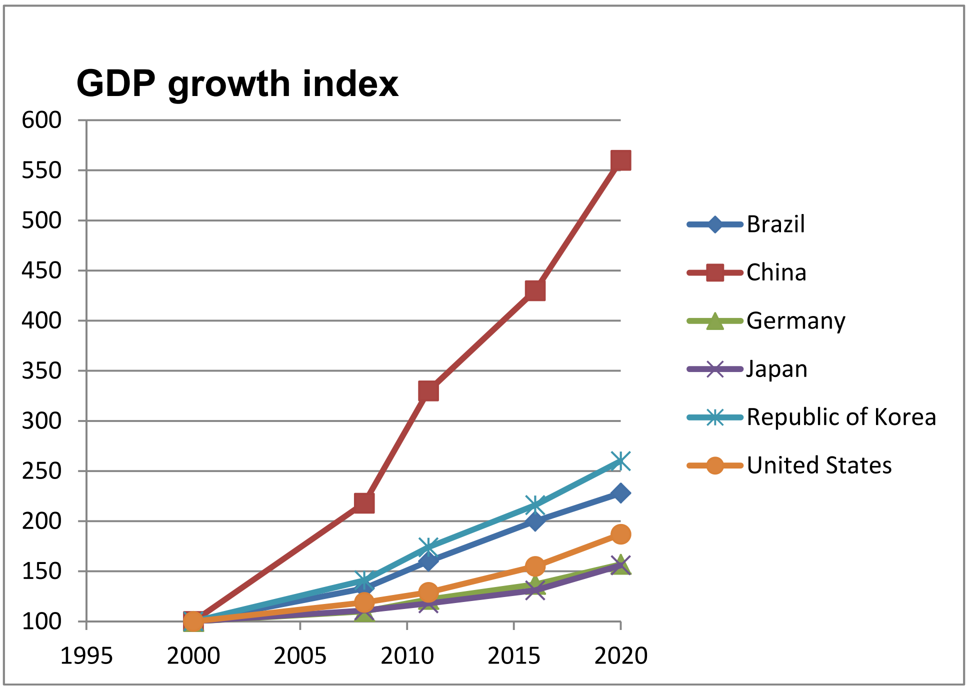


USA and particularly Brazil are forecast to have a significant increase in population. The rate of increase in the Asian countries is slowing, and the population in Japan is beginning to decline markedly.

Real GDP [at 2000 prices]

Country	GDP, 2000 = 100%			Growth		
	2008	2011/12	2016est	2020est	2012 to 16	2016 to 20
Brazil	133	160	200	228	+25%	+14%
China	218	330	430	560	+30%	+30%
Germany	110	122	137	157	+12%	+15%
Japan	111	118	131	156	+11%	+19%
Rep. of Korea	141	174	216	260	+24%	+20%
United States	119	129	155	187	+20%	+20%

The above figures for 2008 to 2016 have been taken from the International Monetary Fund's World Economic Outlook (WEO) Database, April 2012 Edition. The forecasts for 2020 are from Euromonitor



7.2 Growth per sector

REAL PRODUCTION (Figures adjusted by price deflator)

The forecasts are projections of past growth, with an allowance for the recession.

[Index, where 2000 = 100, except for China and Brazil, where for lack of data, 2004 = 100]

Food & Drink	**2000**	**2004**	**2008**	**2011**	**Ave annual % increase '00-'08. '08-'11**	**2016e min**	**2016e max**
Brazil	100	133	154	163	6.5% +2%	*190*	*210*
China	…	100	224	329*	28% +21%	*650*	*800*
Germany	100	98	104	107	0.5% +1%	*110*	*115*
Japan	100	98	110	105	1% -1.5%	*105*	*110*
Rep of Korea	…	100	120	123*	5% +1%	*140*	*160*
USA	100	101	113	116	1.5% +1%	*125*	*135*

**2010* Drivers for growth: Consumer demand for processed meals. Hygiene, Worker safety. Employment of food preparation workers in USA is projected to grow 10 percent from 2010 to 2020, about as fast as the average for all occupations. Job opportunities are expected to be good because of the need to replace the large number of workers who leave the occupation each year. [US BLS]

Chemicals	**2000**	**2004**	**2008**	**2011**	**Ave annual % increase '00-'08. '08-'11**	**2016e min**	**2016e max**
Brazil	100	136	113	115	1.5% +1%	*125*	*135*
China	…	100	232	327*	33% +19%	*450*	*550*
Germany	100	103	103	105	0.5% +0.5%	*105*	*115*
Japan	100	96	130	120	3.5% -2.5%	*115*	*130*
Rep of Korea	…	100	140	145*	10% +2%	*170*	*190*
USA	100	103	128	114	3.5% -3.5%	*115*	*130*

