1 Introduction

Chapter 1 reviews definitions and classifications of industrial robots and service robots.

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In the processing of this vast statistical material, errors are inevitable. IFR Statistical Department would be most grateful if the reader, when finding such errors, would notify the IFR Statistical Department so that the accuracy and the comparability of the statistics can be improved year by year.

1.1 SOURCES AND METHODS

1.1.1 COMPLIANCE

In order to ensure confidentiality and prevent statistical data of individual companies to be identified, the aggregated value of the data is used and information is combined as a whole. In case the aggregated value deems insufficient, information will be shown as "unspecified". This rule has been applied since 2015.

1.1.2 COVERAGE

The annual publication World Robotics Industrial Robots: Statistics, Market Analysis, Forecasts, Case Studies and Profitability of Robot Investment covers industrial robots (for definition see section 1.2). Since 2009, service robots are surveyed in a separate study: World Robotics Service Robots. When the term “robots” is used in this study, it should be understood to refer to industrial robots.

The study also contains case studies of actual robot installations. These case studies will show the effects which robots have had on costs, production and employment structure as well as giving an indication of their overall profitability. Both potential and actual robot users are mainly interested in getting information on how robots can solve certain manufacturing problems, how such solutions have been obtained and what the implications are. The provision of “hands-on” information about robot installations is the main objective of this new section. Each issue of World Robotics will contain several case studies, selected from various countries and regions.

Ideally each case study should present:

- A short description of the production process before robotization, with layout and basic production characteristics (machine configuration, material flow, batch sizes, cycle time, labour etc.)
- Problem identification
- An explanation of why robots were selected as a solution
- The proposed layout of the robot installation
- A cost-benefit analysis, ex ante investment calculations and an ex post evaluation of the installation after a certain period of operation.

1.1.3 DATA SOURCES AND RELIABILITY OF DATA

The statistical data collected in the present World Robotics are based on consolidated data provided by nearly all industrial robot suppliers worldwide. Korean robot companies' sales in the Republic of Korea were provided by Korean Machine Tool Manufacturers Association (KOMMA) up to 2014. From 2015, the Korean Assocation of Robot Industry (KAR) has taken over the Korean robot statistics. The Japanese companies' worldwide robot supplies were reported by Japanese Robot Association (JARA) by country and application. The installations in Japan were also classified by industries. The Japanese suppliers did not have detailed information about the final destination of their exports by country and by industry. Therefore their European subsidiaries provided these data for Europe. Since 2011, the data for North America have been based on the statistical results of the Robotic Industries Association of North America (RIA). The statistics are based on the sales/installations data of North American companies and as of 2011 the IFR classification of applications and industries is used. Additionally, data reported directly to the IFR Statistical Department which were not included in the RIA statistics have been taken into account. This resulted in more detailed and more accurate data and made it possible to provide separate reports for the United States, Canada and Mexico by applications and by industries. Since 2013, robot sales of the Chinese robot suppliers have been included. Data have been provided by the China Robot Industry Alliance (CRIA). For the Asian countries - except Japan and the Republic of Korea – the distribution by industries was only partly available. Additionally, the statistics provided by other national IFR robot associations were used to check the country data and to complete the information.

Up to and including 2004, only the information supplied by national robot associations to the IFR Statistical Department were used as the country data for Denmark, Finland, France, Germany, Italy, Japan, Rep. of Korea, North America, Norway and Spain. Additionally, robot suppliers reported consolidated data by countries. In 2004, they provided consolidated data classified by country, by application, and by industry for the first time, and therefore more detailed reports for countries without a reporting national robot association were possible. In cases where no source is indicated in the statistical material (tables and figures), it should be understood that the sources are IFR.

The statistics collected by national robot associations and robot suppliers, which thereafter are processed and published by the IFR Statistical Department, are required to:

- be internationally comparable;
- have a high degree of reliability; and
- permit analysis of the distribution of robots worldwide and in individual regions and countries.

They should also provide estimates of the total robot market.

Data on the annual shipments (sales) of robots is generally more accurate than data on the robot stock. As the years go by, it will be more and more difficult to measure the robot stock and greater efforts should thus be made to obtain accurate supply data.

Estimates for total accumulated annual sales of robots and the operational robot stock are provided for all countries/regions. (definitions see section 1.1.3 below).

Forecasts of investment in industrial robots, presented in chapter 4, are the result of the combination of the analysis of the technical and economic factors which influence robot investment, and the collective knowledge and judgements of some leading robot manufacturers and robot users as well as of national robot associations.

