The Automation Primer

A guide to the future of industrial robotics, system integration and components

Christine Wang
(866) 2 8758 8249
catherine.wang@daiwacm-cathay.com.tw

Important disclosures, including any required research certifications, are provided on the last two pages of this report.
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**Please also see:**

Factory Automation: Industrial robots to hit the ground running  
29 March 2012  
Christine Wang (886) 2 8758 6249 (christine.wang@daiwacm-cathay.com.tw)
Summary

Gaining an in-depth understanding of the market and the trends in the Automation Sector is challenging for investors, given the broad nature of the end-application sub-sectors and the different types of robots and levels of automation. In this primer, Daiwa highlights the current growth areas – industrial robots and the supply chain (system integrators and components).

The Automation Primer aims to arm investors with the knowledge and insights – into the numerous types of industrial robots, applications, market sizes and demand by sub-sector and region, as well as the related supply chain and players in the field – in order that they are better placed to make the right investment decisions.

I would like to thank our guest author, Dr. Pai, for his invaluable contribution to this project.

Christine Wang
Senior Analyst, Technology

Dr. Chung-Che Pai is an Assistant Professor in the Department of Air Transportation Management at Kainan University, Taiwan. He received his Ph.D. in industrial engineering and management at National Chiao-Tung University. His current research and teaching interests are in technology management and supply-chain management. Professor Pai has been a research manager at the Industrial Economics and Knowledge Centre, a section manager in the logistics department of Microtek International Inc., and an engineer at China Motor Corporation. He is a certified industry analyst of the Asia Pacific Industrial Analysis Association.

The guest author, Dr. Chung-Che Pai, is an independent contributor as part of Daiwa's guest author programme, which is separate from the firm's normal research coverage. The views expressed by the guest author herein represent the opinions of the author only, and do not necessarily reflect the opinions of Daiwa, the other authors of this report, or the author's employer.
The Automation Sector has become increasingly attractive to investors over the past two years. Rising demand in China due to labour issues and process improvements, plus robust demand from manufacturing industries have resulted in industrial robots and the supply chain continuing to see high shipment-growth rates since the 2008-09 financial crisis. The Japan Robot Association (JARA) expects the industrial-robot market to have a value 1.5x/3x greater in 2020/2035, compared with 2010. The International Federation of Robotics (IFR) forecasts Asia to account for about 61% of the market globally this year, up from 45% for 2001, with Europe’s share falling to 24% this year from 40% in 2001. The Americas should only account for 15% of the total market this year.

We expect service robots to be the next main trend once the applications they can be used for expand. We see the market for service robots expanding in the future, but for the next two years the focus should continue to be on industrial robots. JARA expects the value of the service-robot market in 2035 to be 40x that of 2010, and the value of this segment to surpass that of industrial robots in about 2020-25. It believes that by 2035, the service-robot market will be about double the value of the industrial-robot market. By region in 2010, the Americas accounted for a 58% share of the service-robot market, followed by Asia (24%) and Europe (18%).

We therefore believe the industrial-robot supply chain will continue to see demand growth over the next few years, especially for the technology leaders. In our view, the next investment opportunities lie in the service-robot supply chain, in which the market value for the consumer segment (personal use) has greater growth potential than the professional service-robot market (IFR forecasts revenue CAGRs of 36% and 5%, respectively, for 2011-14). The biggest applications are likely to include the medical field, defence, and personal-use robots.
Chapter 1

Automation industry: overview
Automation is the use of control systems and information technologies to reduce the need for human work in the production of goods and services. In terms of industrialisation, automation is a step beyond mechanisation. Whereas mechanisation provides human operators with machinery to assist them with the muscular requirements of work, automation greatly decreases the need for human sensory and mental requirements. Automation plays an increasingly important role in the world economy and in daily experience.

Source: Daiwa

Automation has had a considerable impact in a wide range of industries beyond manufacturing (where it started). Once-ubiquitous telephone operators have been replaced largely by automated telephone switchboards and answering machines. Medical processes – such as primary screening in electrocardiography or radiography and laboratory analysis of human genes, sera, cells, and tissues – are carried out at much more quickly and accurately by automated systems. Automated teller machines have reduced the need for bank visits to obtain cash and carry out transactions. In general, automation was responsible for the shift in the world economy from industrial jobs to service jobs in the 20th and 21st centuries.

The robotics market in China, eastern Europe and Latin America, largely driven by Brazil, should flourish in 2012 for similar reasons robots spread through Japan, western Europe, and North America. We expect robotic applications to increase in China, eastern Europe, and Latin America as wages rise. Labour shortages and quality issues are driving mechanisation in China. The robotics market in China has expanded significantly in recent years. Five years ago, it might not have been thought that China would be a big robot market because of its huge pool of labour. But things are changing: China’s labour pool is shrinking, the country has a very high job-turnover rate, and wage growth is high.
## Incentives to automate

<table>
<thead>
<tr>
<th>Source: Daiwa</th>
</tr>
</thead>
</table>

### Technological
- Virtualisation/cyberisation
- Cross-area integration

### Economic
- Globalisation
- Environment
- Energy-saving and carbon-reducing

### Social
- Demographic
  - Ageing population, declining birth rate
- Human consumption habits changed

### Cultural
- Current demographic trends will result in an increase in the elderly population and a diminishing number of younger people.

### Political
- CO₂ emissions

### Environmental
- Environmental protection is gaining increasing importance around the world and it is the overall trend in the whole industry to realise ‘green’ production processes.
- Suitable energy is increasing, as part of the need to substitute non-renewable resources as well as to reduce energy consumption.
- The need for alternative energy is increasing, as part of the need to substitute non-renewable resources as well as to reduce energy consumption.

### Demographic shifts
- Current demographic trends will result in an increase in the elderly population and a diminishing number of younger people.

### Environmental regulations
- The need for alternative energy is increasing, as part of the need to substitute non-renewable resources as well as to reduce energy consumption.
- The need for alternative energy is increasing, as part of the need to substitute non-renewable resources as well as to reduce energy consumption.

### Energy costs
- The need for alternative energy is increasing, as part of the need to substitute non-renewable resources as well as to reduce energy consumption.
- The need for alternative energy is increasing, as part of the need to substitute non-renewable resources as well as to reduce energy consumption.

### Reduction in operating costs
- Direct and overhead costs can be reduced, eg, energy costs can be reduced by turning off unnecessary lighting or heating.
- Using robots has a positive impact on the reduction in waste and the cost of consumable goods.

### Reduction in capital costs
- Using robots has a positive impact on the reduction in waste and the cost of consumable goods.
- Robots are precise and consistent. They can continuously produce high-quality finished products.

### Improvements in product quality and consistency
- Robots are precise and consistent. They can continuously produce high-quality finished products.

### Improvements in the quality of work for employees, complying with health and safety rules
- Robots can improve the working conditions of staff. Dangerous, tedious, and dirty work is transferred from man to machine.

### Increase in production-output rates
- Robots can work at a consistent speed 24 hours a day, seven days a week. Robots can be programmed to handle new products off-line, ensuring new products are introduced for faster production.

### Increasing flexibility in product manufacturing
- Robots can provide flexibility to the production line, performing multiple tasks for a variety of products.

### Reduction in material waste and increase in yield
- Using robots increases the volume of finished products that comply with the required standards.

### Saves space in high-value manufacturing areas
- Robots can be placed on the shelves, on the walls or even on the ceilings. They can also be programmed to work in confined spaces where no valuable floor space is lost.

### Competitiveness in the global market
- Relocation of production sites to low-wage countries can be avoided. Thus jobs can be saved.

### Source: Daiwa
In this primer, we separate automation into industrial robots, service robots, system integration, and robot components.

### Scope of automation

**Industrial robots**
An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial-automation applications.

**Service robots**
A robot that operates partly or fully autonomously and performs services useful to the well-being of humans and equipment, excluding manufacturing operations. As service robots are still in the early phase of development and diffusion, they have no standardised definition yet, which, among other things, differentiates them from other types of equipment, in particular the manipulating industrial robot.

**System integration**
A robotic system integrator is able to analyse a manufacturer’s system requirements and provide a robotic solution that will improve quality, throughput, and productivity to give a return on investment.

**Robot components**
Industrial robots have always depended on the availability of typical key components, such as actuators, sensors, robot arms, end-effectors, and controllers. Besides component functionality and performance data, the aspects of physical and logical integration within standard system architectures in hardware and software are of increasing importance. It should be noted here that there is a clear trend to share both components and architectural aspects at least in part with other complex mechatronic systems, such as service robots and even automobiles.

---

**Automation structure**

- **Demand Pull**
- **STEEP**
  - BRICs
  - SMEs
- **Industrial Automation Applications**
  - Automobile
  - Electronic
  - Semiconductor
  - Chemistry
  - ...
- **Technology Push**
  - Robot Collaboration
  - Human-Robot Interactions
  - Safety
- **Process Equipment, Device, Software, Middle ware...**
- **Robot Component**
- **Robotics**
- **System Integration**

Source: Daiwa
Industrial robots

**Definition**

An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications.

**Market size**

Estimated worldwide annual shipments of industrial robots

Global market share of installed industrial robots (2011)

**Main suppliers of industrial robots**

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Specialty</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABB Flexible Automation</td>
<td>Switzerland</td>
<td>First company to sell 100,000 industrial robots</td>
</tr>
<tr>
<td>Adept Technology, Inc.</td>
<td>US</td>
<td>Small parts-assembly robots</td>
</tr>
<tr>
<td>Denso Robotics</td>
<td>Japan</td>
<td>Automotive robots; world’s largest user of robots</td>
</tr>
<tr>
<td>FANUC Robotics</td>
<td>Japan</td>
<td>Full line of manufacturing robots</td>
</tr>
<tr>
<td>Kawasaki Robotics (US)</td>
<td>US</td>
<td>Seven axes; controllers; industrial robots</td>
</tr>
<tr>
<td>KUKA Robotics Corp.</td>
<td>US</td>
<td>PC-based modular robots</td>
</tr>
<tr>
<td>Mitsubishi Heavy Industries</td>
<td>Japan</td>
<td>Injection-molding robots</td>
</tr>
<tr>
<td>Comau</td>
<td>Italy</td>
<td>Industrial robots</td>
</tr>
<tr>
<td>Staubli</td>
<td>Switzerland</td>
<td>Six-axis industrial robots</td>
</tr>
<tr>
<td>Yaskawa-Motoman</td>
<td>Japan</td>
<td>Robotics; motion controls; drives</td>
</tr>
</tbody>
</table>

Source: Companies, Daiwa estimates

Source: IFR

Source: Companies, Daiwa estimates
Service robots

Definition

A robot that operates partly or fully autonomously and performs services useful to the well-being of humans and equipment, excluding manufacturing operations. Service robots can be classified generally into two types by purpose: 1) for professional use; service robots used for a commercial task, usually operated by a trained operator; and 2) for personal use; used for non-commercial tasks, usually by a lay person(s).

Market size

Global market size of service robots

Market share by region for service robots (2010)

Main suppliers of service robots

<table>
<thead>
<tr>
<th>Region</th>
<th>Company</th>
<th>Specialty</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>Anver Corporation</td>
<td>Vacuum end-effectors and other vacuum technologies</td>
</tr>
<tr>
<td></td>
<td>Friendly Robotics</td>
<td>Robotic lawn mowers</td>
</tr>
<tr>
<td></td>
<td>Robot</td>
<td>High-tech and consumer mobile robots (Roomba)</td>
</tr>
<tr>
<td></td>
<td>RedZone Robotics</td>
<td>Hazardous environment mobile robots</td>
</tr>
<tr>
<td></td>
<td>Robotic-technology Inc.</td>
<td>Military mobile robots</td>
</tr>
<tr>
<td></td>
<td>Intuitive Surgical</td>
<td>Surgical robots</td>
</tr>
<tr>
<td>Switzerland</td>
<td>K-Team</td>
<td>Consumer-grade autonomous mobile robots</td>
</tr>
<tr>
<td>Canada</td>
<td>LAPP Canada</td>
<td>Cable and connector supplier</td>
</tr>
<tr>
<td>Germany</td>
<td>Leoni Protec</td>
<td>Robot cables</td>
</tr>
<tr>
<td></td>
<td>Fronhauser</td>
<td>Humanoid/partner robot,</td>
</tr>
<tr>
<td>Japan</td>
<td>Toyota</td>
<td>Consumer mobile robots (vacuuming, robot pets)</td>
</tr>
<tr>
<td></td>
<td>Matsushita</td>
<td>Humanoid/partner robots</td>
</tr>
<tr>
<td>Korea</td>
<td>Samsung</td>
<td>Robot cleaners, edutainment robots</td>
</tr>
<tr>
<td></td>
<td>Yujin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hanool Robotics</td>
<td></td>
</tr>
<tr>
<td>Taiwan</td>
<td>Matsuba</td>
<td>Robot cleaners, edutainment robots</td>
</tr>
<tr>
<td></td>
<td>Compal</td>
<td></td>
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<tr>
<td></td>
<td>MSI</td>
<td></td>
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<tr>
<td></td>
<td>ASUSTek</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hiwin Technologies</td>
<td></td>
</tr>
</tbody>
</table>

Source: Companies
Components

An industrial robot typically has five parts: an actuator, robot arms, end-effector (sometimes robot arms and end-effectors are called manipulators) sensors, and controllers. The actuator is the engine, or motor, that moves the links into their designated positions. Sensors allow the robot to receive feedback about its environment. Robot arms can vary in size and shape. The robot arm is the part that positions the end-effector. With the robot arm, the shoulder, elbow, and wrist move and twist to position the end-effector into the desired spot. The controller is the ‘brain’ of the robot and allows the parts of the robot to operate together.