**2010* Drivers for growth: Ageing. Safety

Rubber & Plastics	**2000**	**2004**	**2008**	**2011**	**Ave annual % increase '00-'08. '08-'11**	**2016e min**	**2016e max**
Brazil	100	119	125	127	3% +1%	*140*	*155*
China	…	100	222	311*	30% +18%	*500*	*600*
Germany	100	101	105	112	0.5% +2%	*115*	*125*
Japan	100	102	127	142	3.5% +3.5%	*160*	*175*
Rep of Korea	…	100	138	144*	9% +2%	*165*	*185*
USA	100	94	93	92	-1% -1%	*90*	*100*

**2010* Drivers for growth: Auto industry. Consolidation. Worker safety, Cost/ quality

Electronic/ Electrical	**2000**	**2004**	**2008**	**2011**	**Ave annual % increase '00-'08. '08-'11**	**2016e min**	**2016e max**
Brazil	100	110	130	122	3.5% -2%	*140*	*155*
China	…	100	167	209*	17% +12%	*350*	*420*
Germany	100	97	155	163	7% +1.5%	*170*	*190*
Japan	100	75	74	56	-2.5% -7%	*50*	*70*
Rep Of. Korea	…	100	133	143*	8% +3.5%	*180*	*200*
USA	100	99	124	102	3% -5.5%	*95*	*110*

*2010 Drivers for growth: Changing products. Green energy. Solar/electric vehicles.

Automotive	**2000**	**2004**	**2008**	**2011**	**Ave annual % increase '00-'08. '08-'11**	**2016e min**	**2016e Max**
Brazil	100	158	207	220	13.5% +3%	*250*	*280*
China	…	100	206	342*	26.5% +30%	*800*	*1,000*
Germany	100	112	117	130	2% +3.5%	*140*	*155*
Japan	100	122	158	137	7% -4%	130	150
Rep Of. Korea	…	100	125	132*	6% +2%	*160*	*180*
USA	100	100	71	77	-3.5% +2.5%	*85*	*100*

*2010 Drivers for growth: Consumer demand in China and industrialising countries

The source is OECD and Metra Martech interpretation of maximum and minimum for 2016

7.3 Change factors

Sectors where speed of change, or customisation, require a new approach to manufacturing.

New industries without a legacy of employment: PhotoVoltaics ,Electric Vehicles, Renewables, Energy Management,

	Cycle length	Low cost labour factor	H&S and Env.
The large automotive players, driven by competitive fashion, safety, economy and technology.	Short and getting shorter	Growing	
The component suppliers and foundries	Less so	Strong/ growing	Growing
Paintshops			Strong
Electronics for controls and consumer goods such as phones	Short and getting shorter	Strong/ growing	
Electronics interface with specialist plastics [solar cells, photovoltaics etc or other advanced materials], particularly clean rooms .	Awaiting step changes in technology	Pending	
Food and beverage, [health, cleanliness and safety]	Less so	Less so	Growing
Pharmaceuticals, [life sciences and table top robotics are set for growth ?] Metra Martech	Fast development in R&D, slower in general line production	Basics already, More advanced growing.	

Areas where employment is likely to be increased directly due to robotics:

Sectors	Current World employment	Increase '08 to '11 in employment
Automotive [to meet increase in demand in China, India, …]	11 to 13 million	1 million
Electronics and components, [new applications/products]*	7 to 10 million	0.5 to 1 million
Renewable energy	3.5 million	1 million
The skilled systems integrator and the in-house operators	150,000 to 200,000	25,000 to 50,000
The robotics industry	150,000	
Food and beverage [new applications]	17 to 22 million	2 million

Metra Martech *Note the full electrical/ electronics sector is 12 to 15 million

7.4 New Growth Sectors

New products, new demand for robotics

Potential new jobs because of robotics

	2012-2016	2016 to 2020
Food industry	*60,000 to 80,000*	*70,000 to 90,000*
Photovoltaics	*60,000 to 100,000*	*90,000 to 150,000*
Wind power	*5000 to 10,000*	*15,000 to 30,000*
Electric vehicles	*2,000 to 3,000*	*5,000 to 10,000*
New consumer electronics	*150,000 to 200,000*	*125,000 to 150,000*
Service Robot mfr and sell	*50,000 to 100,000*	*60.000 to 120,000*
Other new job potential		
Downstream jobs	*400,000 to 600,000*	*500,000 to 800,000*

Metra Martech

7.5 Food and Drink

Growth of robot use in packaging and despatch is expected to continue. It has a neutral or negative effect on employment. Growth in areas like processed foods create new jobs.