For several years IFR and UNECE have cooperated closely in the compilation, processing and analysis of worldwide statistics on industrial robots. In 2005, the total responsibility for World Robotics was transferred to the IFR Statistical Department.

1.1.4 OPERATIONAL STOCK AND ACCUMULATED ANNUAL SALES

When calculating the operational stock, it is assumed that the **average service life is 12 years** and that there is an **immediate withdrawal** of the robots after 12 years. Where countries actually do surveys of the robot stock or have routines for their own calculation of operational stock, for instance in Japan, then those figures are naturally used here as the operational stock of robots.

The assumptions behind the latter stock measurement were investigated in an UNECE/IFR pilot study, carried out in 2000 among some major robot companies (see annex B in **World Robotics 2001**). From this investigation it was clear that an assumption of 12 years' average service life might be too conservative. The study indicated that **the average service life was closer to 15 years**. However, before the IFR undertake a complete recalculation of the robot stock, further investigations are necessary in order to confirm this higher level of service life. In the meantime, a stock measurement based on the last 12 years of robot sales will be the one used in the detailed tables as an indication of the **minimum level of the operational stock**. On the worldwide level, the result of using a stock measurement based on 15 years of robot sales will be shown in chapter 2, as an illustration of how the size of the stock changes when moving from 12 to 15 years' accumulated sales.

1.1.5 INTERPRETATION OF THE CONCEPTS OF SHIPMENTS, SALES AND SUPPLY

Annual shipments, supply and sales are used as three synonymous concepts. They originate from the information provided by robot suppliers in a particular country about sales in that country. Domestic sales of robots are derived as domestic production plus imports minus exports. In this publication no particular distinction is made between these four concepts and they are all used as a proxy for the number of robots installed in a particular year.

1.1.6 REVISION OF TIME-SERIES DATA ON THE ROBOT STOCK AND ANNUAL SUPPLY

As has been pointed out in previous issues of World Robotics data on the robot stock of the **former USSR** has been continuously revised downwards. Reported data originated from the end of the 1980s and the early 1990s before the change in the economic system. In view of the profound industrial restructuring, it can be suspected that a large share of those robots reported earlier has been taken out of operation - some robots probably never even entered into operation in the first place. It should also be noted that as much as 80% of the 1990 robot stock consisted of simple sequence-controlled robots. From 2007, the stock of these old robots has no more been considered.

Data for **Singapore** was revised significantly downwards in the 1997 issue, after a stricter application of the definition of industrial robots as set up by IFR. As a result of gaining access to more detailed statistical data, as well as meta-data, the data for the Republic of Korea, Slovakia, Slovenia and Switzerland was revised significantly downwards in the 1998 issue of World Robotics.

Up to and including 2000, **Japan** consistently reported data, which included both multipurpose industrial robots and dedicated industrial robots (see section 1.2 for definitions), while other countries, in principle, have only reported data on multipurpose industrial robots. For this period, data for Japan was therefore not directly comparable with that of other countries. However, as of 2001, data for Japan has been much more comparable in coverage to that of the EU and the United States.

Up to 2003, the annual data for **North America** (USA, Canada, Mexico) only comprises what has been reported to the Robotic Industries Association (RIA) by its member companies. From 2004 up to 2010, the data were revised and based on the consolidated data of robot suppliers worldwide and JARA. Since 2004, more companies have been included, therefore the 2004 data cannot be compared directly with the data for 2003. The distribution by industries is based on the results of the RIA order statistics, because exports from Japan were not subdivided by industries. It is completed with additional data from companies. In addition, the distribution by applications is completed with data taken from the RIA statistics. Exports by North American suppliers are excluded. Since 2011, the data for North America have been based on the statistical results of the Robotics Industries Association of North America (RIA). The statistics are based on the sales/installations data of North American companies and as of 2011 the IFR classification of applications and industries is used. Additionally, data reported directly to the IFR Statistical Department which were not included in the RIA statistics have been taken into account. This resulted in more detailed and more accurate data and made it possible to provide separate reports for the United States, Canada and Mexico by applications and by industries.

1.1.7 DATA COVERAGE AND WHERE TO ACCESS DATA FOR PREVIOUS YEARS

The present publication analyses the sales of industrial robots in 2016 and estimates the size of the operational stock of industrial robots at year-end. Data is broken down by **application areas**, **industrial branches** and **types of robots**.

Chapter 1 reviews definitions and classifications of industrial robots and service robots.

Chapter 2 analyses the **worldwide diffusion of industrial robots in the period 2011-2016**.

For the United States, Japan, Germany, the Republic of Korea and some other countries, data on the **value of the robot market** is presented. For some countries, **unit sales values of robots** are also calculated. Based on certain assumptions of the sales value per robot sold in all other countries, estimates are made of the **total world market for industrial robots**.