Market size

Components as a % of the total market (2010) (US$m)

- Whole robots: 13,965 (57%)
- Components: 6,370 (26%)
- Others: 4,165 (17%)

Breakdown of components (US$m)

- Robot arm/ end effector: 1,520 (24%)
- Sensors: 1,560 (24%)
- Controllers: 1,700 (27%)
- Actuators: 955 (15%)

Source: Datamonitor, Daiwa estimates
### Main component suppliers of robots

#### Actuators

<table>
<thead>
<tr>
<th>Country</th>
<th>Company</th>
<th>Specialty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>SMC</td>
<td>Cylinder accessories, valve accessories, actuators, connectors, valves and manifolds</td>
</tr>
<tr>
<td>Japan</td>
<td>Yaskawa</td>
<td>World's largest manufacturer of AC drives and motion-control products</td>
</tr>
<tr>
<td>Germany</td>
<td>Festo</td>
<td>Air reservoirs, valves, pneumatic drives, cylinders, pneumatic connection technology</td>
</tr>
<tr>
<td>US</td>
<td>Bosch</td>
<td>Hydraulic motion technology, automation products</td>
</tr>
<tr>
<td>Japan</td>
<td>Omron Corporation</td>
<td>Controllers and sensors, motions and drives</td>
</tr>
<tr>
<td>Germany</td>
<td>Siemens</td>
<td>Servo motors, PC-based and embedded controllers</td>
</tr>
</tbody>
</table>

#### Sensors

<table>
<thead>
<tr>
<th>Country</th>
<th>Company</th>
<th>Specialty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>Olympus Optical Co.</td>
<td>Optical sensors</td>
</tr>
<tr>
<td>Japan</td>
<td>Omron Corporation</td>
<td>Controllers and sensors</td>
</tr>
<tr>
<td>US</td>
<td>Reis Robotics</td>
<td>Robot sensing systems</td>
</tr>
<tr>
<td>US</td>
<td>RG Software</td>
<td>Automation and voice recognition software</td>
</tr>
<tr>
<td>Canada</td>
<td>Servo-Robot Inc.</td>
<td>Sensors for arc welding, laser sensors</td>
</tr>
<tr>
<td>US</td>
<td>Futek</td>
<td>Sensor technologies and robot accessories</td>
</tr>
<tr>
<td>Germany</td>
<td>SICK</td>
<td>Sensor technologies</td>
</tr>
</tbody>
</table>

#### Robot arms and end-effectors

<table>
<thead>
<tr>
<th>Country</th>
<th>Company</th>
<th>Specialty</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>PHD, Inc.</td>
<td>End-of-arm tools and actuators</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Staubli</td>
<td>Six-axis industrial robots</td>
</tr>
<tr>
<td>England</td>
<td>TM Robotics</td>
<td>Selective compliant assembly robot arm (SCARA) and Cartesian robotic arms</td>
</tr>
<tr>
<td>US</td>
<td>Yamaha Robotics</td>
<td>SCARA and Cartesian assembly robots</td>
</tr>
<tr>
<td>US</td>
<td>Zayeran</td>
<td>Grippers</td>
</tr>
<tr>
<td>Switzerland</td>
<td>ABB</td>
<td>Industrial robots</td>
</tr>
<tr>
<td>US</td>
<td>Adept Technology, Inc.</td>
<td>Small parts assembly robots</td>
</tr>
<tr>
<td>US</td>
<td>Anwer Corporation</td>
<td>Vacuum end-effectors and other vacuum technologies</td>
</tr>
<tr>
<td>US</td>
<td>Applied Robotics</td>
<td>Robot parts, tool changers; collision sensors</td>
</tr>
<tr>
<td>Japan</td>
<td>FANUC Robotics</td>
<td>Full line of manufacturing robots</td>
</tr>
<tr>
<td>Japan</td>
<td>Yaskawa-Motoman</td>
<td>Automated robotic solutions, controllers</td>
</tr>
</tbody>
</table>

#### Controller

<table>
<thead>
<tr>
<th>Country</th>
<th>Company</th>
<th>Specialty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Joker Robotics</td>
<td>Controllers and mobile robot systems</td>
</tr>
<tr>
<td>Japan</td>
<td>Omron Corporation</td>
<td>Controllers and sensors</td>
</tr>
<tr>
<td>US</td>
<td>Kawasaki Robotics</td>
<td>Controllers, industrial robots</td>
</tr>
<tr>
<td>US</td>
<td>Epson Robotics</td>
<td>PC-Based robot control software</td>
</tr>
<tr>
<td>Japan</td>
<td>Olympus Corp.</td>
<td>Process and control equipment</td>
</tr>
<tr>
<td>Germany</td>
<td>Siemens</td>
<td>PC-Based and embedded controllers</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Advantech</td>
<td>PC-Based and embedded controllers</td>
</tr>
<tr>
<td>US</td>
<td>Adept</td>
<td>Industrial robots, robot and motion controls</td>
</tr>
<tr>
<td>Japan</td>
<td>Yaskawa-Motoman</td>
<td>Automated robotic solutions, controllers</td>
</tr>
</tbody>
</table>

Source: Companies
System integration

Definition

Integration is the process of programming and outfitting industrial robots so they can perform manufacturing and automation tasks. A robotics system integrator should be able to: 1) perform a feasibility study on a client’s project, 2) provide helpful cost-saving tips, 3) produce tooling and part fixturing, and 4) incorporate the system into the client’s factory setting.

An example of system integration in the automobile industry

Source: Daiwa

Source: BCC
Regional differences in robotics developments

<table>
<thead>
<tr>
<th>Key technology areas</th>
<th>Japan</th>
<th>US</th>
<th>Korea</th>
<th>EU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial</td>
<td>Industrial</td>
<td>Military</td>
<td>Industrial</td>
<td>Industrial</td>
</tr>
<tr>
<td>Humanoid</td>
<td>Autonomous vehicles</td>
<td>Domestic (especially networked robots)</td>
<td>Domestic</td>
<td></td>
</tr>
<tr>
<td>Entertainment</td>
<td>Domestic</td>
<td>Security</td>
<td>Service sector</td>
<td></td>
</tr>
<tr>
<td>Domestic</td>
<td>Military</td>
<td>Military</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key drivers and strategies

<table>
<thead>
<tr>
<th>Regional differences in robotics developments</th>
<th>Key drivers and strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>Strong background in industrial robots, automobiles, and consumer electronics</td>
</tr>
<tr>
<td>US</td>
<td>Commercialisation of simple robots (e.g., iRobot) by private enterprise and university spin-offs</td>
</tr>
<tr>
<td>Korea</td>
<td>Strong cultural affinity with robots (especially humanoid robots)</td>
</tr>
<tr>
<td>EU</td>
<td>Strong software industry</td>
</tr>
<tr>
<td>EU-funded projects and initiatives, including the Beyond Robotics programme</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>Production of robots to alleviate problems of an ageing population</td>
</tr>
<tr>
<td>US</td>
<td>Robotics R&amp;D driven by defence-related funding (e.g., DARPA)</td>
</tr>
<tr>
<td>Korea</td>
<td>Production of robots to alleviate problems of an ageing population</td>
</tr>
<tr>
<td>EU-fundeds projects and initiates, including the Beyond Robotics programme</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>Companies starting to rent expensive robots for R&amp;D, PR, and security roles</td>
</tr>
<tr>
<td>US</td>
<td>The US Army wants to use robotics to develop unmanned military vehicles and craft</td>
</tr>
</tbody>
</table>

Source: SRIC-Bi

Developments likely in the main markets over the next few years

<table>
<thead>
<tr>
<th>Developments</th>
<th>Korea</th>
<th>Japan</th>
<th>North America</th>
<th>Germany</th>
<th>China</th>
<th>Taiwan</th>
<th>India</th>
<th>Brazil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main applications:</td>
<td>Electronics, automotive</td>
<td>Automotive, electronics, food &amp; beverage, chemicals</td>
<td>Automotive, pharmaceuticals and medical</td>
<td>Automotive, use of new materials, energy-efficient production</td>
<td>Modernisation of existing production sites, automotive</td>
<td>Automotive electronics, machinery</td>
<td>Automotive, electricity, solar production, agricultural</td>
<td>Usage is low</td>
</tr>
<tr>
<td>Growth in automotive industries</td>
<td>Strong</td>
<td>Strong</td>
<td>Mild</td>
<td>Strong</td>
<td>Strong</td>
<td>Mild</td>
<td>Mild</td>
<td>High</td>
</tr>
<tr>
<td>Growth in electronic industries</td>
<td>Mild</td>
<td>Strong</td>
<td>Strong</td>
<td>Mild</td>
<td>Strong</td>
<td>Strong</td>
<td>Mild</td>
<td></td>
</tr>
<tr>
<td>Growth in other industries</td>
<td>Mild</td>
<td>Strong</td>
<td>Strong</td>
<td>Strong</td>
<td>Strong</td>
<td>Strong</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Specific areas with good potential</td>
<td>LCD TVs, LED lighting</td>
<td>Photovoltaic products, Hybrid and electric cars</td>
<td>Chemical industry, Alternative and renewable energy photovoltaic products</td>
<td>Development of alternative-drive systems</td>
<td>Motor vehicles</td>
<td>Electronics industry, Machinery industry</td>
<td>Automotive industry</td>
<td>Manufacturing sectors</td>
</tr>
<tr>
<td>Plastics industry</td>
<td>Environmental technologies, Lithium-ion batteries and solar cells</td>
<td>Solar-cell production, Use of new materials</td>
<td>Energy-efficient production</td>
<td></td>
<td></td>
<td>Solar-technology industry</td>
<td>Agricultural industry</td>
<td></td>
</tr>
<tr>
<td>Pharmaceutical industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Food industry</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Source: Daiwa
Chapter 2

Industrial robotics
What is industrial robotics?

Industrial robotics generally refers to an automatically-controlled, reprogrammable, multipurpose manipulator that is programmable in three or more axes. It may be either fixed in place or mobile for use in industrial-automation applications. The number of axes should be understood as the basic feature supplied by the producer, and not axes added later by the user.

Through the using of industrial robots, manufacturers using machine tools can keep their factories operating longer hours. Robots function as operators of machine tools, providing tools, materials, and parts from storage areas. This enables machining centres to keep running 24 hours a day, seven days a week.

Source: IFR

Industrial robot: gluing

Source: IFR

Industrial robot: palletising

Source: IFR

Industrial robot: flat-panel-display handling

Source: IFR

Industrial robot: SCARA robot

Source: IFR

Industrial robot: parallel robot

Source: IFR

Industrial robot: wafer handler

Source: IFR
The main objectives of investing in robots are to reduce operating costs, to provide improved and more constant product quality, and to increase the production-output rate. Investments in robots are often undertaken with several of the below aims simultaneously in mind. However, investing in robots increases overall productivity and competitiveness globally. The relocation of production sites to low-wage countries can be avoided.

- Reduces operating costs
- Reduces capital costs
- Improves product quality and consistency
- Improves quality of work for employees, complying with health and safety rules
- Increases production-output rates
- Increases flexibility in product manufacturing
- Reduces material waste and increases yield
- Saves space in high-value manufacturing areas

### Line production vs. cell production

Consumer products are increasingly individualised, with a quick time-to-market. As a result, flexibility is increasingly important. There is growing interest in high-mix, low-volume production systems. Cell-production systems for the high-mix, low-volume production are beginning to take the place of line-production system for mass production.

#### Line production

- Machines and workers are deployed alongside a conveyor line to carry out only one specific task.
- Changes in work procedures and parts do not occur very often.

#### Cell production

- A production cell is a self-contained unit responsible for a significant part of the finished object.
- Robots in a cell-production system should be able to deal with a variety of goods. Once programmed for several processes they can easily switch from process to process.
A deeper understanding of industrial robotics
We break down industrial robotics by mechanical type and by end purpose in production.

<table>
<thead>
<tr>
<th>Page</th>
<th>Classification</th>
<th>Type</th>
<th>Technology development</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>Mechanical</td>
<td>Articulated</td>
<td>High</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>Cartesian</td>
<td>High</td>
</tr>
<tr>
<td>21</td>
<td></td>
<td>SCARA</td>
<td>High</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td>Cylindrical</td>
<td>High</td>
</tr>
<tr>
<td>23</td>
<td>Purpose</td>
<td>Handling &amp; machine-tending</td>
<td>High</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>Welding and soldering</td>
<td>High</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>Dispensing</td>
<td>High</td>
</tr>
<tr>
<td>26</td>
<td></td>
<td>Processing</td>
<td>High</td>
</tr>
<tr>
<td>27</td>
<td></td>
<td>Assembling and disassembling</td>
<td>High</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td>Cleanroom and others</td>
<td>High</td>
</tr>
</tbody>
</table>
**Mechanical: articulated**

**Definition:** an articulated robot is one for which the arm has at least three rotary joints.

**Principle**

![Articulated Robot Diagram](source: Daiwa)

**2010 numbers**

<table>
<thead>
<tr>
<th></th>
<th>Worldwide shipments</th>
<th>Shipments YoY growth</th>
<th>Market share</th>
<th>Peak year</th>
<th>Peak-year shipment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>70,100</strong></td>
<td></td>
<td><strong>75%</strong></td>
<td><strong>59%</strong></td>
<td><strong>2008</strong></td>
<td><strong>76,600</strong></td>
</tr>
</tbody>
</table>

**Source:** IFR

**Key applications**

- Used in almost all applications.
- These robots are mainly used for welding, dispensing and handling. The following applications increased significantly in 2010: welding, dispensing, handling operations such as material-handling and handling operations at machine tools, packaging, picking, placing, measuring, testing, metal casting, and stamping/forging/bending.
- The demand for articulated robots for processing and assembly doubled YoY for 2010, according to the IFR.
- The demand for cleanroom applications tripled YoY for 2010.

**Shipments by region, 2010**

- Americas: 15%
- Europe: 33%
- Asia: 51%
- Others: 1%

**Market share by region**

- Americas: 2009: 30%, 2010: 31%
- Asia/Australia: 2009: 45%, 2010: 44%
- Europe: 2009: 20%, 2010: 20%
- Africa: 2009: 5%, 2010: 5%
- Total: 2009: 100%, 2010: 100%

**Source:** IFR
Mechanical: Cartesian

**Definition:** A Cartesian robot is one where the arm has three prismatic joints and where the axes are coincident with a Cartesian co-ordinate system.

**Principle**

A Cartesian robot with its axes labeled: x, y, and z, and an end-platform.