Growth areas are expected to be:

Frozen and chilled food in Europe had sales of over €16bn in 2011, which is around 40% of the world market. Europe is the largest consumer of frozen foods while ROW segment is expected to have the highest growth rate due to the emergence of Australia, Brazil and Argentina as the new frozen food markets. Other world markets are expected to grow at 3 to 3.5% a year.

Ready meals accounted for almost 43 per cent of this in value sales. *The European market is growing at 2.5 to 3% a year. Drivers in ready meals manufacture are safety, hygiene and meeting local needs and costs. Development of the ready meals market is creating a whole new market, and so new employment.

The confectionery market can be seen as a microcosm of the wider processed food industry in China. Annual growth in some areas of the country is at 10%, and despite market growth of 150% over the last decade, there is still potential for high growth. Currently, the Chinese consume less than 1.2kg of confectionery per person every year, against a global average of 2.1kg, and buy mainly during the festive seasons, rather than all year round as in other markets.

Slaughter houses are another area which is receiving attention. It is heavy dangerous work and involves considerable skill. Use of robots would reduce the working hazard, but could have a negative effect on employment. There are several reports of trials, but large scale use does not yet seem to have been achieved.

"We will probably launch a project related to butchery in slaughterhouses and butchery factories because it's really high volume production and involves very heavy (physically and psychologically) jobs for people. But, it's quite a difficult technical challenge to butcher an animal and experienced butchers are very adept at doing that. Spot welding is relatively simple compared to butchering an animal carcass effectively.

But, now sensor technology is emerging…We have had robot sensors for a long time but only just now are they becoming viable in industrial applications. So, it's a good time to look outside the box a bit at new applications." [Robot expert 2010]

Several trial sites for using robots in applications such as fore-paw clipper, (since May 2005). • Bung dropper(since May 2005) • H-bone cutter (since May 2005) • Belly and breast opener (since August 2005)

MRI, Institute for Safety and Quality of Meat, Kulmbach, Germany

Pork spine cutter for Danish Crown slaughter house[2012]

"Obviously, the robot is designed to do a man's job out on the line. But that doesn't mean that we'll be firing a man for each robot that comes in,"

The robot should be seen as an ergonomic tool which relieves one man of hard work," says the factory manager. **The spinecutter robot is a true world first**. It has been developed in collaboration between KJ Industries A/S and Danish Crown, and a prototype has been on trial at the slaughterhouse in Esbjerg over the past six months. Now the machine has finally been handed over to DC, and it is working so well that similar robots are on their way to several of DC's slaughterhouses.

It is a relatively simple way of streamlining production, increasing speed and at the same time improving the working environment for employees, among other things by reducing noise levels,"

Use of robots in Food and Drink manufacture

Growth in robotics related jobs in the six countries could be of the order of 40,000 to 50,000 jobs. In world terms this could be 60,000 to 80,000 jobs.

Food & Drink	Brazil	China	Germany*	Japan	S Korea	USA
Employment [thousands]	**1,600**	**2,700**	**858**	**1,420**	**161**	**1,662**
Employment growth2000-2008	+40%	+50%e	+11%	-5%	+5%	-2%
Employment growth2009-2016	*50%*	*50%*	*10%*	=	*5%*	=**
Added employment [thousands]	**800**	**1,300**	**86**	**=**	**8**	**=**

Robots in use 2008	**30 to 50**	**600- 700**	**4,600**	**3,400**	**200**	**6.300**
growth2000-2008	n/a	800%e	100%	4%	n/a	50%
growth2009-2016	*200%*	*500%*	*60%*	*20%*	*80%*	*50%*
Added robots to 2016	60 to 100	3,000 to 3,500	2,700	650 to 700	150 to 200	3.000 to 3,250

Employment due to robotics 2008	1,000 to 2,000	10,000 to 20,000	4,000 to 5,000	5.000 to 8,000	1,000 to 1,500	10,000 to 12,000
New robotics jobs						
due to growth***	500 to 1,000	5,000 to 10,000	400 to 500	=	100 to 150	=
due to new products****	5,000	20,000	3,000	5,000	<1,000	5,000
Total new jobs due to robotics	**5,500 to 6,000**	**25,000 to 30,000**	**3,500**	**5,000**	**1,000**	**5,000**

Metra Martech

*Germany is advanced in robot use, but relatively behind in the acceptance of ready meals and other processed food.