For more than 40 countries, analysis is provided on the development of **industrial robot densities**, defined as the **number of industrial robots per 10,000 people employed** in the manufacturing industry.

Summary tables of the **2016 world robot stock** and the **2016 supply of robots, broken down by countries on the one hand and by application areas and industrial branches on the other**, are also presented. Thus, for instance, the reader can easily see how many welding robots were supplied in 2016, the total stock at the end of 2016, and its distribution by countries. The reader can also, for instance, find out how many robots were sold to the transport equipment industry and how the sales were distributed by countries.

Chapter 3 analyses statistical data on industrial robots for some **40 countries**, with uniform table set-ups which lend themselves to country comparisons. In compliance with the new, extended rules regarding the aggregational factor of the IFR Industrial Robot Statistics, the IFR summarized the concluded results of various countries into sub-regions where necessary. A similar process has been established from 2015 onwards for the results that are based on classification of application areas and classification of industries within individual countries.

Chapter 4 contains **forecasts for the world industrial robot market for the period 2017-2020** as well as main trends in the customer industries and in the main countries.

Chapter 5 contains **case studies** from different countries, illustrating how industrial robots have been applied in various production processes and what effects they have had on profitability, productivity, employment, throughput times, cycle times etc.

The results of the Service Robots statistics as well as the analysis are published in a separate study: **World Robotics – Service Robots 2017**.

The present issue of World Robotics can be ordered on the website:

www.ifr.org

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1.2 INDUSTRIAL ROBOTS - DEFINITION AND CLASSIFICATION

1.2.1 DEFINITION (ISO 8373:2012) AND DELIMITATION

The annual surveys carried out by IFR focus on the collection of yearly statistics on the production, imports, exports and domestic installations/shipments of industrial robots (at least three or more axes) as described in the ISO definition given below. Figures 1.1 shows examples of robot types which are covered by this definition and hence included in the surveys.

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. If countries declare that they included dedicated industrial robots, or are suspected of doing so, this will be clearly indicated in the statistical tables. It will imply that data for those countries is not directly comparable with those of countries that strictly adhere to the definition of multipurpose industrial robots.

- 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 that should not be included in the international survey are:

- Equipment dedicated for loading/unloading of machine tools (see figure 1.3).
- Dedicated assembly equipment, e.g. for assembly on printed circuit boards (see figure 1.3).
- Integrated Circuit Handlers (pick and place)
- Automated storage and retrieval systems
- Automated guided vehicles (AGVs) (see “World Robotics Service Robots”)

The submission of statistics on industrial robots is mandatory for IFR member associations. In some countries, however, data is also collected on all types of manipulating industrial robots, that is, both multipurpose and dedicated manipulating industrial robots. Optionally, national robot associations may therefore also submit statistics on all types of manipulating industrial robots, which will be included in the publication World Robotics under the respective country chapter.

INDUSTRIAL ROBOT AS DEFINED BY ISO 8373:2012:

AN AUTOMATICALLY CONTROLLED, REPROGRAMMABLE,

MULTIPURPOSE MANIPULATOR

PROGRAMMABLE IN THREE OR MORE AXES,

WHICH CAN BE EITHER FIXED IN PLACE

OR MOBILE FOR USE IN INDUSTRIAL AUTOMATION APPLICATIONS

The terms used in the definition above are explained in more detail below:

- Reprogrammable: designed so that the programmed motions or auxiliary functions can be changed without physical alteration;
- Multipurpose: capable of being adapted to a different application with physical alteration;
- Physical alteration: alteration of the mechanical system (the mechanical system does not include storage media, ROMs, etc.)
- Axis: direction used to specify the robot motion in a linear or rotary mode

1.2.2 CLASSIFICATION BY TYPES OF ROBOTS

In agreement with the robot suppliers, robots should be classified only by mechanical structure as of 2004.

Classification by mechanical structure:

- Linear robots (including cartesian and gantry robots)
- SCARA robots
- Articulated robots
- Parallel robots (delta)
- Cylindrical robots
- Others
- Not classified

Figures 1.1 illustrates the mechanical configuration of these types of robots. Below, some further explanations and definitions are given for the various classifications by types of robots.

The number of axes should be understood as the basic feature supplied by the producer and not axes added later by the user.