**Cartesian robots**

Source: Daiwa

**2010 numbers**

- **Worldwide shipments:** 25,400
- **Shipments YoY growth:** 127%
- **Market share:** 22%
- **Peak year:** 2010
- **Peak-year shipment:** 25,400

**Source:** IFR

**Key applications**

- Mainly used for plastic moulding, packaging, picking and placing, and assembly
- The demand for linear/Cartesian gantry robots for packaging, picking and placing for the electronics industry rose substantially.
- Plastic moulding – the main application of these robots - recovered considerably YoY for 2010.
- Cleanroom applications and assembly also increased YoY for 2010, according to the IFR.

**Shipments by region, 2010**

- **Asia:** 51%
- **Europe:** 33%
- **Americas:** 15%
- **Others:** 1%

**Market share by region**

- **Americas:** 15%
- **Asia/Australia:** 25%
- **Europe:** 20%
- **Africa:** 15%
- **Total:** 95%

**Source:** IFR
Mechanical: SCARA

Definition: a robot in which the arms have concurrent prismatic or rotary joints.

Principle

Source: Daiwa

Source: IFR

2010 numbers

Worldwide shipments: 15,400
Shipments YoY growth: 285%
Market share: 13%
Peak year: 2010
Peak-year shipment: 15,400

Source: IFR

Key applications

- Cleanroom applications and assembly – the main applications, accounting for about 78% of total demand – increased significantly YoY for 2010, according to the IFR.
- In addition, demand for their use in packaging, picking and placing rose considerably YoY for 2010.

Source: IFR

Shipments by region, 2010

Market share by region

Source: IFR
Mechanical: cylindrical

**Definition:** a robot for which the axes form a cylindrical co-ordinate system.

**Principle**

**2010 numbers**

- **3,955** Worldwide shipments
- **70%** Shipments YoY growth
- **3%** Market share
- **2005** Peak year
- **6,667** Peak-year shipment

**Key applications**

- The electrical and electronics industries saw increased orders for cleanroom applications (the main application for this robot type) in 2010.
- Some 97% of all cylindrical robots installed in Asia in 2010.

**Shipments by region, 2010**

- Asia, 97%
- Europe, 0.4%
- America, 2%

**Market share by region**

- Americas
- Asia/Australia
- Total

Source: IFR
Purpose: handling & machine-tending

Overview

Material-handling was the most important handling operation in 2010. Customers increasingly looked for solutions to automate material-handling during the production process. Robots remove, position, feed, transpose, move, etc. the work piece or the material quickly and precisely.

Machine-tending means handling during assembly, handling operations during glass or ceramics production or food production.

Handling operation

- Material-handling was the biggest demand driver for 2010 with a 13% share, followed by packaging, picking and placing (10%), and plastic moulding (8%).
- Material-handling: demand was mainly from North America, Japan, and Germany.
- Packaging, picking and placing: the biggest market was Korea (72% of demand), due to the country’s heavy investment in the electronics industry, followed by Germany and the US.
- Plastic-moulding: the biggest markets were Germany, Japan and China.

2010 numbers

<table>
<thead>
<tr>
<th></th>
<th>Worldwide shipments</th>
<th>Shipments YoY growth</th>
<th>Market share</th>
<th>Worldwide cumulative units</th>
<th>Cumulative YoY growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>48,162</td>
<td>86%</td>
<td>41%</td>
<td></td>
<td>401,295</td>
<td>3%</td>
</tr>
</tbody>
</table>

Source: IFR

Key applications

- Material-handling: demand was mainly from North America, Japan, and Germany.
- Packaging, picking and placing: the biggest market was Korea (72% of demand), due to the country’s heavy investment in the electronics industry, followed by Germany and the US.
- Plastic-moulding: the biggest markets were Germany, Japan and China.

Shipments by region, 2010

- America 14%
- Europe 33%
- Asia 53%

Source: IFR

Global shipments & market share

![Graph showing global shipments and market share for 2005 to 2010](image)
Purpose: welding and soldering

Overview

Demand for welding robots was on a downward trend from 2005-08 and fell sharply in 2009. In 2010, demand recovered significantly.

Welding

- Welding is the predominant application area, particularly in countries that are major motor-vehicle producers.
- About 77% of total welding-robot shipments for 2010 were shipped to the major car-production centres worldwide: China, Germany, North America, Korea, and Japan.
- For the first time, by far the highest number of units was sold in China, which accounted for 26% of the total demand of welding robots for 2010. This was due to the country’s huge investment in the automotive industry in 2010. Germany ranked No.2, as car manufacturers, in particular, invested in welding robots.

Soldering

2010 numbers

- Worldwide shipments: 30,326
- Shipments YoY growth: 91%
- Market share: 26%
- Worldwide cumulative units: 308,670
- Cumulative YoY growth: 3%

Source: IFR

Key applications

- Welding is the predominant application area, particularly in countries that are major motor-vehicle producers.
- About 77% of total welding-robot shipments for 2010 were shipped to the major car-production centres worldwide: China, Germany, North America, Korea, and Japan.
- For the first time, by far the highest number of units was sold in China, which accounted for 26% of the total demand of welding robots for 2010. This was due to the country’s huge investment in the automotive industry in 2010. Germany ranked No.2, as car manufacturers, in particular, invested in welding robots.

Shipments by region, 2010

- Asia: 60%
- Europe: 20%
- Americas: 14%

Source: IFR

Global shipments & market share

Source: IFR
Purpose: dispensing

Overview

Robots for dispensing accounted for 3% of total demand in 2010 with about 3,900 units sold. Robots for painting and enamelling accounted for almost 2% of total worldwide demand.

Dispensing

- The demand for robots for applying adhesive, sealing materials or similar materials reached a record high in 2010.
- Robots for other dispensing and spraying applications (e.g., powder-coating, the application of mould-release agents, the area-measured application of adhesive, the spraying of wax for conservation purposes) increased continuously from 2005-10.
- Most of the dispensing robots (painting, sealing spraying, etc) were installed in China and Korea in 2010.

2010 numbers

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worldwide shipments</td>
<td>3,907</td>
</tr>
<tr>
<td>Shipments YoY growth</td>
<td>43%</td>
</tr>
<tr>
<td>Market share</td>
<td>3%</td>
</tr>
<tr>
<td>Worldwide cumulative units</td>
<td>42,298</td>
</tr>
<tr>
<td>Cumulative YoY growth</td>
<td>3%</td>
</tr>
</tbody>
</table>

Key applications

- The demand for robots for applying adhesive, sealing materials or similar materials reached a record high in 2010.
- Robots for other dispensing and spraying applications (e.g., powder-coating, the application of mould-release agents, the area-measured application of adhesive, the spraying of wax for conservation purposes) increased continuously from 2005-10.
- Most of the dispensing robots (painting, sealing spraying, etc) were installed in China and Korea in 2010.

Shipments by region, 2010

<table>
<thead>
<tr>
<th>Region</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>80%</td>
</tr>
<tr>
<td>America</td>
<td>14%</td>
</tr>
<tr>
<td>Europe</td>
<td>26%</td>
</tr>
</tbody>
</table>

Source: IFR
Purpose: processing

Overview

Robots for processing accounted for less than 2% of total demand for 2010. Annual sales in this application group have been flat and at a rather low level over recent years.

2010 numbers

- Worldwide shipments: 1,792
- Shipments YoY growth: 81%
- Market share: 1.5%
- Worldwide cumulative units: 22,448
- Cumulative YoY growth: -5%

Source: IFR

Key applications

- The main applications of processing robots include laser-cutting, water-jet cutting, mechanical-cutting/grinding/deburring, and milling/polishing.
- Robots for mechanical cutting/grinding/deburring accounted for the largest number of shipments among processing robots, with annual shipments of 1,036 units for 2010.
- Processing robots accounted for less than 2% of the total demand globally. About 81% of all processing robots in operation were installed in 2010 (1,800 units).

Shipments by region, 2010

- Asia: 67%
- Europe: 24%
- America: 9%

Source: IFR
Purpose: assembling and disassembling

Overview

Annual sales of assembly robots dropped from 15,383 units in 2005 to 5,903 units in 2009, then rose sharply to 12,984 for 2010.

Assembling

Disassembling

2010 numbers

<table>
<thead>
<tr>
<th></th>
<th>Worldwide shipments</th>
<th>Shipments YoY growth</th>
<th>Market share</th>
<th>Worldwide cumulative units</th>
<th>Cumulative YoY loss</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>12,984</strong></td>
<td></td>
<td><strong>120%</strong></td>
<td><strong>11%</strong></td>
<td><strong>95,586</strong></td>
<td><strong>-9%</strong></td>
</tr>
</tbody>
</table>

Source: IFR

Key applications

- About 49% of all assembly robots were shipped to Japan (6,320 units).
- In countries where there is a high volume of electronics production, cleanroom applications and assembly are the most important demand drivers of robots.
- The main applications for assembly and disassembling robots include fixing, press-fitting (including bonding), assembling/mounting/inserting, and disassembling. Fixing and press-fitting accounted for 81% of annual shipments of all assembling and disassembling robots in 2010.

Source: IFR

Shipments by region, 2010

<table>
<thead>
<tr>
<th>Region</th>
<th>% of shipments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>77%</td>
</tr>
<tr>
<td>Europe</td>
<td>9%</td>
</tr>
<tr>
<td>America</td>
<td>14%</td>
</tr>
</tbody>
</table>

Source: IFR

Global shipments & market share

'000 of units

Source: IFR
Purpose: cleanroom and others

Cleanroom robots perform tasks in isolated environments, and are sealed and insulated from dust and air particles. Their surfaces are often ground or painted to prevent deposits from forming.

Cleanroom robots for flat panel display

Cleanroom robots for semiconductor

Source: Daiwa

2010 numbers

Worldwide shipments: 17,879
Shipments YoY growth: 187%
Market share: 15.1%
Worldwide cumulative units: 108,165
Cumulative YoY growth: 6%

Source: IFR

Key applications

- Sales of cleanroom robots for semiconductors and flat-panel displays fell continuously over 2006-09, but tripled in 2010. Both applications were predominantly for the electronics and communication-equipment industries.
- Most of the cleanroom robots were shipped to the few countries that are important suppliers of electronic products: Korea, Japan, the US, Mainland China and Taiwan.
- Unclassified robots accounted for a 1.3% share of total global shipments in 2010, with 1,528 units.
- Sales of other robots (mainly parallel robots) rose by 242% YoY to about 3,450 units in 2010, and accounted for only about 3% of total demand. These robots are used mainly for packaging, picking and placing in the food and beverage industry, the electronics industry and others.

Shipments by region, 2010

Asia 78%
Europe 1%
America 21%

Source: IFR

Global shipments & market share

[Graph showing global shipments and market share for 2005-2010]

Source: IFR
Industry demand ground to a halt at about the time of the global financial crisis in 2008-09, but 2010 robot sales almost doubled compared with those in 2009, to 118,337 units. The automotive and electronics industries were the two main drivers of the strong recovery in demand.

- **Automotive industry**: strengthened its investment in automation to increase production in emerging markets and gain market share in the traditional markets
- **Others**: sectors like rubber and plastics, metal and machinery, food and beverages, and the electronics industry have made large investments to optimise their production processes in 2010.

The IFR expects the industrial robot market to expand in the foreseeable future. It forecasts a shipment CAGR of 6% for 2012-14, with the number of shipments reaching 166,700 units by 2014. As for the outlook for operational industrial robots, the IFR forecasts shipments of them to reach 1.3m units in 2014, up from 1m units in 2010.

If we look closer at the end demand for 2010, we can see that for industrial robots, 41% were for handling, 26% for welding, 14% for cleanroom, and 11% for assembly. Shipments for the electronics industry were especially strong in 2010 (28% for automotive, 26% for electrical/electronics, and 9% for the chemical industry). If we were to analyse the stock of operational industrial robots (based on 1m units in the world in 2010), 39% of them are for handling, 30% for welding and 9% for assembly. This shows us that demand within various industries is gradually shifting, and that overall demand for industrial robots should remain strong in the following years.
From the following charts, we think it is clear that demand from Asia (including Australia and New Zealand) will continue to grow by more than the rest of the world in the following years. IFR forecasts Asia to account for 60% of total worldwide demand by 2014, up from 39% in 2001. If we compare stock levels in 2010, we can see that demand for industrial robots in Asia will increase by 39% YoY until 2014, 7% YoY in Europe, and 27% YoY in the Americas during the same period, based on the IFR numbers. As such, we think this means the outlook for the industrial robot industry looks bright.

The growth in the number of robot installations will come mainly from emerging markets (especially China and Southeast Asia) in the coming years and from North America. Robot supplies to the traditional markets will increase slowly and could even decrease during this period.

<table>
<thead>
<tr>
<th>Region</th>
<th>Country</th>
<th>Growth potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>China</td>
<td>√√√</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>√√</td>
</tr>
<tr>
<td></td>
<td>Korea</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>India</td>
<td>√√</td>
</tr>
<tr>
<td></td>
<td>Southeast Asia</td>
<td>√√</td>
</tr>
<tr>
<td>Americas</td>
<td>Russia</td>
<td>√√</td>
</tr>
<tr>
<td></td>
<td>US</td>
<td>√√√</td>
</tr>
<tr>
<td></td>
<td>Brazil</td>
<td>√√</td>
</tr>
<tr>
<td>Europe</td>
<td>Western Europe</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>Eastern Europe</td>
<td>√√√</td>
</tr>
<tr>
<td></td>
<td>Central Europe</td>
<td>√√√</td>
</tr>
</tbody>
</table>
Demand by region: 2009

- Asia: 53%
- Europe: 31%
- Americas: 15%
- Africa: 1%

Source: IFR

Demand by region: 2014E

- Asia: 61%
- Europe: 22%
- Americas: 17%
- Africa: 1%

Source: IFR forecasts
Demand from Asia

In Asia, most countries will see a considerable increase in the number of industrial robots in operation by 2014. The most dynamic markets are China, Korea and the ASEAN countries. Huge investments by the electronics and motor-vehicle industries were mostly responsible for this large increase in robot sales over the past few years.

Unlike the Americas, Asia is more exposed to the electronics industry. Both Japan and Korea have 45-55% exposure to the electronics industry, and both have a further 19-24% exposure to cleanroom applications. Globally, Taiwan has the highest percentage of robots used in cleanrooms, with 30% of total applications.