**US Bureau of Labor Statistics predicts a fall of 0.1% in the food industry up to 2018. It predicts a growth of 4 to 5% in the installation, maintenance and operation of machinery and equipment, accounting for an additional 6,000 to 7,000 employees.

*** up to 1% of the added employment.

**** up to ½% of the total employment

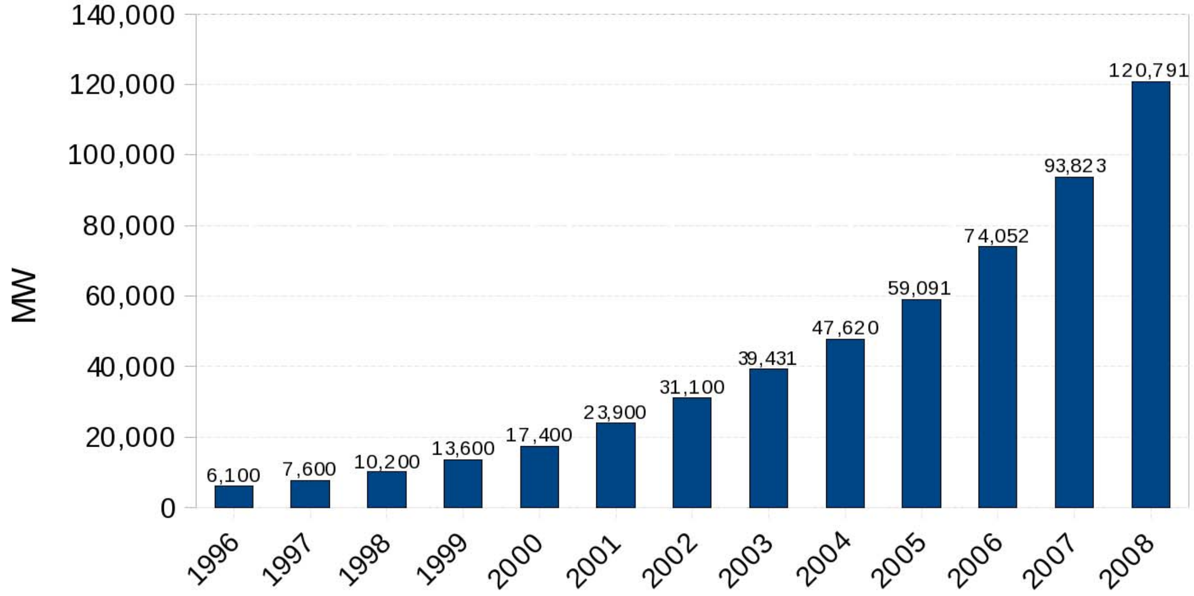
7.6 Renewable energy.

Renewable Energy, where large volumes of standard items such as photovoltaic cells or energy storage systems are manufactured and may also be assembled.

An international study by the UN Environment Programme in 2008 estimated world employment in renewable energy industries, and took a view on the position in 2030. Metra has put in an intrapolated figure for 2016.

World employment	2006	*2016*	*2020*	2030
Wind industry	300,000	*500,000*	800,000	2,100,000
Solar PV	170,000	*800,000*	1,500,000	6,300,000
Solar thermal	600,000	1,000,000	1,500,000	
Biomass growing/processing	1,200,000	*3,000,000*	5,000,000	12,000,000
Total	2,300,000	*5 to 5.5 million*	*8 to 9 million*	20 million +

[Low carbon jobs in an interconnected world]



Worldwide installed capacity *[EWEA]*

Growth in Installed Capacity

Trends suggest that capacity will more than double in the period up to 2016. As the table below shows, China has provided the greatest growth, but USA has also been expanding fast.

MW Wind Generating capacity

Country	**2005 MW**	**2008 MW**	**2010 MW**	***Number of units installed in 2005 to 2010 [based on av 1.5MW]***	**2011e MW**
Brazil	29	339	932 [2009]	*600*	
China	1,266	12,210	41,800	*26,000*	55,000
Germany	18,426	23,903	27,214	*6,000*	29,000
Japan	1,040	1,880	2,304	*800*	
Rep of Korea	119	278	348	*150*	
USA	9,149	25,170	40,200	*20,000*	45,800
Brazil	59,024	121,188	157,855 [2009]	*100,000*	

The numbers of turbines built to achieve these figures will depend on the size of the unit. 15 to 30,000 a year in the world.