Robots broken down by mechanical structure are based on the following definitions:

Cartesian robot: robot whose arm has three prismatic joints and whose axes are coincident with a cartesian coordinate system

SCARA robot: a robot, which has two parallel rotary joints to provide compliance in a plane

Articulated robot: a robot whose arm has at least three rotary joints

Parallel robot: a robot whose arms have concurrent prismatic or rotary joints

Cylindrical robot: a robot whose axes form a cylindrical coordinate system

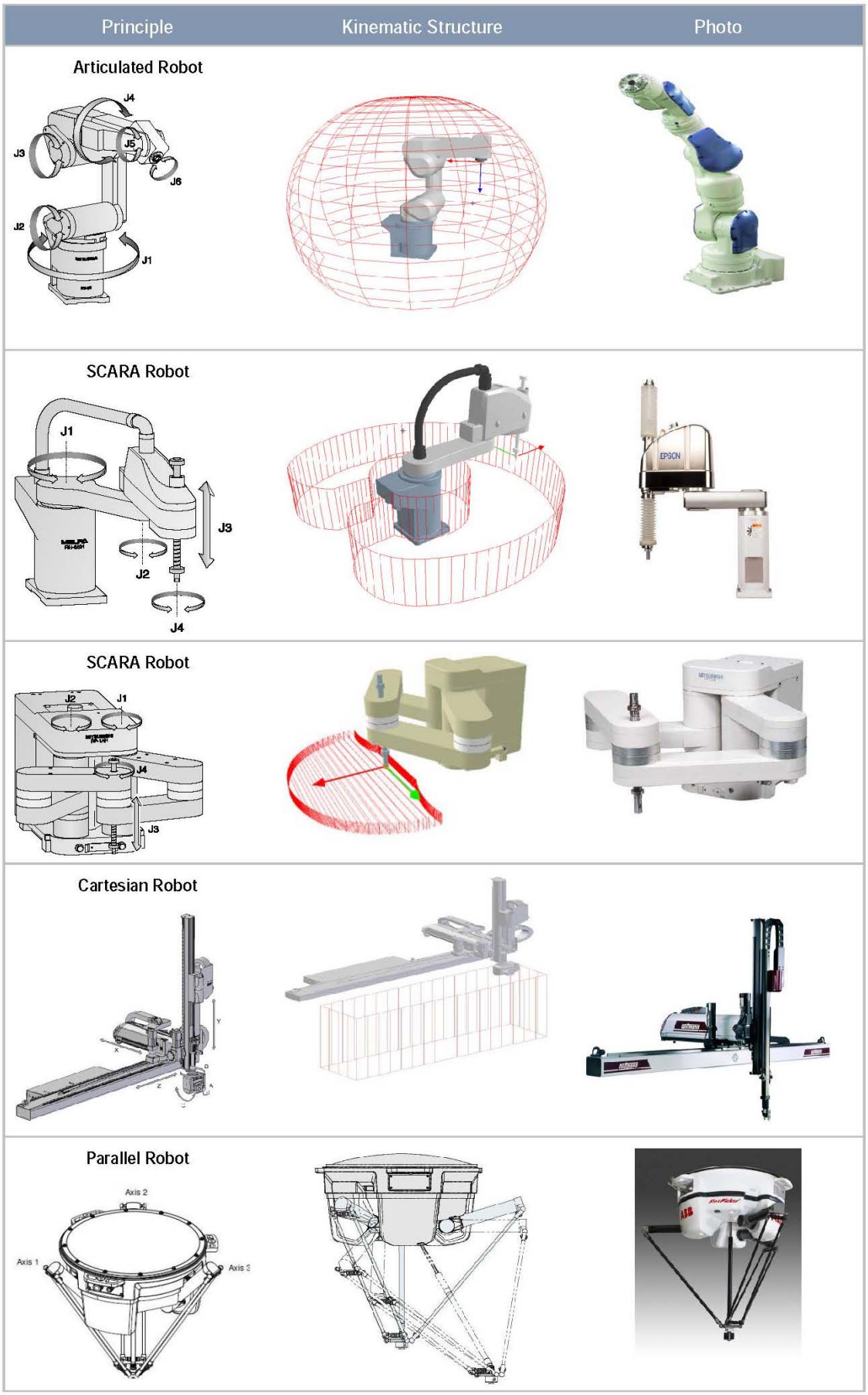


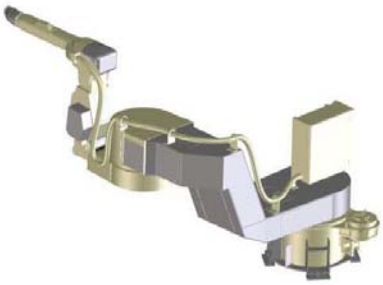
Figure 1.1: Classification of industrial robots by mechanical structure

Examples of articulated robots:

Flexible mounting possibilities – optimized working range

Welding Robot

Examples of articulated robots:



The Swingarm is an articulated robot combined with SCARA elements

Different dualarm robots

Examples of applications of articulated robots:

Handling for metal casting

Palletizing

Welding

Painting

Packaging

Handling for forging

Examples of applications of articulated robots:

FDP handling

Wafer handler

Examples of SCARA robots and their applications:

Assembly

Packaging

Examples of linear/Cartesian/gantry robots:

Linear robot

Gantry robot

Examples of applications of cartesian robots:

Handling for plastic moulding

Sealing

Laser welding

Pressing

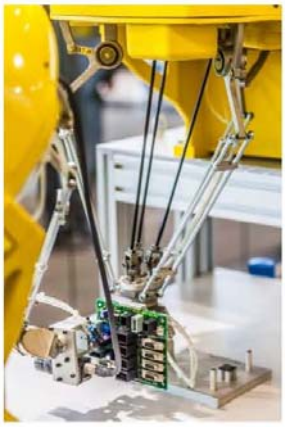
Examples of parallel robots:

Examples of applications of parallel robots:

Picking and placing

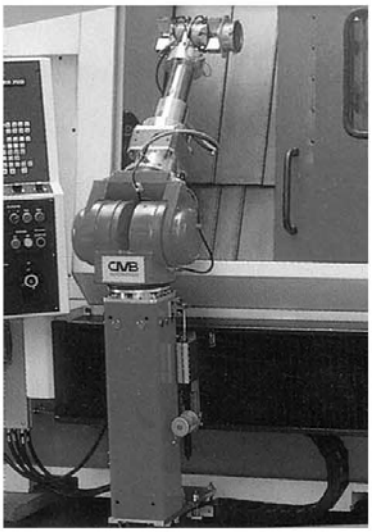
Assembly

Handling



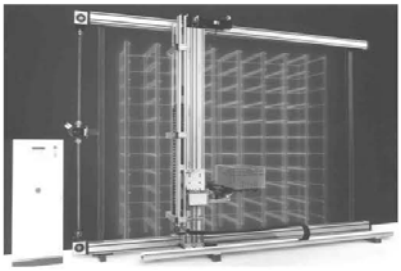
Examples of dedicated industrial robots not to be included in the statistics

Dedicated machine-tool loader



Printed circuit board assembler

Automated storage and retrieval system



1.2.3 CLASSIFICATION BY INDUSTRIES

As from the 2010 issue, data broken down by industrial branches is reported in accordance with the International Standard Industrial Classification of All Economic Activities (ISIC) revision 4. In previous issues, data was presented according to ISIC revision 2 or 3. In conjunction with the change of classification system, the number of branches to be surveyed by the IFR questionnaire was extended somewhat, reflecting the need for deeper analysis of the distribution of robots. (see table 1.1). All earlier data was transferred into this classification.

Table 1.1

IFR class	Categories, divisions and classes of economic activities, ISIC, rev. 4	Definitions
A-B	Agriculture, hunting and forestry; fishing	Crop and animal production, hunting and related service activities, forestry and logging, fishing and aquaculture
C	Mining and quarrying	Mining of coal and lignite, extraction of crude petroleum and natural gas, mining of metal ores, mining support service
D	Manufacturing	
10-12	Food products and beverages; Tobacco products	
13-15	Textiles, leather, wearing apparel	Textiles; Wearing apparel; dressing & dyeing of fur; Luggage, handbags, saddlery, harness and footwear
16	Wood and wood products (incl. furniture)	Manufacture of wood, products of wood (incl. wood furniture) and products of cork
17-18	Paper and paper products, publishing & printing	Manufacture of pulp, paper and converted paper production, printing of products, such as newspapers, books, periodicals, business forms, greeting cards, and other materials, and associated support activities, such as bookbinding, plate- making services, and data imaging; reproduction of recorded media, such as compact discs, video recordings, software on discs or tapes, records etc.
19-22	Plastic and chemical products	
19	Chemical products, pharmaceuticals, cosmetics	Manufacture of basic pharmaceutical products and pharmaceutical preparations. This includes also the manufacture of medicinal chemical and botanical products
20-21	Unspecified chemical, petrolium products	Transformation of crude petroleum and coal into usable products, transformation of organic and inorganic raw materials by a chemical process and the formation of products
22	Rubber and plastic products without automotive parts*	(e.g. rubber tires, plastic plates, foils, pipes, bags, boxes, doors, etc.) rubber and plastic parts for motor vehicles should be reported in 29.3.2
23	Glass, ceramics, stone, mineral products n.e.c. (without automotive parts*)	Manufacture of intermediate and final products from mined or quarried non-metallic minerals, such as sand, gravel, stone or clay, manufacture of glass, flat glass ceramic and glass products, clinkers, plasters, etc.
24-28	Metal	
24	Basic metals (iron, steel, aluminium, copper, chrome)	e.g. iron, steel, aluminium, copper, chrome etc.
25	Metal products (without automotive parts*), except machinery and equipment	e.g. metal furniture, tanks, metal doors, forging, pressing, stamping and roll forming of metal, nails, pins, hand tools, etc.
28	Industrial machinery	e.g. machinery for food processing and packaging, machine tools, industrial equipment, rubber and plastic machinery, industrial cleaning machines, agricultural and forestry machinery, construction machinery etc.