By 2014, the number of operational robots in China will be three times higher than in 2010. Japan, on the other hand, will see the number of accumulated operational industrial robots in 2014 falling to below the 2010 level, even though the downward trend in the number of accumulated robots should cease from this year, according to IFR.
### Expectations for China
- IFR estimates an CAGR growth of 20% for 2012-14, which is a lot higher than the 5% for the US.
- Besides the modernisation of existing production sites, industries are building new production sites to gain market share in China’s huge consumer market.
- China is the biggest production site for cars in the world. The PRC Government wants to increase the importance of local companies. As such, it might be only a question of time to when the government will require China-made parts for motor vehicles produced in the country.

### Japan
- The tsunami and nuclear disasters in Fukushima in March 2011 put a halt to the progression being made in the industry.
- Exports of Japanese robots will increase, especially in growing markets. Considering this, we feel it is safe to assume that the number of robots supplied annually to Japan in 2014 might not reach the level seen in 2008. However, due to the increase in exports, production should achieve a new peak. The average annual demand for robots in Japan will rise by about 5% per year over 2012-14, according to IFR.

### Korea
- A further strong increase above the new peak level seen in 2011 is not realistic as Korea is one of the most automated countries in the world. After the huge investment in the electronics and automotive industries in the past few years, a cyclical decrease is highly likely over 2012-14. As a result, robot installations may decrease slightly on average during the 2012-14 period. The IFR forecasts average annual shipments in the period to be 19,667, compared with 24,500 got 2011.

### India
- IFR expects an above-average increase in investment in robots for 2011. Although, this will depend on the extent to which announced projects are executed. However, during 2012-14, we expect a substantial increase in robot installations.
- The automotive industry and some other industries such as the solar technology industry have announced huge investment plans for their production sites in the coming years.
North America and Mexico are the biggest consumers, accounting for 96% of total demand in the Americas in 2010. Interestingly, North America is more exposed to the electronics industry, while Brazil and Argentina are more exposed to the rubber, plastic and metal industries. Both areas see high demand for their automotive industries.

The US Government recently decided to make robotics a priority. Four agencies (the National Science Foundation, the National Institutes of Health, NASA, and the United States Department of Agriculture) have unveiled a joint programme that will provide up to US$70m in research funding for next-generation robotics.

The need to modernise production across all industries is huge. The robot density in North America has increased significantly over the past years, but is still far behind that of Japan, Germany and South Korea. Types of robot: the majority are articulated robots, especially in Canada (>80%), Mexico (>80%), Brazil (70% of total) and Argentina (92%). The US is more diversified and has more exposure to the SCARA type used in the electronics industry.
The European market is more diversified compared with Asia and the Americas. The biggest consumer is Germany, with 46% of the total demand in Europe, followed by Italy 15%, France 7%, Spain 6%, and the UK 3%. Germany saw higher industrial robot demand growth in 2010 compared with the other countries in Europe.

Eastern and Central Europe will see higher demand growth compared with western Europe over 2012-14. During this period, robots installations will rise by about 15% on average per year, higher than the about 5% in Germany over the same period.

Apart from the automotive industry, which is the key end user, Germany, Italy and the UK are more exposed to the metal and chemical industries. France and Spain, however, are more exposed to the food and beverage industries.

### Share in the Europe (shipments in 2010)

<table>
<thead>
<tr>
<th>Country</th>
<th>Market share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>46</td>
</tr>
<tr>
<td>Italy</td>
<td>15</td>
</tr>
<tr>
<td>France</td>
<td>7</td>
</tr>
<tr>
<td>Spain</td>
<td>6</td>
</tr>
<tr>
<td>UK</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>30,600 units (up 50%YoY)</td>
</tr>
</tbody>
</table>

Source: IFR

### Operational robots by country (2010)

<table>
<thead>
<tr>
<th>Country</th>
<th>Market share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>42</td>
</tr>
<tr>
<td>Italy</td>
<td>18</td>
</tr>
<tr>
<td>France</td>
<td>10</td>
</tr>
<tr>
<td>Spain</td>
<td>8</td>
</tr>
<tr>
<td>UK</td>
<td>4</td>
</tr>
<tr>
<td>Others</td>
<td>18</td>
</tr>
</tbody>
</table>

Source: IFR

### Demand YoY in Europe

![Graph showing demand YoY in Europe](source: IFR)

### Shipments by end application industry

![Graph showing shipments by end application industry](source: IFR)

### Demand by purpose (2010)

![Pie chart showing demand by purpose](source: IFR)

### Shipments by industry (2010)

![Pie chart showing shipments by industry](source: IFR)
The automotive industry continues to be the main demand-growth driver worldwide for robot installations, and invests the most in new technologies, additional capacities and renovation of production sites. Investment in general industry (i.e., all industries except for automotive) is gaining momentum as well. The trend towards automation, which was interrupted by the economic crisis in 2008-09, will boost robot installations. This is highlighted by an increasing trend of using robots in the following industries:

- Packaging in the food and beverage industry,
- Pharmaceutical and cosmetics industries, and
- Electronics industry.

It is necessary to provide the right robotic solutions for companies in general industry, as well as focusing on increasing the acceptance of robotics in SMEs by providing more flexible and cost-effective robots. We expect the high volume of orders to come from the automotive industry in next few years. There are many SMEs operating in general industry. Traditionally, SMEs do not invest in robots or if they do, quantities are very low. However, there is a great potential to have a large volume of purchased robots in general industry if SMEs start to order robots, even in small quantities. Due to the large number of SMEs, even low quantity orders can result in an overall large volume.

### Worldwide demand by industry (2010)

<table>
<thead>
<tr>
<th>Industry</th>
<th>% of total robots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>34%</td>
</tr>
<tr>
<td>Electronic</td>
<td>26%</td>
</tr>
<tr>
<td>Food &amp; beverages</td>
<td>9%</td>
</tr>
<tr>
<td>Chemical</td>
<td>8%</td>
</tr>
<tr>
<td>Metal, basic metals &amp; machinery</td>
<td>4%</td>
</tr>
</tbody>
</table>

### % of total robots in automotive industry by country (2010)

- **Slovakia**: 70%
- **Germany**: 60%
- **Spain**: 50%
- **Czech Republic**: 40%
- **Brazil**: 30%
- **France**: 25%
- **Belgium**: 20%
- **North America**: 15%
- **Poland**: 10%
- **United Kingdom**: 5%
- **Rep.of Korea**: 5%
- **Portugal**: 5%
- **Australia**: 5%
- **Italy**: 5%
- **Sweden**: 5%
- **Japan**: 5%

Source: IFR

### High demand in the automotive industry

The following chart shows the huge potential that we see for industrial robots. Even the global automotive industry still has a lot of room for most countries to consume more industrial robots in the following years.

### Number of robots used per 10,000 workers in the auto industry (2010)

- **Japan**: 1,600 (units)
- **Italy**: 1,500
- **Germany**: 1,400
- **USA**: 1,300
- **Spain**: 1,200
- **Republic of Korea**: 1,100
- **France**: 1,000
- **United Kingdom**: 900
- **Slovenia**: 800
- **Canada**: 700
- **Portugal**: 600
- **Taiwan**: 500
- **Sweden**: 400
- **Thailand**: 300
- **Czech Republic**: 200
- **Malaysia**: 100

Source: IFR
The automotive industry is the most important purchaser of industrial robots globally. The industry saw demand growth slow from 2006-09 and pick up in 2010, when the investment in robots was one of the main drivers of the strong recovery in robot shipments. Demand is largely from both the emerging markets and mature markets. For example: the traditional car markets such as those of western Europe, North America and Japan are still heavily investing in this industry because the key players want to gain market share in these relatively saturated markets.

From the following data, we can see that the automotive industry accounts for more than a 30% share of all robot shipments among all industries, regardless of where globally. In addition, Asia seems to be a bigger consumer of industrial robots, with China and Korea leading demand. We expect this trend to continue.

**2010 numbers**

- **Worldwide shipments**: 40,772
- **Share of all industries in terms of 2010 shipments**: 35%
- **Worldwide cumulative units**: 373,223
- **China**: No.1 consumer

**Demand is mainly from…**

- Key production sites: China, Korea, Germany, North America and Japan.
- Emerging markets (China): intensified investment in production capacities for its huge growing internal market.
- Traditional markets: increased investment in robot installations for modernisation and retooling.

**Markets**

**Shipments to automotive industry by country (2010)**

- Korea: 14
- Japan: 12
- North America: 10
- China: 8
- Taiwan: 6
- Germany: 4
- Italy: 2
- France: 0

**Operational units by country (automotive) (2010)**

- Japan: 140
- Germany: 120
- France: 100
- Italy: 80
- Spain: 60
- United Kingdom: 40
- Sweden: 20

**Share by region (automotive industry) (2010)**

- **Asia**: 56%
- **Europe**: 30%
- **Americas**: 14%
- **All others**: 0.1%

**Automotive industry as a % of total industry robot demand by region**

- Europe
- Worldwide
- Asia
- Americas
- All others
The electronics industry (including computers and equipment, radios, TVs and communication devices and equipment, and medical, precision and optical instruments) were the second main driver of the recovery in robot sales in 2010. Also, it is the second-largest user of industrial robots, accounting for 14% of total operational stock as at the end of 2010.

**2010 numbers**

- **Worldwide shipments**: 31,305
- **Share among all industries in terms of 2010 shipments**: 26%
- **Worldwide cumulative units**: 146,539
- **Korea**: No.1 consumer

**Demand is mainly from...**

- 83% of 2010 sales to the **electronics industry** were shipped to Korea, Japan and North America.
- The **electronics industry** is the most important industry in the Korea, Japan and Taiwan. The electronics industry is the second-largest customer in North America and China, with 22% and 12% of total demand, respectively.

## Markets

**Shipments to the electronics industry by country (2010)**

**Share by region (electronics industry) (2010)**

- **Asia**: 78%
- **Americas**: 11%
- **Europe**: 11%

**Electronics industry as a % of total industry robot demand by region (2010)**

**Source**: IFR
The operational stock of industrial robots in the chemical industry has been steadily increasing since 2001, reaching 11% as at the end of 2010. This is also partly the result of more complete coverage from 2004. However, the stock decreased in 2009 by 3% YoY compared with 2008, to 110,100 units.

The chemical/rubber and plastics industries in Japan, North America, China and Germany ordered 59% of this industry’s total worldwide demand 2010.

After years of continuing demand growth, the rubber and plastics industry reduced its investment in robots in 2008 and 2009, from a peak of about 14,800 units in 2007 to 5,800 units for 2009. In 2010, sales increased by 54% YoY to 8,940 units, which is still far below the peak level. The industry’s share of total demand was about 8% in 2010. Robot sales to the pharmaceuticals and cosmetics industry peaked at almost 1,500 units in 2010, accounting for a 1% share of total demand in 2010. Sales grew continuously until 2008 and decreased slightly only in 2009. From 2010, the industry returned to growth.

Markets

Shipments to the chemical industry by country (2010)

Share by region (chemical industry) (2010)

Chemical industry as a % of total industry robot demand by region (2010)
 Demand: metal/machinery industries

- In 2010, sales to the metal product industry recovered by 63% (YoY) to about 4,500 units, which was half of the global volume in 2008. In 2009, only about 2,700 robots were ordered by this industry.

- The metal product industry’s share of 2010 operational robot stock was 5%, which increased by 3% to about 53,600 units over the period. The machinery industry’s share decreased by 7% in 2010 to about 38,200 units.

2010 numbers

9,325 Worldwide shipments

8% Share among all industries in terms of 2010 shipments

97,427 Worldwide cumulative units

China No.1 consumer

Demand is mainly from...

- 76% of the robots used in the metal and machinery industry were supplied to China, Germany, Japan, North America and Italy.

- In 2010, the metal and machinery industry became the most important consumer of industrial robots in Portugal, Sweden and the Netherlands.

Markets

Shipments to metal/machinery industry by country (2010)

Source: IFR

Share by region (metal/machinery industry) (2010)

Source: IFR

Metal/machinery as a % of total industry by region (2010)

Source: IFR
The food and beverage industry increased its robot orders by 32% YoY to almost 4,350 units in 2010, accounting for a 4% share of total demand globally.

The stock in the food industry accounted for almost 3% of the total, 14% higher than in 2009.

**2010 numbers**

<table>
<thead>
<tr>
<th>Worldwide shipments</th>
<th>4,492</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share among all industries in terms of 2010 shipments</td>
<td>4%</td>
</tr>
<tr>
<td>Worldwide cumulative units</td>
<td>26,302</td>
</tr>
</tbody>
</table>

**North America**

- No.1 consumer

**Demand is mainly from...**

- About 58% of global robot sales to this industry were to Europe.
- The food and beverage industry had a relatively high share of annual 2010 robot demand in Spain, France, Belgium, Switzerland and the Netherlands (13-16%).
- The food and beverage industry in North America and Germany ordered the most industrial robots globally, 935 and 913 units respectively, which together accounted for about 41% of total 2010 demand. Italy and Japan followed with 478 and 429 units, respectively.

**Markets**

**Shipments to food & beverage industry by country (2010)**

**Share by region (food & beverage industry) (2010)**

- Europe: 60%
- Americas: 21%
- Asia: 10%
- All others: 1%

**Food & beverage as of total industry by region (2010)**

Source: IFR
Chapter 3
System integration
Integration is the process of programming and outfitting industrial robots so they can perform manufacturing and automation tasks. A robotics integrator is a company that analyses robotic-system needs, provides a plan for automation, and puts the automation into production.

A robotics-system integrator should be able to:
- Perform a feasibility study on clients’ projects
- Provide helpful cost-saving tips
- Produce tooling and part fixtures
- Incorporate the system into clients’ factory settings

Full value chain for building robots and system integration
Fine manipulation/high precision. The installation and change-over times for robot work cells are highly dependent on negotiating tolerances in processes, product geometrics, and product positions/presentation. This last aspect is even more important as product components continue to decrease in size. A goal for robot makers is to achieve greater precision through the use of an increase in the number of sensors and improved sensor data processing.

Human-robot-collaborative work cells. A co-operative task executed by both robot and worker can increase overall productivity.