Typically 1.5 to 3MW units are now used, but there are plans for 7.5 to 10 MW, and by the year 2020, they may be double that size.

Robotics use in the wind energy sector include:

Assembly of component parts such as gear boxes
Shaping of blades, inspection
Welding of structures
Painting the structures

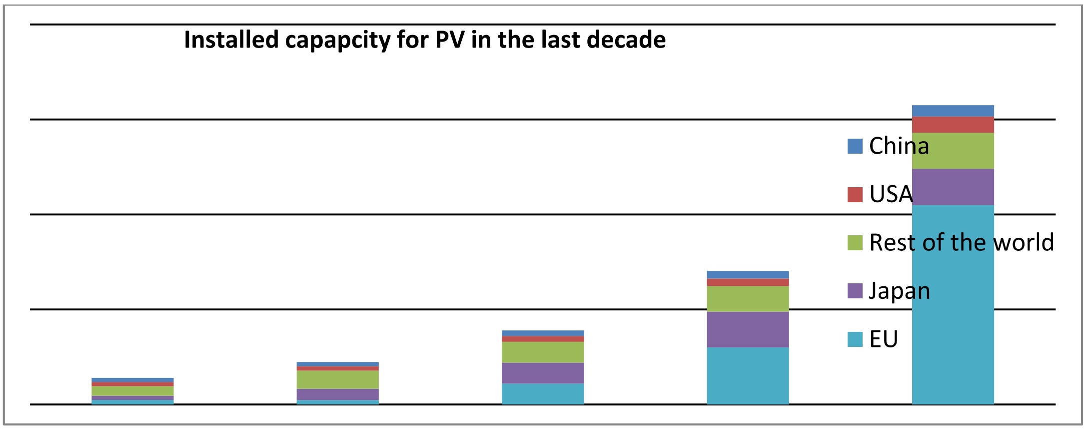
Between five and ten percent of the 400,000 or so people in the wind business today are connected to manufacturing and directly to robotics. That is of the order of 20,000 to 40,000 people. In the next four years, the total number of people involved is expected to rise by 100,000 to 500,000. In the period 2016 to 2020 the addition is expected to be 300,000 making a total of 800,000.

Two gantry machines operating side by side can each produce a 45-meter blade-shell half in less than two hours, with half the manual labor of conventional methods. MAG has also developed a flat charge laminator that automates the production lay-up of composite wind turbine blade parts, such as spares, beams and stringers.
Assembly magazine Feb 2011

By extrapolation this could mean at least an extra 5,000 to 10,000 people employed due to robotics in 2016 and in the period to 2020 an added 15,000 to 30,000.

Photovoltaics. [PV]

Installed capacity of PV has also expanded fast, but the capacity installed is little more than a tenth of the wind power capacity at 16,000MW in 2008.



In 2010 Metra recorded:
"Today there is a boom in photovoltaic panels. The production of these too is heavily dependent on robots and jobs are created downstream. These are all sectors that have invested heavily in automation and in robotics."
[robot expert]

The picture in 2012 turned out quite different.

There is currently a large oversupply of solar panels. Production capacity for photovoltaic (PV) solar panels this year stands at 59 GW, which is about double the 30 GW expected to sell, [*according to GTM Research*]. This is certainly a problem for solar module manufacturers—though the positive effect of this situation is that panels are lower cost.

Some producers are likely to go out of business, but overall the result is almost certainly the emergence of a smaller number of winners who will take the PV business on to the big growth formerly predicted. *[Metra]*

Current solar module prices range from about 70 to 90 cents per megawatt, less than half of the price three years ago. Module prices may go as low as 45 cents by 2015.

New demand is developing from countries such as Bahrain, Jordan, Chile, Ukraine, Serbia and Puerto Rico where solar is an option even without subsidies; renewable energy is becoming increasingly important in developing nations across North Africa and Asia. As a readily available and abundant source, solar power is attracting the big money. *[Solar Market Trends:The What and Why of Panel Oversupply June 29, 2012 Kathleen Zipp]*

In 2010, The European PV Association commented that the future use of photovoltaics is heavily dependent on Government support and Government policies on energy. The European Photovoltaic Association [EPVA] has provided three scenarios which illustrate the great potential together with the enormous uncertainty about the actual outcome. The three 2010 scenarios showed:

PV Scenario ***[GW capacity]*** [1,000 MW = 1 GW]	**2008**	**2009**	***2012****	***2016***	***2020***	**Comment**
1a Reference scenario X1.5 [2012 to 2016] 1b x1.9[2012 to 2-016]	16 16	23 23	35 40	55 75	77 120	2009, 73% Europe, 11% Nth America, 9% Japan. 2020, 50% Europe, 25% USA, 20% OECD Pacific
2, Accelerated x3	16	23	60	180	345	2020, 40% Europe, 22% Nth America,
3 Paradigm shift x3.5	16	23	80	280	688	2020, 50% Europe, 21% N America

*[EPVA] * best fit value estimated*

The 2012 view is that, with lower costs now possible, Asia may increase its share to as much as 40% rather than the 30% predicted above.