Sources: IFR

Table 1.1 (continued)

IFR class	Categories, divisions and classes of economic activities, ISIC, rev. 4	Definitions
26-27	Electrical/electronics	
275	Household/ domestic appliances	(e.g. refrigerators, vacuum cleaners, lawn mowers, lamps, ovens, shavers, vacuum cleaners, etc.)
271	Electrical machinery and apparatus n.e.c. (without automotive parts*)	Manufacture of power, distribution and specialty transformers; electric motors, generators and motor generator sets; switchgear and switchboard apparatus; relays and industrial controls, batteries and accumulators; manufacture of current-carrying wiring devices and non current- carrying wiring devices for wiring electrical circuits regardless of material, fiber optic cables and insulating of wires; manufacture of electric light bulbs and tubes and parts and components thereof (except glass blanks for electric light bulbs), electric lighting fixtures and lighting fixture components (except current-carrying wiring devices)
260	Electronic components/devices	Manufacture of electronic capacitors and resistors, microprocessors, bare printed circuit boards, electron tubes, electronic connectors, integrated circuits (analog, digital or hybrid), diodes, transistors and related discrete devices, inductors (e.g. chokes, coils, transformers), electronic component type, electronic crystals and crystal assemblies, solenoids, switches and transducers for electronic applications, interface cards (e.g. sound, video, controllers, network, modems), printer cables, monitor cables, USB cables, connectors etc.
261	Semiconductors, LCD, LED (incl solar cells and solar thermal collectors)	Manufacture of dice or wafers, semiconductor, finished or semi- finished and of display components (plasma, polymer, LCD), light emitting diods (LED), including solar cells and solar thermal collectors
262	Computers and peripheral equipment	Manufacture of desktop, laptop, main frame computers and hand-held computers (e.g. PDA), magnetic disk drives, flash drives and other storage devices,optical (e.g. CD-RW, CD- ROM, DVD-ROM, DVD-RW) disk drives, printers, monitors, keyboards, all types of mice, joysticks, and trackball accessories, dedicated computer terminals, computer servers, scanners, including bar code scanners, smart card readers, virtual reality helmets, computer projectors (video beamers), computer terminals, like automatic teller machines (ATM's), point-of-sale (POS) terminals, not mechanically operated, of multi-function office equipment, such as fax-scanner-copier combinations
263	Info communication equipment domestic and professional (TV, radio, CD, DVD-Players, pagers, mobile phones, VTR etc.) without automotive parts*	Manufacture of video cassette recorders and duplicating equipment, televisions, television monitors and displays,audio recording and duplicating systems, stereo equipment, radio receivers, speaker systems household-type video cameras, jukeboxes, amplifiers for musical instruments and public address systems, microphones, CD and DVD players, karaoke machines, headphones (e.g. radio, stereo, computer), video game consoles Manufacture of pagers, cellular phones, mobile communication equipment, telephone and facsimile equipment, incl. telephone answering machines, data communications equipment, such as bridges, routers, and gateways, transmitting and receiving antenna, cable television equipment, radio and television studio and broadcasting equipment, including television cameras, modems, carrier equipment, burglar and fire alarm systems, sending signals to a control station, radio and television transmitters, infrared devices (e.g. remote controls)
265	Medical, precision and optical instruments	Manufacture of measuring, testing, navigating and control equipment for various industrial and non-industrial purposes, including time-based measuring devices such as watches and clocks and related devices; manufacture of irradiation, electromedical and electrotherapeutic equipment, manufacture of optical instruments and photographic equipment
29	Automotive	
291	Motor vehicles, motor vehicle engines and bodies	Manufacture of cars, trucks, buses and their engines, manufacture of bodies (coachwork) for motor vehicles, manufacture of trailers and semitrailers
293	Parts and accessories for motor vehicles:	
2931	Metal products	metal parts of motor vehicles (e.g. brakes, gearboxes, axles, road wheels, suspension shock absorbers, radiators, silencers, exhaust pipes, catalytic converters, clutches, steering wheels, steering columns and steering boxes)
2932	Rubber and plastic	tyres, plastic parts of motor vehicles (e.g. bumpers)
2933	Electrical/electronics	electrical/electronic parts of motor vehicles (e.g. generators, alternators, spark plugs, ignition wiring harnesses, power window and door systems, assembly of purchased gauges into instrument panels, voltage regulators, navigation systems, communication equipment, electric motors; switchboard apparatus; relays, batteries and accumulators;airbags
2934	Glass	auto glass
2939	Other	car seats, safety belts, airbags
30	Other transport equipment	e.g. ships, locomotives, aeroplanes, spacecraft vehicles
91	All other manufacturing branches	
E	Electricity, gas and water supply	
F	Construction	General construction and specialized construction activities for buildings and civil engineering works. It includes new work, repair, additions and alterations, the erection of prefabricated buildings or structures on the site and also construction of a temporary nature
P	Education, research and development	
90	All other non-manufacturing branches	
99	Unspecified	