Co-operating robots. As unit prices drop at increasing rates, the cost of typical robot peripherals can be drastically reduced, while at the same time providing more flexibility. The result is a network of interlinked robots that co-operate on transport, machining, handling and assembling work pieces.

Hyper-flexible manufacturing systems. Product volumes and lifetimes are especially uncertain when it comes to consumer goods. The adaptation of new batches, product variants or new products need to be shortened because specifications have to be altered for rapidly-changing products in short time periods by typically a magnitude of one order compared with today. This should result in the consistent modularisation of manufacturing systems, both in terms of software and hardware:

Micro- and nano-manufacturing. As products become smaller, manufacturing technology has to be scaled. However, materials, manufacturing, processes and design principles for micro-systems differ from traditional products and manufacturing. These micro systems usually incorporate rich sensor capabilities for optimised process control, and robotic devices for the automated handling, assembly and machining of micro-parts. We expect the manufacturing of nano-systems to follow the introduction of radically new and fully automated processes requiring new robotic devices, possible based on completely different motion-generating principles.
The demands of system integration in terms of logistics, automation and control technology are big. For example, fragile substrates, some of which are 1.5 sq m in area but only about 3mm thick, have to be transported and transferred from station to station gently and smoothly, but at the same time rapidly and precisely. We expect process management software to produce efficient workflows, collect relevant product-related data and monitor every work piece, as well as all quality standards. In our case study, Taiwan system integrator, Kenmec Mechanical Engineering (Kenmec, Not rated), usually resolves these tasks and challenges with sound, integrated expertise.
Number of people used in the production of 1GW of photovoltaic capacity (currently)

- Production of poly silicon: 250 to 500
- Ingot process: 250 to 500
- Cell manufacture: 3,000 to 6,000
- Panel lamination & associated applications: 1,500 to 3,000
- Solar system integration: 2,500 to 5,000
- Total: 8,000 to 16,000

75% savings in direct labour

2,000 to 4,000 in total

WITHOUT ROBOTICS

WITH ROBOTICS

Source: Daiwa

Types of robot used in the typical PV process steps

- Silicon Ingot
- Silicon Wafer
- Solar Cell
- Module
- PV System

Variety of arm types depending on volume and process

ARTICULATED
CARTESIAN GANTRY
PARALLEL
SCARA

Source: Adept
Kenmec: raw materials and components used in its solar cell automation

<table>
<thead>
<tr>
<th>Items</th>
<th>Raw materials</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment and systems</td>
<td>steel, iron, aluminium, etc.</td>
<td>In-house design and manufacturing</td>
</tr>
<tr>
<td>Key components</td>
<td>bearing, servo motor, driving belt, spring, die, guide rod, reducer, etc.</td>
<td>Most of the components are purchased from domestic suppliers. Some unique parts are purchased from Japan and Germany. For example, the robot arms are purchased from Fanuc (Japan).</td>
</tr>
<tr>
<td>Electrical control</td>
<td>PC, human-machine interface, sensor, valve, server control, touch switch, power supply, fan, lighting, air cylinder, vision inspector, etc.</td>
<td>Source: Kenmec</td>
</tr>
</tbody>
</table>

Source: Kenmec

Cost structure (2011)

Next 5-10 years

According to Daiwa’s head of solar research, Pranab Sarmah, the industry will reach retail grid parity over the next 2-3 years. By then, the main demand driver will be the availability of project finance, rather than subsidies. This should help underpin integrated photovoltaic-product growth. Advanced and efficient solar technologies will continue to emerge. A large number of players will be consolidated into a few large players over this period, as overcapacity forces weaker players out of the market. We also see industry profit margins settling at the same level as those for typical commoditised products, somewhere around or just below 10%.

PV country installations, GW (2010)

Source: solarbuzz, Daiwa
The industry structure of the TFT-LCD manufacturing supply chain features component suppliers as the upstream companies, manufacturers as the mid-stream companies, and set plants/distributors as the downstream companies. The suppliers provide the manufacturer at each manufacturing stage with components, including bare glass, colour filters, polarisers, flexible printed circuits (FPC), IC drivers, backlight units, and upper covers. The industrial trend in the TFT-LCD industry is the increasing area of the glass substrate. Due to the higher fragility and difficulty in handling glass substrate, demand for both automation and system integration should keep growing in the future.

**TFT-LCD production systems provided by Kenmec**

For array and cell processes, Kenmec mainly provides logistics and conveyor systems.

For LCM and CF processes, Kenmec provides whole-line automation solutions.

**Cost structure**

- Key components 30.0%
- Product line setup 10.0%
- Robot platform 10.0%
- Manufacturing of equipment 20.0%
- Labour 10.0%
- Other 10.0%

Source: Kenmec, Daiwa
Electronic manufacturing services (EMS) industry

A system integrator integrates all the mechanical systems, robotics hardware, software and special subsystems, eg, for positioning, and then programmes the robot to do a task, often with a simulation beforehand. System integrators are a major resale channel for all the main robot suppliers globally. Having a portfolio of system integrators is a key competitive advantage for a robot supplier as it allows entry to new vertical market segments — and it is essential to cover all geographic markets. Often, without a capable S/I, it is hard to enter certain markets.

Cost structure of EMS system integration

Usually, for industrial robotics, the robot itself accounts for perhaps less than half of the actual application costs. In EMS automation systems, one of the main applications for a robot is the assembly function. Taking an assembly system as an example, most of the cost would usually be for programming, followed by the robot, feeders, end-grippers and tooling.

Case study

<table>
<thead>
<tr>
<th>Kentec product lines for EMS (2010)</th>
<th>process</th>
<th>product</th>
<th>share</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electronic module product</strong></td>
<td>Surface mount technology (SMT), assembly and packaging, auto insertion, hand insertion, board level and box level testing, small &amp; medium size TFT LCD/LCM OEM.</td>
<td>Control board for automation machine, LCD TV, TFT LCD, camera module, smartphone main board, 3.5G modem, consumer electronic products</td>
<td>67.8%</td>
</tr>
<tr>
<td><strong>TFT-LCD control board</strong></td>
<td>Backend process, DET process</td>
<td>Touch panel lamination for handsets, notebook PCs, tablets, POS displays, GPS devices, etc</td>
<td>19.0%</td>
</tr>
<tr>
<td><strong>Touch panel product</strong></td>
<td>R&amp;D and sales of electronic products</td>
<td>Blu-ray display, portable media player, IP TV STB, etc</td>
<td>6.6%</td>
</tr>
<tr>
<td><strong>ODM product</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Kentec

Example of an integrated system for the manufacturing of a NB board

Source: Daiwa
Chapter 4

Components
An industrial robot usually comprises five parts: an actuator, robot arms, an end-effector (the robot arms and end-effector are sometimes called the manipulator), sensors, and a controller.

**Sensor**
Est. 2010 market size: US$1.5bn
Leading suppliers: SICK, Futek, Omron

**Actuator**
Est. 2010 market size: US$955m
Leading suppliers: Yaskawa, Siemens

**Robot arm & end-effector**
Est. 2010 market size: US$1.6bn
Leading suppliers: Fanuc, ABB, Yaskawa

**Controller**
Est. 2010 market size: US$1.7bn
Leading suppliers: Omron, Epson, Siemens

Source: Companies, Datamonitor, ABB, Daiwa estimates

**Global robot market size and shares in 2010 (US$m)**

- Whole robots: 57%
- Components: 20%
- Others: 17%

Source: Datamonitor, Daiwa estimates

**Global component market size and shares in 2010 (US$m)**

- Sensors: 24%
- Actuators: 15%
- Robot arm/ end effector: 24%
- Controllers: 27%
- Others: 10%

Source: Datamonitor, Daiwa estimates
Main suppliers of robots and components in Japan

Complete robot

**Industrial robot:**
FANUC, Yaskawa, Kawasaki, DAIHEN, Mitsubishi Electronics, YAMAHA, KOBELCO, Toyoda, Nachi, etc.

**Service robot:**
Honda, Toyota, Fuji Heavy Industries, Hitachi, Toshiba, Mitsubishi, Sony, Fujitsu, NEC, Panasonic, Ishikawajima-Harima Heavy Industries, Kawada, Bandia, Sukudaoriginal, Omron, Alsok, Secom, TMSUK, ZMP, etc.

Sensor

**Visual sensor:**
CCD, Sony, Panasonic, Sharp, Fuji Micro Device, Hamamatsu, Photonics, Mitsubishi, Toshiba, Olympus, Hitachi, Fujitsu, etc.

**Ultrasound sensor:**
Ceramic, Murata, etc.

**Force sensor:**
Nitta, BL EUTOTIC, etc.

**Gyroscope sensor:**
Murata, Sumitomo, Panasonic, NEC-TOKIN, Tokimec, etc.

Actuator

**Linear Motor:**
Yaskawa, Sodick Plastics, Hitachi Metals, Yokogawa, etc.

**Linear motions and drives systems:**
THK, NSK, Sumitomo, etc.

**Servo motor:**
Yaskawa, Mitsubishi, Sanyo, Panasonic, FANUC, Omron, Tarnagawa, etc.

**Reducer:**
TS Corp, Sumimoto, etc.

Control, intelligence

**Biped walking technology:**
Honda, Sony, Kawada, Fujitsu, AOTOMATION, General Robotics, etc.

**Speech recognition technology:**
Asahi-Kasei, NEC, System Technologies, etc.

**Force sensor:**
Nitta, BL EUTOTIC, etc.

**Facial expression control:**
AGI, Kokoro, etc.

**Artificial intelligence:**
Inter Robot, CAI, AGI, etc.

State-of-the-art and Infrastructure technology

The University of Tokyo, Waseda University, Nagoya University, Tokyo Institute of Technology, University of Tsukuba, Tohoku University, Kobe University, Osaka University, Kyoto University, Ritsumeikan University, Hiroshima University, Kyushu University, National Institute of Advanced Industrial Science and Technology, Riken, etc.

Fishbone chart for robot components

**Power module**
- Storage battery
- Power converter
- Storage battery
- Battery exchange
- Touch screen
- PC barebone
- Wireless
- RS232 expansion
- Image capture card
- Video recorder
- Mobile communication interface
- SLAM software

**Environment sensor**
- Temperature sensors arrays
- Flame sensor
- Heat sensor
- CO sensor
- Smoke sensor
- Pressure sensor
- e-compass
- Odometer
- RFID decoding
- Radar scanner
- Ultrasound sensor
- Infrared sensor
- C8051 F005
- ATME 89C51
- Electromagnetically actuated brake
- Propping jockey wheel
- Omni-Directional Wheel

**Distance sensor**
- Robot component
- Propping jockey wheel
- Slotted drive pulley
- Omni-Directional Wheel

**Human-machine interface**
- Touch screen
- PC barebone
- Wireless
- RS232 expansion
- Image capture card
- Video recorder
- Mobile communication interface
- SLAM software

**Platform control**
- C8051 F005
- ATME 89C51
- Electromagnetically actuated brake
- Propping jockey wheel
- Omni-Directional Wheel

**Actuator module**
- Motor
- Motor actuator
- 3 phase encoder
- Electromagnetically actuated brake
- Omni-Directional Wheel

Source: Companies, Daiwa
The actuator is the engine or motor that moves the links into their designated positions. The links are the sections between the joints. Industrial robots generally used one of the following types of drives: hydraulic, electric, or pneumatic. Hydraulic drive systems give a robot great speed and strength. An electric system provides a robot with less speed and strength. Pneumatic drive systems are used for smaller robots that have fewer axes of movement.

### Classifications

**1. Pneumatic actuator**

Many industrial robots use compressed air as their source of motion energy. The compressed air itself, though, requires another source of energy (usually electricity) to form the pneumatic pressure. The components through which the compressed air is distributed (pumps, tubes) require cleaning, refitting, and maintenance.

**Source:** AirTAC

**2. Hydraulic actuator**

Compressed oil as an energy source is generally reserved for robots in heavy manufacturing duties. It is a loud and unclean source of robotic motion, requires a second energy source to move oil through the robotic components, and, like pneumatic sources, requires scheduled maintenance.

**Source:** Daiwa

**3. Electric actuator**

The most common source of energy for robotics motion, electric servo motors are relatively quiet, have less frequent maintenance schedules, and do not rely on a second source of energy. AC/DC Servo, stepper, and brushless motors today power industrial robots as well as some mobile service robots. Most industry service robots and consumer-grade mobile robots rely heavily, however, on battery packs for comotion. Alkaline, lithium-ion, nickel-cadmium, and carbon-zinc batteries are all commonly used for electric actuators.

**Source:** Daiwa
Key players

<table>
<thead>
<tr>
<th>Actuator</th>
<th>Country</th>
<th>Company</th>
<th>Specialty</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Japan</td>
<td>SMC</td>
<td>Cylinder accessories, valve accessories, actuators, connectors, valves and manifolds</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>Yaskawa</td>
<td>World’s largest manufacturer of AC drives and motion control products</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>FESTO</td>
<td>Air reservoirs, valves, pneumatic drives, cylinders, pneumatic connection technology</td>
</tr>
<tr>
<td></td>
<td>USA</td>
<td>Bosch</td>
<td>Hydraulic motion technology, automation products</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>Omron Corporation</td>
<td>Controllers and sensors, motion and drives</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>Siemens</td>
<td>Servo motors, PC based and embedded controllers</td>
</tr>
</tbody>
</table>

Source: Companies

<table>
<thead>
<tr>
<th>Linear motion</th>
<th>Country</th>
<th>Company</th>
<th>Linear motion product line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Japan</td>
<td>THK</td>
<td>Ball screws, linear guideways, roller linear guideways</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NSK</td>
<td>Ball screws, linear guideways, roller linear guideways</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>Star (Bosch)</td>
<td>Linear guideways, roller linear guideways, roller ball screws</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Steinmeyer</td>
<td>Ground ball screws</td>
</tr>
<tr>
<td></td>
<td>US</td>
<td>Thomson (Danaher)</td>
<td>Aerospace ball screws</td>
</tr>
<tr>
<td></td>
<td>Swiss</td>
<td>Schneeberger</td>
<td>Roller linear guideways</td>
</tr>
<tr>
<td></td>
<td>Taiwan</td>
<td>Hiwin</td>
<td>Ball screws, linear guideways, roller screws</td>
</tr>
</tbody>
</table>

Source: Companies

Technology trends

- **2010**
  - Mostly electric, pneumatic, or hydraulic motors; lightweight high-density actuators, standard gears

- **2015**
  - Continuously variable transmissions; ball-socket joints; improved energy-saving and power-weight ratios

- **2020+**
  - High energy efficiency; safe, powerful actuators; micro actuation; use of smart materials; powerful pneumatics and hydraulics

Source: Daiwa
Sensors

Overview

Sensors allow the robot to receive feedback about its environment. They can give the robot a limited sense of sight and sound. The sensor collects information and sends it electronically to the robot being controlled. One use of these sensors is to keep two robots that work closely together from bumping into each other. Sensors can also assist end effectors by adjusting for part variances. Vision sensors allow a pick and place robot to differentiate between items to choose and items to ignore.