Use of robots

Although there are many differences between solar and semiconductor manufacturing overall, the processes are similar in that they manufacture sensitive wafers at their core. While semiconductor production requires very clean environments and single wafers can cost thousands of dollars, the solar industry does not require such stringent cleanrooms and a single wafer may cost $5.

The current Solar generation industry is listed as a relatively low density robot user at >50 to 100 robots per 10,000 employed.

As the industry expands, the need for automated manufacture and assembly will grow. EPVA figures estimate that 30 full time jobs are created for each MW of solar power module produced and installed. 2008 to 2009 showed an increase in capacity of 23 – 16 = 7,000 MW. That would mean 210,000 jobs in 2008. Assembly and installation account for more than 75% of this or 160,000.

If we assume that the sector expands by the accelerated scenario mentioned above, this implies a 3x increase from 2012 to 2016, if the slower reference scenario is taken, a more conservative 1.5x increase would be the case. Because of the current slowdown, we should assume not more than the 2x increase, let us say 1.9x. That would mean an expansion of 75 – 40 = 35GW between 2012 and 2016. This is equivalent to 30x 35x 1000 x .75 = 800,000 new jobs in assembly and installation.

The rapid expansion would certainly bring the need for robotics to the front. The use of thinner and thinner silicon or other materials is an added factor calling for the use of robots. By 2016, the lower costs mentioned above and with the help of robotics, to reduce the cost to an attractive level, After 2016, the demand should/may expand very rapidly.

If 10% of this can be attributed to robotics, **that would mean 60,000 to 100,000 jobs over the four years to 2016.**

The 2016 to 2020 picture suggests [still using the conservative forecast] an increase of 90,000 to 150,000 jobs.

7.7 Electric storage media and electric vehicles.

This encompasses a range of products from:

1) Potentially massive energy storage units to reduce the effects of peaks and troughs in energy production [for example wind generation depends on wind to be blowing] and energy use [itself subject to peaks and troughs].
2) Through to systems for electric cars, which are likely to be produced in great numbers.

The automotive application is the most likely to be the one which will occur within the time scale of the present study. It presents real opportunity for robotics.

Forecasts for the sector show continued growth in output, and in Employment.

Electric vehicles forecasts.

JD Power have also made forecasts of the future acceptance of electric vehicles. Their analysis [and that of others] shows that they will remain a small proportion of the total for many years as the technology still does not completely compete with the performance of the internal combustion engine.

:Electric Vehicles	2012		2016		2020	
	Number	% of total	Number	% of total	Number	% of total
China	20,000	0.1	78,000	0.5		
Europe	120,000	1.3	605,000	2.9		
Japan	20,000	2	724,000	17.2		
US	487,000	3.3	1.6 m	9.5		
World[1]	1m	1.5	3.1m	5		
World[2]		<1%	1.1m	1.4	3.8*m	3.5%

[1]*[based on JD Power forecasts]*

[2]*Pike research forecasts*

JD Powers have reduced their forecast recently on the basis that battery costs are not coming down fast enough.

Pike Research forecast that Electric Vehicles will continue to be a niche market in the global transportation industry, projecting that vehicles that use electricity for propulsion will represent less than 1.4% of the global market in 2017. Nearly half of the demand is likely to come from Asia (led primarily by China) while Europe and the United States are likely to constitute 25% and 21% shares respectively.

> The United States could have the capacity by 2015 to produce enough battery packs for 500,000 cars. But this year, due to high prices, plug-in vehicle sales won't even reach a tenth of that in the United States. As a result, advanced battery makers in the United States have struggled. A123 Systems went bankrupt. Dow said its battery joint venture Dow Kokam had dropped markedly. And an LG Chem factory meant to supply batteries for the Chevrolet Volt has been built, but the factory is sitting idle, waiting for demand to pick up.