Sources: IFR

1.2.4 CLASSIFICATION BY APPLICATIONS

From 2004, the applications have been revised in agreement with the robot suppliers. All earlier data was transferred into the revised classification. The table 1.2 below shows the type of classification, by application areas.

Table 1.2

IFR Class	Application area	Definitions
110	Handling operations/ Machine tending	Assistant processes for the primary operation (the robot doesn't process the main operation directly)
111	Handling operations for metal casting	including die-casting
112	Handling operations for plastic moulding	also inserting operations for injection moulding
113	Handling operations for stamping/forging/ bending	
114	Handling operations at machine tools	
115	Machine tending for other processes	e.g. handling during assembly, handling operations during glas or ceramics production or food production Robots that handle workpieces at an external welding TCP (i.e. MIG/MAG torch or spot gun) need to be reported in the appropriate welding classification (i.e. 161 for arc welding or 162 for spot welding) and shall not be counted to the classification of handling operations.
116	Handling operations for measurement, inspection, testing	triage, quality inspection, calibrating
117	Handling operations for palletizing	all sectors, all kinds and sizes of pallets
118	Handling operations for packaging, picking and placing	e.g. operations during primary and secondary packaging
119	Material Handling n.e.c.	e.g. transposing, handling during sandcasting
160	Welding and soldering (all materials)	
161	Arc welding	
162	Spot welding	
163	Laser welding	
164	other welding	e.g. ultrasonic welding, gas welding, plasma welding
165	Soldering	
170	Dispensing	
171	Painting and enamelling	area-measured application of lacquer (surface coat)
172	Application of adhesive, sealing material or similar material	spot-wise and line-wise
179	Dispensing others/ Spraying others	e.g. powder coating, application of mould release agent, area-measured application of adhesive, spraying of wax to conserve)
190	Processing	enduring changing, the robot leads the workpiece or the tool, material removal
191	Laser cutting	
192	Water jet cutting	
193	Mechanical cutting/grinding/ deburring/ milling/polishing	
198	Other processing	e.g. gas/plasma cutting, drilling, bending, punching, shearing
200	Assembling and disassembling	enduring positioning of elements
201	Fixing, press-fitting	screw/nut-driving, clinching, reveting, bonding
202	Assembling/ mounting/ inserting	also temporarily positioning to facilitate the assembling process
203	Disassembling	recycling, removal of cover after processing
208	Other assembling	not mentioned before
900	Others	
901	Cleanroom for FPD	
902	Cleanroom for semiconductors	
903	Cleanroom for others	
905	Others	not mentioned before
999	Unspecified	the application is unknown

Sources: IFR

1.3 DEFINITION AND CLASSIFICATION OF SERVICE ROBOTS

1.3.1 DEFINITION

In a joint effort started in 1995 the United Nations Economic Commission for Europe (UNECE) and IFR engaged in working out a preliminary service robot definition and classification scheme, which has been absorbed by the current ISO Technical Committee 184/Subcommittee 2 resulting in a novel ISO-Standard 8373 which had become effective in 2012[18]. A preliminary extract of the relevant definitions is given here:

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

Please note: According to the definition, “a degree of autonomy” is required for service robots ranging from partial autonomy (including human robot interaction) to full autonomy (without active human robot intervention). Therefore, in addition to fully autonomous systems service robot statistics include systems, which may also be based on some degree of human robot interaction or even full tele-operation. In this context human robot-interaction means information and action exchanges between human and robot to perform a task by means of a user interface.