Classifications

Laser
Laser sensing technologies are the most commercially promising of the lot. Lasers provide ultra-precise industrial sensing, especially in the welding of joints and seams.

Sonar and radar
Sonar and radar technologies determine distance ranging and proximity detection via time-of-flight detection. The technologies send audible chirps by either a pulse (radar) or modulated wavelength (sonar); echoes are created around objects, then the sound returns to a transducer. Distance and proximity are measured in terms of how long it takes the sound wave to return to the robot sensor. The technologies are popular and most useful with mobile robots that need to navigate unstructured environments. Ultrasensitive sonar can penetrate land, which makes the application especially pertinent to mining applications.

Intensity-based infrared and digital infrared
These sensing technologies rely on the light-sensitive relationships between phototransistors and photoresistors or, in the case of digital infrared, on specific frequency detection. Infrared technologies are best used in distance ranging and proximity detection applications. Infrared technology can be very sensitive to ambient light, so it works best in controlled environments. It is a fairly simple technology to integrate into robot architecture, even those of hobby applications.
Photoreflecting

Photoreflecting sensors interpret the reflecting shades of light in an environment to determine distance, depth, and differences in object density. The most common photoreflecting sensor for robot applications is the cadmium sulphide cell (CdS cell). Such cells are good sensors for indoor use because their sensitivity can determine subtle shadows around edges of objects and allow for fairly precise mobility within an indoor environment.

Source: Daiwa

Tactile

Tactile sensing technologies include bumpers and bend sensors. Bumpers are made of plastic or rubber and are mounted on the periphery of the robot. When the bumper comes in contact with an object, a tiny switch is activated inside the robot and the resulting electrical impulse is the catalyst that tells the robot to ‘back away’. Bend sensors work in the same fashion, but they are long and protrude from the robot’s body-like whiskers.

Source: Daiwa

Video/optical

The most important technology concerning video and optical sensing systems is still-infant stereo visioning technology. Stereo vision sensing usually involves two cameras mounted on a mobile robot. The cameras will capture a 3-D image, but problems still arise when the 3-D image is consolidated into 2-D for use and analysis by the robot. The cameras capture large amounts of information, including colour, so the technology relies on intense processing speeds for real-time robot reactions.

Source: Daiwa

Piezo

Piezo technology is currently used heavily in gyroscopic duties pertaining to equilibrium applications, such as in proper balancing and precise turning of planes and helicopters. Piezo sensors can be of a very small size, making them useful for even hobby applications, but they are also precise enough for industrial applications. The ceramic and quartz technologies inherent to piezo sensors make them relatively expensive.

Source: Daiwa
Key players

<table>
<thead>
<tr>
<th>Country</th>
<th>Company</th>
<th>Specialty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>Olympus Optical Co.</td>
<td>Optical sensors</td>
</tr>
<tr>
<td>Japan</td>
<td>Omron Corporation</td>
<td>Controllers and sensors</td>
</tr>
<tr>
<td>USA</td>
<td>Reis Robotics</td>
<td>Robot sensing systems</td>
</tr>
<tr>
<td>USA</td>
<td>RG Software</td>
<td>Automation and voice recognition software</td>
</tr>
<tr>
<td>Canada</td>
<td>Servo-Robot Inc.</td>
<td>Sensors for arc welding; laser sensors</td>
</tr>
<tr>
<td>USA</td>
<td>Futek</td>
<td>Sensor technologies and robot accessories</td>
</tr>
<tr>
<td>Germany</td>
<td>SICK</td>
<td>Sensor technologies</td>
</tr>
</tbody>
</table>

Source: Company, Daiwa

Technology trends

- 2010
  - Gradual replacement of special hardware (frame grabbers, cameras); 3D vision sensors with a low resolution

- 2015
  - Higher frame rate of visual sensors; greatly improved 3D vision sensors, no moving parts in laser scanners

- 2020+
  - Visual processes on sensor or dedicated processors; multimodal sensing for intrinsic safety

Source: Daiwa
Robot arms and end effectors

Overview

Robot arms
Robot arms can vary in size and shape. The robot arm is the part that positions the end effector. With the robot arm, the shoulder, elbow, and wrist move and twist to position the end effector in the exact right spot. Each of these joints gives the robot another degree of freedom. A simple robot with three degrees of freedom can move in three ways: up and down, left and right, and forward and backward. Many industrial robots in factories today are six-axis robots.

End effector
The end effector connects to the robot's arm and functions as a hand. This part comes in direct contact with the material the robot is manipulating. Some variations of an effector are a gripper, a vacuum pump, magnets, and welding torches. Some robots are capable of changing end effectors and can be programmed for different sets of tasks.

Categories

<table>
<thead>
<tr>
<th>Grippers</th>
<th>Rubber-plated phalanges (generally two large phalanges per tool) utilized for grasping, turning, lifting, or placing objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lasers</td>
<td>Emit beams of light used for cutting or discovery of location</td>
</tr>
<tr>
<td>Deburrers</td>
<td>Grind the imperfections off of metal to make smooth surfaces</td>
</tr>
<tr>
<td>Carriers</td>
<td>Generally long fork-like or flat table-like appendages used to pick up boxes and pallets</td>
</tr>
<tr>
<td>Torches</td>
<td>Flame emitters used primarily in welding applications</td>
</tr>
<tr>
<td>Brushes</td>
<td>Can be used as sanding advocates, painting tools, material application tools, or debris lifters</td>
</tr>
<tr>
<td>Vacuum handlers</td>
<td>Use air suction to grip, move, and place objects</td>
</tr>
<tr>
<td>Nano-technological</td>
<td>Extremely specialised tools that provide certain robots the ability to perform atomic-level functions</td>
</tr>
</tbody>
</table>

Key players

<table>
<thead>
<tr>
<th>Country</th>
<th>Company</th>
<th>Specialty</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>PHD, Inc.</td>
<td>End-of-arm tools and actuators</td>
</tr>
<tr>
<td>Swiss</td>
<td>Staubli</td>
<td>Six-axis industrial robots</td>
</tr>
<tr>
<td>England</td>
<td>TM Robotics</td>
<td>SCARA and Cartesian robotic arms</td>
</tr>
<tr>
<td>USA</td>
<td>Yamaha Robotics</td>
<td>SCARA and Cartesian assembly robots</td>
</tr>
<tr>
<td>USA</td>
<td>Zaytran</td>
<td>Grippers</td>
</tr>
<tr>
<td>Swiss</td>
<td>ABB</td>
<td>Industrial robots</td>
</tr>
<tr>
<td>USA</td>
<td>Adept Technology, Inc.</td>
<td>Small parts assembly robots</td>
</tr>
<tr>
<td>USA</td>
<td>Anver Corporation</td>
<td>Vacuum end-effectors and other vacuum technologies</td>
</tr>
<tr>
<td>USA</td>
<td>Applied Robotics</td>
<td>Robot parts; tool changers; collision sensors</td>
</tr>
<tr>
<td>Japan</td>
<td>FANUC Robotics</td>
<td>Full line of manufacturing robots</td>
</tr>
<tr>
<td>Japan</td>
<td>Yaskawa-Motoman</td>
<td>Automated robotic solutions, controllers</td>
</tr>
</tbody>
</table>

Source: Companies
Technology trends

2010
• Task-specific end effectors, especially grippers, mostly pre-programmed or taught grasping strategies; flexibility with tool changers

2015
• Multifinger grippers for a variety of objects; grasps computed online; gripping of human tools

2020+
• Dexterous hands; grasping of all objects; use of multiple hands; future goal: human dexterity and assembly skills

Source: Daiwa
Controllers

Overview

The controller is the ‘brain’ of the robot and allows the parts of the robot to operate together. It works as a computer and allows the robot to also be connected to other systems. The controller runs a set of instructions written in code called a programme. The programme is inputted with a teach pendant. Many of today’s industrial robots use an interface that resembles or is built on the Windows operating system.

Functions

- User interface
- Data storage
- Interaction with other computational resources
- Real-time control of joints’ motion
- Sensor data acquisition
- Interaction and synchronization with other machines
- Motion planning

Source: Daiwa

Key players

<table>
<thead>
<tr>
<th>Country</th>
<th>Company</th>
<th>Specialty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Joker Robotics</td>
<td>Controllers and mobile robot systems</td>
</tr>
<tr>
<td>Japan</td>
<td>Omron Corporation</td>
<td>Controllers and sensors</td>
</tr>
<tr>
<td>USA</td>
<td>Kawasaki Robotics</td>
<td>Controllers: industrial robots</td>
</tr>
<tr>
<td>USA</td>
<td>Epson Robotics</td>
<td>PC-based robot control software</td>
</tr>
<tr>
<td>Japan</td>
<td>Olympus Corp.</td>
<td>Process and control equipment</td>
</tr>
<tr>
<td>Germany</td>
<td>Siemens</td>
<td>PC based and embedded controller</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Advantech</td>
<td>PC based and embedded controller</td>
</tr>
<tr>
<td>USA</td>
<td>Adept</td>
<td>Industrial robots, robot and motion control</td>
</tr>
<tr>
<td>Japan</td>
<td>Yaskawa-Motoman</td>
<td>Automated robotic solutions, controllers</td>
</tr>
</tbody>
</table>

Source: Companies
The Automation Primer
Spring 2012

Technology trends

2010
- Control through cascades; state-space controllers; sliding-mode controller; feedback linearisation

2015
- Predictive, distributed, self-calibrating, self-tuning controllers

2020+
- Fault-tolerant controllers; automatic reconfiguration of controllers

Source: Daiwa
Chapter 5

Cross-country analysis of the Pan-Asia players
The demand for industrial robots in Japan was about 22,000 units in 2010, about 70% higher than in 2009. Japan has by far the highest robot density in the world. The largest number of industrial robots operating in the factories around the world are in Japan.

Japan is the predominant robot manufacturing country. In 2010, about 60% of global annual supplies were produced in Japan.

The market size of industrial robots has been falling continuously in Japan since reaching a peak of almost 44,000 units in 2005.

In 2010, the total operational stock of robots declined considerably by 14% YoY to 286,000 units.
China

China is the most rapidly growing robot market in the world. It was ranked No. 3 after Japan and Korea in terms of market size (in terms of sales volume) in 2010.

Most of the robots in China are imported from Japan, Europe or North America, with more than 70% coming from Japan. China conducts major research in robotics in co-operation with the system integrators using Japanese or European robots.

Huge investments in the automotive industry, especially by other countries in Asia, have boosted robot installations in China over the past years.

In 2010, 15,000 industrial robots were sold to China, about 170% more than in 2009.

The operational stock or accumulated sales at the end of 2010 was at least 52,300 units (up 40% YoY).

### Market size

#### Demand for industrial robots

```
<table>
<thead>
<tr>
<th>Year</th>
<th>Units</th>
</tr>
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<tbody>
<tr>
<td>2001</td>
<td>0.7</td>
</tr>
<tr>
<td>2002</td>
<td>0.5</td>
</tr>
<tr>
<td>2003</td>
<td>1.5</td>
</tr>
<tr>
<td>2004</td>
<td>3.5</td>
</tr>
<tr>
<td>2005</td>
<td>4.5</td>
</tr>
<tr>
<td>2006</td>
<td>5.8</td>
</tr>
<tr>
<td>2007</td>
<td>6.6</td>
</tr>
<tr>
<td>2008</td>
<td>7.9</td>
</tr>
<tr>
<td>2009</td>
<td>5.5</td>
</tr>
<tr>
<td>2010</td>
<td>15.0</td>
</tr>
</tbody>
</table>
```

Source: IFR

#### Operational stock of industrial robots

```
<table>
<thead>
<tr>
<th>Year</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>0.6</td>
</tr>
<tr>
<td>2000</td>
<td>0.9</td>
</tr>
<tr>
<td>2001</td>
<td>1.6</td>
</tr>
<tr>
<td>2002</td>
<td>2.2</td>
</tr>
<tr>
<td>2003</td>
<td>3.6</td>
</tr>
<tr>
<td>2004</td>
<td>7.1</td>
</tr>
<tr>
<td>2005</td>
<td>11.6</td>
</tr>
<tr>
<td>2006</td>
<td>17.3</td>
</tr>
<tr>
<td>2007</td>
<td>23.9</td>
</tr>
<tr>
<td>2008</td>
<td>31.8</td>
</tr>
<tr>
<td>2009</td>
<td>37.3</td>
</tr>
<tr>
<td>2010</td>
<td>52.3</td>
</tr>
</tbody>
</table>
```

Source: IFR

### 2010 market share by application and industry

#### By application

- Handling: 30% (2010), 25% (2009), 20% (2008)
- Welding: 25% (2010), 20% (2009), 15% (2008)
- Dispensing: 15% (2010), 10% (2009), 5% (2008)
- Assembling: 10% (2010), 5% (2009), 2.5% (2008)
- Cleanroom: 5% (2010), 2.5% (2009), 1% (2008)
- Others/unspecified: 5% (2010), 7.5% (2009), 10% (2008)

Source: IFR

#### By industry

- Automotive: 55% (2010), 50% (2009), 45% (2008)
- Electrical/electronics: 12% (2010), 10% (2009), 8% (2008)
- Rubber and plastics: 10% (2010), 12% (2009), 14% (2008)
- Metal: 12% (2010), 10% (2009), 8% (2008)
- Food: 2% (2010), 2% (2009), 2% (2008)
- Other vehicles: 2% (2010), 2% (2009), 2% (2008)
- Others: 7% (2010), 5% (2009), 3% (2008)

Source: IFR
In 2010, Korea became the largest robot market in the world following Japan in terms of annual demand. The country has the third-highest level of robot density in the world, trailing Japan and Germany.