At the time of the previous Metra Martech survey Coda in USA, planned a new Lithium ion battery plant for automotive applications with an initial output of 20,000 battery sets a year, with 1,000 employees, [20 battery sets a year per person], but each set can cost the user $10,000. The turnover per employee is $200,000. In December 2012 Coda laid off staff as sales had been poor, they say following a poor crash test result.

The breakthrough will occur when battery costs get down to $200 to $300 per kWh. Automotive analysts are watching battery costs closely because batteries typically account for more than a quarter of the cost of a plug-in vehicle. In April[2012], Bloomberg New Energy Finance estimated battery costs at $689 per kilowatt hour, down from $800 a year earlier. Other estimates for where the prices go from here include $400 per kWh by 2020, 500 by 2014, another less than $200 per kWh by 2014.

The cost per battery pack can be broken into two parts – the batteries themselves and the pack. The pack costs can be trimmed considerably with mass-manufacturing. Instead of hand assembling each battery pack and set of battery modules (a series of cells), semi-automated assembly can increase the throughput of the teams assembling dramatically while keeping the same number of people around, reducing the amount of employee-hours spent per battery pack. The materials cost currently account for up to 75%.

The cell costs don't come down as easily.

Robots are used in high accuracy assembly and handling of hazardous materials in battery and fuel cell production. The robots also improve quality and consistency

Batteries contain hazardous materials such as lead and lithium, and robotics help to remove people from the hazardous environments where these materials are used.

Batteries for electric vehicles are much larger and heavier than conventional car batteries. People cannot package these batteries manually and need robotics for these tasks.

Currently Lithium ion batteries are the preferred type, but their manufactured cost needs to be greatly reduced. The robot opportunity identified by Paul Kellett of AIA is for increased use of vision systems. [*The Electric Car Of The Future, AIA 2009*]

There is a variety of new cell types in development including a new dry battery being developed by both Toyota and General Motors.

One of the other prospects here, is that cars may have batteries replaced rather than re-charged [this is still being widely debated]. This saves the user hours of re-charging, It also means that there will be more than twice as many of these large battery sets in circulation than is the case with the conventional car battery.

There is likely to be a whole new set of service station facilities to cope with these battery changes or charging requirements.

Hybrid vehicles require a high voltage battery of about 150V, which is currently provided by connecting nickel-metal-hydride cells in series.

Worldwide, employment in the conventional automotive battery industry is believed to be of the order of 25,000 to 30,000. VB Autobatterie in Europe has an output of 4 million+ batteries a year, six plants and employs 2,400 people [about 1,600 batteries per person a year, selling at $100]. This is a turnover of $160,000 per employee. Now part of the Johnsons Controls group, it is the largest supplier of automotive batteries in Europe. The new batteries are likely to be made by a few large companies, and probably from outside the automotive sector.

Benchmark figures for the electronics sector show $300,000 to 350,000 per employee.

Presuming battery pack sales of sales of $15bn by 2016 [see Pike forecasts] this would equate to manufacturing employment of between 40,000 and 50,000. Current employment is of the order of 5,000 to 10,000

The introduction of electric vehicles will displace conventional vehicles, so the bodywork will not create new jobs.

It is too early to say how many employees will be added downstream, until accepted standards for charging or replacement are agreed.

Fuel cells

Forecasts in this area are varied, the general position seems that the future is heavily dependent on further research, and also on the cost of the Lithium or Platinum components. A great deal of research money is being spent on the subject for military as well as transport applications.

The general position appears to be that of the order of 75,000 units were shipped in 2009 [world], but very high growth rates are expected. One forecast expects the growth to be 75% a year for the next few years. Another expects output to double by

2014. This is still small compared to the potential market of tens of millions. Most of these fuel cells will be used in automotive applications and are included above.

7.8 The growth of service robotics as a new industry

The next generation of service robots will be used in industry, but some are forecast to become "Consumer products". This implies major new manufacturing activity. As quantities will be large, and precision and consistency are critical, this new manufacturing is going to need robotics. Alongside this is the employment of a whole new workforce.

RIA note

"As stated by the US Roadmap, "Robotics technology has historically been defined by the automotive sector and driven by price and the need to automate specific tasks particular to large volume manufacturing. The new economy is much less focused on mass manufacturing, however, and more concentrated on producing customized products.

The model company is no longer a large entity such as GM, Chrysler, or Ford but small and medium sized enterprises…. The need in such an economy is far more dependent on higher degrees of adaptation, ease of use, and other factors that enable small runs of made-to-order products."