With this definition, manipulating industrial robots (which can be either fixed in place or mobile) could also be regarded as service robots, provided they are installed in non-manufacturing operations. Service robots may or may not be equipped with an arm

[18] ISO 8373:2012 Robots and robotic devices - Vocabulary; http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=55890 .

structure as is case with some industrial robots. Often, but not always, service robots are mobile.

In some cases, service robots consist of a mobile platform on which one or several arms are attached and controlled in the same mode as the arms of industrial robot. Furthermore, contrary to their industrial counterparts, service robots do not have to be fully automatic or autonomous. In many cases these machines may even assist a human user or be tele-operated.

Due to their multitude of forms and structures as well as application areas, service robots are not easy to define.

1.3.2 CLASSIFICATION OF SERVICE ROBOTS BY APPLICATION AREAS

Since the mid-90s, UNECE and IFR have adopted a preliminary system for classifying service robots by categories and types of interaction which has converged over the year into the current classification scheme. For both personal/domestic robots and professional service robots, the classification of service robot according to application areas and types is shown in table 1.3.

As from 1997, IFR started regularly to collect statistics on service robots, including data on manipulating industrial robots used in service robot applications, according to the current versions of the classification scheme. Recognizing the difficulties in collecting primary statistics from suppliers of service robots, it is not surprising that aggregated statistics from individual countries are very scarce.

Since very few national organizations have any comprehensive statistics on service robots at all, UNECE and IFR decided to collect statistics directly from the manufacturers of service robots. This process has been maintained ever since with the only difference of transferring all statistics related activities to the IFR Statistical Department since the year 2005. Manufacturers are asked to report data broken down by application areas as shown in table 1.3 for professional and personal/domestic applications.

The results of the statistics as well as the analysis are published in World Robotics – Service Robots 2017.

Table 1.3

Classification of service robots by application areas and types of robots; service robots for personal/domestic use.

Types of robots	
I	Personal/Domestic Robots
1-6	Robots for domestic tasks
1	- Robot companions / assistants / humanoids
2	- Vacuuming, floor cleaning
3	- Lawn mowing
4	- Pool cleaning
5	- Window cleaning
6	- Home security & surveillance
7	- Others
8-11	Entertainment robots
8	Toy/hobby robots
9	Multimedia robots
10	Education and research
11	Others
12-14	Elderly and handicap assistance
12	- Robotized wheelchairs
13	- Personal aids and assistive devices
14	- Other assistance functions
16	Other personal/domestic robots

Source: IFR

Table 1.3 (continued)

Classification of service robots by application areas and types of robots; service robots for professional use

	Types of robots
II	Professional service robots
17-22	Field robotics
17	- Agriculture (broad acre, greenhouse, fruit-growing, vineyard)
18	- Milking robots*
19	- other robots for livestock farming
20	- Mining robots
21	- Space robots
22	- Others
23-27	Professional cleaning
23	-Floor cleaning, professional*
24	-Window and wall cleaning (including wall climbing robots)
25	-Tank, tube and pipe cleaning
26	- Hull cleaning (aircraft, vehicles, etc.)
27	-other cleaning tasks
28-30	Inspection and maintenance systems
28	- Facilities, plants
29	- Tank, tubes, pipes and sewers
30	- Other inspection and maintenance systems
31-34	Construction and demolition
31	- Nuclear demolition & dismantling
32	- Building construction
33	- Robots for heavy/civil construction
34	- Other construction and demolition systems
35-39	Logistic systems
35	- Autonomous guided (AGV) vehicles in manufacturing environments*
36	- AGVs in non-manufacturing environments (indoor)
37	- Cargo handling, outdoor logistics
38	- Personal transportation (AGV for persons)
39	- Other logistics
40-43	Medical robotics
40	- Diagnostic systems
41	- Robot assisted surgery or therapy
42	- Rehabilitation systems
43	- Other medical robots
44-46	Rescue und security applications
44	- Fire and disaster fighting robots
45	- Surveillance/security robots without UAV
46	- Other rescue and security robots
47-51	Defense applications
47	- Demining robots
48	- Unmanned aerial vehicles
49	- Unmanned ground based vehicles (e.g. bomb fighting)
50	- Unmanned underwater vehicles
51	- Other defense applications
52	Underwater systems (civil/general use)
53	Powered Human Exoskeletons*
55	Mobile Platforms (general use)*
56-60	Public relation robots and joy rides
56	Hotel and restaurant robots
57	Mobile guidance, information, telepresence robots
58	Robots in marketing
59	Robot joy rides
60	other public relation
61	Other professional service robots not specified above

Source: IFR