The most important industries are the automotive and electronics industries.

The estimated operational stock of robots at the end of 2010 had reached some 101,000 units, representing an increase of 28% YoY.

### 2010 market share by application and industry

#### By application

- Handling
- Welding
- Dispensing
- Processing
- Assembling
- Cleanroom

#### By industry

- Industrial machinery 28%
- Chemical, rubber and plastics 3%
- Motor vehicles 3%
- Communication 4%
- Motor vehicles 28%
- Chemical, rubber and plastics 3%
- Metal Product 1%
- Specified 2%
- Automotive parts 2%
- Others 4%
- Unspecified 11%
- Unspecified 0%
Taiwan

Demand for industrial robots

The electrical/electronics industry – especially electronic components, communications equipment and automotive electronics – is highly developed in Taiwan. The automotive industry is dominated by Japanese motor vehicle suppliers. Taiwan is also an important production site for body parts and plastic parts for the automotive industry. The country is heavily dependent on China as a major export nation.

In 2010, the size of the robot market (in terms of sales volume) increased by 123% YoY to 3,300 units, almost the same level as in 2008 before the 2008-09 financial crisis. In 2010, investment in the electrical/electronics industry and metal and machinery industry increased considerably.

The operational stock at the end of 2010 was estimated at about 27,000 units, or 10% above the 2009 level. Total accumulated sales up to the end of 2010 amounted to about 33,000 units.

Operational stock of industrial robots

2010 market share by application and industry

By application

By industry

Source: IFR

Source: IFR
### Policy and vision comparisons

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>China</th>
<th>Korea</th>
<th>Taiwan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fiscal budget</strong></td>
<td>US$57.6bn (2007)</td>
<td>863 program: Rmb106bn/5 years</td>
<td>n.a.</td>
<td>US$167m/4 years</td>
</tr>
<tr>
<td><strong>Goal</strong></td>
<td>To reach domestic market size of ¥6.2tn by 2025</td>
<td>To reach 13.3% global market share by 2013, 20% by 2018; production value to reach W4tn by 2013, W20tn by 2018</td>
<td>To reach 13.3% global market share by 2013, 20% by 2018; production value to reach W4tn by 2013, W20tn by 2018</td>
<td>Production value double by 2020, labour force to grow 50% by 2013, double by 2020.</td>
</tr>
</tbody>
</table>
| **Production Value (industrial + service)** | 2006: ¥725.9bn  
2008: ¥1tn | 2006: W766bn  
| **Industrial Robot (whole robot/ components)** | Leading sales and exports of whole robots in the world. Leading sales of components for: numerical controls, servo motors, and sensors, etc. | Fast development in automation products and automated product lines | Highly autonomous automotive and semi industries to support domestic demands. Most robots (>60%) currently rely on imports. | Mass usage for semi and FPD industries, but the robots and components are mostly imported. Local players provide system integration and maintenance. |
| **Service Robot (whole robot/ components)** | Human-like technology is leading the world. Actively developing in professional cleaning, securities, and other robotic applications | Focus on demand for applications in service robots and hazard robots, developing technologies in design, manufacture, intelligent control, and system integration. | Forming robotics market by establishing linkage between communication, robotics/components/ contents and software industries. | Three-phase emphasis on development in education, entertainment, home, and care products. Goal is to become design and manufacturing centre for intelligent robots. |
| **Key end application fields** | Japanese government is funding growing industries such as photovoltaic, lithium-ion batteries and electric vehicles. | Various types of industries to build new production sites in order to gain market share. | Emerging investment in OLED, LED lighting, thin-film solar cell, polycrystalline silicon. | Electronics industry and machinery industry |
| **Development features** | Developing service robots on the back of advantage in industrial robot. Main focus is to solve domestic problems, such as aging populations, labour shortage, etc. Preparing for commercialization. | Upgrade and transform the industries to strengthen competitiveness; develop emerging industries; high-end and intelligent equipment manufacture. | To develop home robots based on its ICT infrastructure. Viewing robotics as fundamental and integrated technology. Established Intelligent Development and Penetration Enhancement Policies. | Ability to combine IT, communication EMS competence to develop robot. Long-term development in key components. Targets to increase the proportion of industrial robots, as well as paid-in resource and reinforce supportive measurements. |

Source: IEK

### Robotics comparison

<table>
<thead>
<tr>
<th>Area</th>
<th>Degree or level of activity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input</strong></td>
<td>U.S.</td>
</tr>
<tr>
<td>Basic, university-based research (individuals, groups, centres)</td>
<td>*****</td>
</tr>
<tr>
<td>Applied, industry-based research (corporate, national labs)</td>
<td>**</td>
</tr>
<tr>
<td>National or multi-national research initiatives or programmes</td>
<td>**</td>
</tr>
<tr>
<td>University-industry-government partnerships</td>
<td>**</td>
</tr>
<tr>
<td>Robotic vehicles: military and civilian</td>
<td>****</td>
</tr>
<tr>
<td>Space robotics</td>
<td>**</td>
</tr>
<tr>
<td>Humanoids</td>
<td>**</td>
</tr>
<tr>
<td>Industrial robotics: manufacturing</td>
<td>**</td>
</tr>
<tr>
<td>Service robotics: non-manufacturing</td>
<td>**</td>
</tr>
<tr>
<td>Personal robotics: home</td>
<td>**</td>
</tr>
<tr>
<td>Biological and biomedical applications</td>
<td>****</td>
</tr>
</tbody>
</table>

Source: WTEK
### SWOT analysis for the Greater China players

#### Strengths
- Integrated vertical and horizontal supportive systems for ICT and machinery industries
- Intact industrial clusters with integrated supply chain of upstream and downstream components
- High quality of human resources
- High local content rate and considerable experience of domestic panel makers

#### Weaknesses
- Low self-manufacturing capability in controllers, high-efficiency AC servo motors and high-precision reducers
- Technology and human resources for ICT have not been fully integrated with automation industries
- Current automation equipment interface standard needs to be improved
- Brand recognition needs to be improved

#### Opportunities
- Development in supporting upgrade for manufacturing sector and automation for service sector
- Growing labour costs in China, greater demands for automation
- Liberalisation of cross-Strait trade, greater opportunities for local automation-equipment industry

#### Threats
- Heavy reliance on overseas suppliers for key components, including motor-drive modules, controllers, visual modules
- Europe, the US, and Japan are leading in technology, with emerging markets behind them
- High demand for local content rate due to the signing of the Economic Cooperation Framework Agreement with Taiwan

Source: Daiwa
Chapter 6

Conclusions
The Japan Ministry of Economy, Trade and Industry (METI) and the New Energy and Industrial Technology Development Organization (NEDO) have announced projections for the robot market to expand to ¥9.7tn by 2035, driven by the expansion of robots into new sectors such as services, in addition to growth in manufacturing and other existing sectors.

We believe the current industrial robot supply chain will still enjoy secular growth in the next few years, especially for the technology leaders and market-share gainers. The next investment opportunities lie in the service robot supply chain, in which the market size (in value) for the consumer market (personal use) has higher growth than that for the professional market (based on the IFR forecasts, we estimate revenue CAGRs of 36% and 5% respectively for 2011-14). The biggest applications include medical robotics, field robotics, defence applications and personal use robots. Please refer to the supplier list of service robot on page 9.

Within the personal-use robot market, we forecast both domestic robots and entertainment robots to enjoy high revenue CAGRs from 2011-14 (42% and 21%, respectively). Domestic robots will have a larger market size (in terms of revenue) by 2014, according to the IFR, with a size of about 4x that of entertainment robots. The market size for domestic robots by 2014 should be around a similar size to that for field robots (biggest sub-market for professional robots), and will be bigger than the medical robot market.

Technologies related to entertainment and domestic robots have become more and more mature over the past few years, with many developed countries investing in and manufacturing a diverse number of applications. According to IFR, the total market value for domestic robots in 2010 was US$369m and US$159m for entertainment robots. IFR estimates the total market value for the period of 2011 to 2014 to amount to US$4.3bn for domestic robots and US$1.1bn for entertainment robots. For domestic robots, we estimate that total annual shipments could reach 3.1m units in 2014 from 1.4m units in 2010, implying a 4-year CAGR of 21%. For entertainment robots, we estimate that total annual shipments will reach 1.4m units in 2014, from 0.76m in 2010, implying a 4-year CAGR of 17%.

For professional robots, the most significant emerging investment opportunities are in field robots. Field robots refer to those robotic technologies other than industrial robots that can be applied to working fields, typically for traditional non-tech industries such as agriculture, milking, farming, and mining, etc. The global market value of field robots was US$744m in 2010. IFR forecasts a total market value of US$4.9bn for the period from 2011 to 2014. We estimate the annual total shipment of field robots to reach 8,563 units in 2014 from 4,198 in 2010, implying a 4-year CAGR of 20%.

Medical and defence robots currently are the main applications among professional robotics. In the short term, the growth potential would not be as large as other professional robots for two main reasons. First of all, the entry barriers for medical and defence robots are high considering their high cost and technology requirement, which would confine the penetration to some level. Second, the applications for medical and defence robots have been highly concentrated in a few developed countries, such as the US, Japan, and Germany in the past, and will...
continue to be so over the next few years. Although the applications are unlikely to take off in the next 2-3 years, these two fields are still good long-term growth stories for investment since it is foreseeable that the entry barrier and investment cost will be lowered to a level enabling more and more nations to increase their applications in the medical and defence robotics fields.

## Opportunities for different applications

<table>
<thead>
<tr>
<th>Application Category</th>
<th>Current Businesses</th>
<th>Emerging Economies</th>
<th>Robots for Small Companies</th>
<th>Emerging Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Robotics</td>
<td>Multipurpose Robots</td>
<td>Used Robots</td>
<td></td>
<td>Advanced Enabling Technologies</td>
</tr>
<tr>
<td></td>
<td>Emerging Economies</td>
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<td>Multiskilled Robots</td>
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<tr>
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<td>Robots for Small Companies</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Defense</td>
<td>UAVs</td>
<td>UGVs</td>
<td>Bomb Disposal</td>
<td>Military Human Augmentation</td>
</tr>
<tr>
<td>Professional Service</td>
<td>Security</td>
<td>Cleaning</td>
<td>Underwater</td>
<td>Medical Robots</td>
</tr>
<tr>
<td></td>
<td>Inspection, Maintenance, and Construction</td>
<td>Public Relations</td>
<td>Fire and Rescue</td>
<td>Combat Robots</td>
</tr>
<tr>
<td>Entertainment</td>
<td>Toy and Leisure Robots</td>
<td>Robot Retail</td>
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<td>Agricultural Robots</td>
</tr>
<tr>
<td>Domestic Robots</td>
<td>Floor Cleaning</td>
<td>Lawn Mowing</td>
<td></td>
<td>Public Assistance</td>
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<tr>
<td>Health Care</td>
<td>Robotic Surgery and Tele-medicine</td>
<td>Pharmacy Automation</td>
<td></td>
<td>Environmental Robotics</td>
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<tr>
<td>Technology Diffusion</td>
<td>Assisted Vehicles</td>
<td></td>
<td></td>
<td>Toy Robots That Become Tool Robots</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>General Humanoid Robots</td>
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<td></td>
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<td>General Home Assistance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Elder Care Robots</td>
</tr>
</tbody>
</table>

Source: SRIC-Bi

Note*: Classified as professional service robot
### Market size

#### Worldwide service robots market size

<table>
<thead>
<tr>
<th></th>
<th>Sales in units</th>
<th>Sales in US$m</th>
<th>Sales in US$m</th>
<th>Sales in US$m</th>
<th>2011-14E CAGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional robots</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Field robotics</td>
<td>4,013</td>
<td>4,198</td>
<td>708</td>
<td>744</td>
<td>4,854</td>
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<tr>
<td>Medical robotics</td>
<td>816</td>
<td>932</td>
<td>1,022</td>
<td>1,361</td>
<td>4,850</td>
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<tr>
<td>Defence applications</td>
<td>6,070</td>
<td>6,125</td>
<td>723</td>
<td>696</td>
<td>2,468</td>
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<tr>
<td>Other professional service robots</td>
<td>13</td>
<td>16</td>
<td>302</td>
<td>357</td>
<td>2,123</td>
</tr>
<tr>
<td>Total number of units/estimated value of professional robots</td>
<td>13,249</td>
<td>13,741</td>
<td>2,754</td>
<td>3,158</td>
<td>14,295</td>
</tr>
<tr>
<td>Personal/domestic robot</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robots for domestic tasks</td>
<td>1,048,488</td>
<td>1,444,806</td>
<td>256</td>
<td>369</td>
<td>4,262</td>
</tr>
<tr>
<td>Entertainment robots</td>
<td>575,917</td>
<td>753,285</td>
<td>123</td>
<td>159</td>
<td>1,094</td>
</tr>
<tr>
<td>Other personal/domestic service robots</td>
<td>350</td>
<td>400</td>
<td>9</td>
<td>10</td>
<td>32</td>
</tr>
<tr>
<td>Total number of units / estimated value of personal/domestic service robots</td>
<td>1,624,803</td>
<td>2,198,540</td>
<td>388</td>
<td>538</td>
<td>5,393</td>
</tr>
<tr>
<td>Total service robot</td>
<td>1,638,052</td>
<td>2,212,281</td>
<td>3,142</td>
<td>3,696</td>
<td>19,688</td>
</tr>
</tbody>
</table>