According to the European Roadmap, the future of robotics will be one of much greater ubiquity. Miniaturization and new sensing capabilities will mean that robotics is used in an increasing number of industries, including those with small and varying lot sizes, materials and product geometries.

Robotics will make great inroads in service industries, especially healthcare where an aging population will require support services, for which human care givers will be too few in number to provide.

Robots will likewise play an important role in transportation and in the provision of home services. Robots will also help protect homes and offices, secure borders and monitor the environment in both routine and emergency operations. Finally, robots will perform key roles in both manned and unmanned space missions."
[Robot Industries Association]

Extract from World Robotics 2010

It is estimated that today more than 200 product ideas, demonstrators, prototypes and products in service robotics are documented for almost any kind of tasks. Even though most ideas have already been introduced, there is still an abundance of specific product opportunities to be taken up by companies. Service robots provide mobility, functionality and multi-media possibilities in all areas of daily life: at home, at work, in public environments, and in remote locations such as deep sea, battlefields and space. In the recent past, experts have seriously discussed the possibilities of emulating the success of the personal computer with the goal of creating a personal robot that would assist individuals in their daily lives. Even though these robot companions or assistants offer up the prospect of appealing to a mass market, it is felt that the required technological progress, attractive product designs and lowcost manufacturing pose significant challenges and may make this idea more of a long-term project that **will not reach full maturity before the year 2020**.

However, a number of efforts, ranging from internationally funded research initiatives through providing platforms for robot companions for advanced research to engaging in ambitious competitions such as RoboCup@home,5 are clearly geared towards addressing the numerous technological challenges on the way to providing dependable personal robots for assisting in everyday tasks.

As the statistics demonstrate, today's service robot market is composed of many niche products for professional services and a few high-volume applications in the domestic environment.

Pioneers in the field of service robotics stress the serious opportunities for new companies entering this growth market with innovative products beyond the occasional robotics hype.
[IFR]

Notes on definitions

Industry sectors.

The IFR statistics [World Robotics report] provide groupings which we have used as the basis for the analyses. The sources of national and international statistical vary considerably in the groupings which they use and we have made allowances for this wherever possible. The national statistics for the five manufacturing sectors in the study countries compare as follows.

Manufacturing Sector Definitions

World Robotics 2010 ISIC	Sectors	Brazil	China	Germany & Japan	Rep of Korea	USA
Food products & beverages [D 10-12]	Food	D15	Based on ISIC Category C covers manufact-uring	ISIC 15	KSIC (based on ISIC) Category D covers manufact-uring	NAICS 311
	Drink			ISIC 16		NAICS 3121
Chemical products, pharmaceuticals [D 19]	Chemical Manu	D24		ISIC 24		NAICS 325
Rubber & Plastic prods excluding auto [D22]	Plastics & Rubber	D25		ISIC 25		NAICS 326 [includes auto]
Metal products [except auto]						
Electrical/ Electronics [D26-27]	Office accounting & Computing machinery. Radio, TV & Communication equipment Medical, precision & optical Electrical machinery & apparatus	D 30, 32, 33, 31	Not split in same way as ISIC – but covers equivalent headings	ISIC 30, 32, 33, 31	Similar categories to ISIC	NAICS 334 and NAICS 335
Automotive [D29]	Transportation equipment	excluded	Motor vehicles are within Transport-ation equip	excluded	Similar to ISIC	NAICS 336 including MV 3361
	Motor vehicles, Trailers etc	D34		ISIC 34		

Definition of Industrial Robots

[provided by IFR]

The annual surveys carried out by IFR focus on the collection of yearly statistics on the production, imports, exports and domestic installations/shipments of

multipurpose manipulating industrial robots with at least three or more axes

A robot which has its own control system and is not controlled by the machine should be included in the statistics, although it may be **dedicated for a special machine**. Other **dedicated industrial robots** should not be included in the statistics.

•Wafer handlers have their own control system and should be included in the statistics of industrial robots. Wafers handlers can be articulated, cartesian, cylindrical or Scara robots. Irrespective from the type of robots they are reported in the application “cleanroom for semiconductors”.

•Flat panel handlers also should be included. Mainly they are articulated robots. Irrespective from the type of robots they are reported in the application “cleanroom for FPD”.
Examples of dedicated industrial robots **not** included in the international survey are:

• Equipment dedicated for loading/unloading of machine tools (see figure I.3).
• Dedicated assembly equipment, e.g. for assembly on printed circuit boards
• Integrated Circuit Handlers (pick and place)
• Automated storage and retrieval systems
• Automated guided vehicles (AGVs)

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