Source: IFR, Daiwa estimates

### Market forecasts for nonindustrial robots and related sectors

<table>
<thead>
<tr>
<th>Research organization</th>
<th>Market sector description</th>
<th>Existing market status</th>
<th>Future market status</th>
</tr>
</thead>
<tbody>
<tr>
<td>IFR</td>
<td>Professional-service robots</td>
<td>39,000 units in 2006</td>
<td>75,000 units in 2010</td>
</tr>
<tr>
<td>IFR</td>
<td>Personal and domestic robots</td>
<td>3.5m units in 2006</td>
<td>7m units in 2010</td>
</tr>
<tr>
<td>ABI Research</td>
<td>Components for personal robots</td>
<td>US$12bn in 2015</td>
<td></td>
</tr>
<tr>
<td>Electronics ca</td>
<td>Educational-robot kits</td>
<td>541,000 units, worth $27.5m, in 2007</td>
<td>35.8m units, worth US$1.69bn in 2014</td>
</tr>
<tr>
<td>Electronics ca</td>
<td>Global market for entertainment and educational robots</td>
<td>US$184.9m in 2007</td>
<td>US$38bn in 2014</td>
</tr>
<tr>
<td>Ministry of Economy, Trade, and Industry (Japan)</td>
<td>Japanese robot market (including industrial robots)</td>
<td>¥500bn in 2003</td>
<td>¥1.8tn in 2025</td>
</tr>
</tbody>
</table>

Source: IFR, ABI Research, Electronics.ca, MarketResearch.com, SRIC-BI

### Home robot shipments by region

Source: ABI Research forecasts

### Home robot shipments by function

Source: ABI Research forecasts
## Reasons to expand the market – past vs. now

### Robot manufacturers' strategy to expand market

<table>
<thead>
<tr>
<th>Areas</th>
<th>Expansion strategy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existing purpose</strong></td>
<td>Cutting costs</td>
<td>Manufacturing localisation, production scale enlargement</td>
</tr>
<tr>
<td>Enlarge support</td>
<td>Overseas supportive unit expansion</td>
<td></td>
</tr>
<tr>
<td>Expand Asia market</td>
<td>Expand sales channel, explore local user market</td>
<td></td>
</tr>
<tr>
<td>Develop high value-added product</td>
<td>Diversification into high value-added products, such as linear motors</td>
<td></td>
</tr>
<tr>
<td>Expand application</td>
<td>Feasible recommendations on applications</td>
<td></td>
</tr>
<tr>
<td>Strengthen proposing ability of systems</td>
<td>Strengthen the ability of making recommendations from peripheral systems</td>
<td></td>
</tr>
<tr>
<td>Cultivate strong system integrators</td>
<td>Co-operate with system integrators to strengthen proposing ability and intensify training programmes</td>
<td></td>
</tr>
<tr>
<td>Improve operability</td>
<td>Lower the technology threshold, gain market share in mid-small scale users</td>
<td></td>
</tr>
<tr>
<td>Introduce to non-automated productions</td>
<td>To automate the assembly lines that were previously difficult to automate</td>
<td></td>
</tr>
<tr>
<td>Business cooperation</td>
<td>Co-operation between R&amp;D, production, and sales</td>
<td></td>
</tr>
<tr>
<td>Localized manufacturing</td>
<td>Local manufacturing of robots in large size, such as transporting LCD glass</td>
<td></td>
</tr>
</tbody>
</table>

| **Emerging purpose**         | Expand similar purpose                  | e.g. transporting LCD glass ➔ transporting solar photo-electricity panels  |
| Expand green purpose         | High value-added green robots            |                                                                             |
| Co-develop                   | Co-develop new applications with tool makers |                                                                             |
| Improve operability          | Lower technology threshold, broadening application spectrum |                                                                             |
| Expand non-automotive areas  | To cope with the rapidly changing market situation and lower return on investment |                                                                             |

Source: Fuji Economy
The industry has undergone many changes and improvements in process automation, with an increasing trend recently towards flexible automation solutions. As a result, the robotic sector has received a great market thrust, with greater acceptance and usage in various industrial sectors. Moreover, robotics with advanced sensing-control-actuation systems that can be programmed for complex activities are further widening the scope of applications.

Current and long-term impact of the drivers and challenges that govern the growth of service robotics industry

- **Flexible automation systems.** Incorporating robotics is the key to increased productivity, better economics and guaranteed product quality, given robotics’ flexibility to handle frequent production changes and an increasing number of product variants. The increasing pace at which global industrial markets change force manufacturers to adopt flexible and efficient automation systems that can be easily programmed to effect any change in an operation conduct. With globalization, there is an increased need for manufacturers to work around changing product volumes and product types across the entire end-user spectrum. In such cases, redeployment of existing equipment saves a lot of cost for the manufacturing sector. Robots with reprogrammable mechanical structures are inherently multipurpose due to their modular design. Improved software matched with intelligent integration makes retooling and changeovers economically feasible at extremely fast rates on the order of milliseconds.

- **Able to handle high volume.** High-volume markets, such as electronics, industrial manufacturing, food and beverage, and pharmaceuticals, most often resort to robotic solutions due to their promising ability to handle high volumes at very high speeds of manufacturing.

- **Consistent precision** is also a highly desirable feature in the manufacturing industry. Precision requirements are extremely stringent in industrial sectors, such as electronics and pharmaceuticals. Robotic systems guarantee precision and accuracy at repeatable, high precision tasks, which make them capable of finding applications in several end-user sectors.

- **A systematic combination** of sensors, controls, and manipulators help in building an intelligent robot. Although robots have proven to be applicable in a number of areas, such as medicine, defence, space, hazardous materials, factory automation, and many others, funding research in newer domains and
applications fronts is still a persisting problem. The development of both computers and robotics has improved productivity, efficiency, and product quality in factory applications. Mechatronics is the newest field, which has been gaining importance.

- From a market development perspective worldwide, **manufacturing robots** are largely researched and manufactured in Japan, followed by Europe. Research on biological and medical applications is the main focus in the US and Europe unlike other parts of the world. **Service robotics** is predominantly focused in Korea, followed by a moderate level of contribution from the US, Japan, and Europe. Humanoid and personal robots are largely manufactured in Japan followed by Korea. While it comes to security and space applications, the major market players are in the US followed by Europe.

- On the whole, a wide knowledge base is required for the design and operation of robotic systems. A researcher working on robotic systems should have a sound understanding of feedback control, sensor and signal conditioning, hardware and computer interfacing, modelling and analysis of dynamic systems, computer programming, actuator control and power electronics.

### Potential implications of change

<table>
<thead>
<tr>
<th>Potential impact</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Service Applications Expand</strong></td>
<td>Occupational-safety regulations increase. Humans reject dull or dangerous jobs. Health-care applications accelerate. The cost of service robots decreases.</td>
</tr>
<tr>
<td><strong>B. Industrial demand increase</strong></td>
<td>Emerging economies demand more robots. The cost of deploying robots continues to decline. Shortage of skilled labor exists globally. Smaller firms adopt robots.</td>
</tr>
<tr>
<td><strong>C. Enabling robotics technologies advance.</strong></td>
<td>Advances in control, sensing, and mobility emerge. Advances in robot-human interfaces occur. Advances proceed in materials technology and mechanical design. Large manufacturers continue humanoid-robot programs.</td>
</tr>
<tr>
<td><strong>D. Public awareness increases.</strong></td>
<td>The media continue to hype robotics technologies. Advances in robotic and synergistic technologies occur. Leisure-robot technology accelerates. Adoption of military robots increases significantly. Consumer acceptance of robots increases.</td>
</tr>
</tbody>
</table>

Source: SRIC-BI
Chapter 7

Appendix
### Automation: major listed players by segment

<table>
<thead>
<tr>
<th>Company</th>
<th>Bloomberg code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industrial robots</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABB</td>
<td>ABB SS</td>
<td>Provides power and automation technologies; operates in segments including power products, power systems, automation products, process automation and robotics.</td>
</tr>
<tr>
<td>Adept Technology, Inc.</td>
<td>ADEP US</td>
<td>Designs, manufactures, and markets robots. Products are used by manufacturers in the electronics, telecommunications, appliances, pharmaceuticals, food processing, and automotive components industries.</td>
</tr>
<tr>
<td>Denso Robotics</td>
<td>6902 JP</td>
<td>Manufacturing electronic parts for automobiles and industrial robots. Its products include automobile air conditioners, air bags, ignition systems, generators, power steering systems, and spark plugs with iridium electrode.</td>
</tr>
<tr>
<td>FANUC Robotics</td>
<td>6954 JP</td>
<td>Manufactures FA systems/equipment and robots. Products include computerized numerically-controlled equipment, servo motors, laser systems, industrial robots, wire-cut electric discharge machines, and CNC drills. Has a JV with General Electric in the FA field.</td>
</tr>
<tr>
<td>Kawasaki Robotics</td>
<td>7012 JP</td>
<td>Designs, develops, and manufactures transport equipment and industrial heavy machinery for military and commercial use. Produces ships, railroad cars, aircraft engines and parts, hydraulic and gas turbines, submarine engines, boilers, and industrial robots. Kawasaki Heavy Industries offers engineering and construction services to industrial plants.</td>
</tr>
<tr>
<td>KUKA Robotics Corp.</td>
<td>KU2 GR</td>
<td>Manufactures production machinery and equipment, and offers production engineering services. Designs and builds automobile factories, and produces welding and assembly systems, industrial robots, turning machines, packaging machinery, and measuring and control instruments for water and gas suppliers. KUKA operates in Europe, the Americas, and Asia.</td>
</tr>
<tr>
<td>Mitsubishi Heavy Industries</td>
<td>7011 JP</td>
<td>Comprehensive heavy machinery maker. Manufactures machinery, ships, turbines and engines, prime movers, aircraft, and machine parts for military and commercial use. Also researches and develops nuclear power plants.</td>
</tr>
<tr>
<td>Yaskawa-Motorom</td>
<td>6506 JP</td>
<td>Manufactures and markets servomotors, controllers, inverters, and industrial robots. Products include spindle controllers, computerized numerical control (CNC) systems, and system engineering.</td>
</tr>
<tr>
<td><strong>Service robots</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASUSTek</td>
<td>2353 TT</td>
<td>Manufactures and markets computer motherboards, interface cards, notebook computers, and related products. Also designs and manufactures cleaning robots.</td>
</tr>
<tr>
<td>Complai Comm</td>
<td>8078 TT</td>
<td>Manufactures telecommunications equipment. Produces cellular telephones for original equipment manufacturers. Also develops entertainment robotics.</td>
</tr>
<tr>
<td><strong>Key components</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LG</td>
<td>36980 KS</td>
<td>Develops and manufactures a variety of robots for cleaning, military and educational use.</td>
</tr>
<tr>
<td>MSI</td>
<td>2377 TT</td>
<td>Manufactures and markets motherboards and video graphic accelerator (VGA) cards. Also developed cleaning robots.</td>
</tr>
<tr>
<td><strong>System Integration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABB</td>
<td>ABB SS</td>
<td>Provides power and automation technologies; operates in segments including power products, power systems, automation products, process automation and robotics.</td>
</tr>
<tr>
<td>Adept Technology, Inc.</td>
<td>ADEP US</td>
<td>Designs, manufactures, and markets robots. Products are used by manufacturers in the electronics, telecommunications, appliances, pharmaceuticals, food processing, and automotive components industries.</td>
</tr>
<tr>
<td>Kenmei Mechanical Engineering</td>
<td>6125 TT</td>
<td>Engages in the manufacture and sale of industrial equipment primarily in Taiwan. Professional provider of system integration.</td>
</tr>
</tbody>
</table>

Source: Daiwa, Bloomberg
## Main expositions in 2012

<table>
<thead>
<tr>
<th>Event</th>
<th>Location</th>
<th>Date</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Automation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automation Shanghai - IAC, TME + SENSOR - Industrial Automation &amp; Control Expo Test &amp; Measurement + SENSOR Expo</td>
<td>Shanghai</td>
<td>June(TBA)</td>
<td>TBA</td>
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<tr>
<td><strong>Machine Tool</strong></td>
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<tr>
<td>EASTPO (SIMTOF) - Shanghai International Machine Tool Fair</td>
<td>Shanghai</td>
<td>7/3-7/6</td>
<td><a href="http://www.eastpo.net/">http://www.eastpo.net/</a></td>
</tr>
<tr>
<td>Qingdao Int’l Machine Tools &amp; Moulds Exhibition (QIMTE)</td>
<td>Qingdao</td>
<td>8/2-8/5</td>
<td><a href="http://www.jninte.com/">http://www.jninte.com</a></td>
</tr>
<tr>
<td>TMTS- Taiwan international Machine Tool show</td>
<td>Taipei</td>
<td>11/7-11/11</td>
<td><a href="http://tmits.tw/">http://tmits.tw/</a></td>
</tr>
<tr>
<td>CIMT - China International Machine Tool Exhibition</td>
<td>Beijing</td>
<td>TBA</td>
<td>TBA</td>
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<tr>
<td><strong>Robot</strong></td>
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<tr>
<td>IREX - International Robot Exhibition</td>
<td>Tokyo</td>
<td>TBA</td>
<td>TBA</td>
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<tr>
<td>AUTOMATE - Robots, Vision, Motion, Solutions</td>
<td>Chicago</td>
<td>TBA</td>
<td>TBA</td>
</tr>
</tbody>
</table>

Source: Daiwa
Daiwa’s Asia Pacific Research Directory

Hong Kong

Regional Research Head Nagahisa MIYABE (852) 2848 4971 nagahisa.miyabe@hk.daiwacm.com
Regional Research Co-head Christopher LOBELLO (852) 2848 4916 christopher.lobello@hk.daiwacm.com
Head of Product Management John HETHERINGTON (852) 2773 8797 john.hetherington@hk.daiwacm.com
Head of Thematic Research; Product Management Tatagata Guha ROY (852) 2773 8732 tatagata.guha@hk.daiwacm.com
Head of China Research, Chief Economist (Regional) Mingchun SUN (852) 2773 8751 mingchun.sun@hk.daiwacm.com
Macro Economics (Regional) Kevin LAI (852) 2848 4926 kevin.lai@hk.daiwacm.com
Head of Hong Kong Research; Regional Property Coordinator; Co-head of Hong Kong and China Property; Property Developers (Hong Kong) Jonas KAN (852) 2848 4439 jonas.kan@hk.daiwacm.com
Automobiles and Components (China) Jeff CHUNG (852) 2773 8793 jeff.chung@hk.daiwacm.com
Head of Greater China FIG; Banking (Hong Kong, China) Grace WU (852) 2848 4430 grace.wu@hk.daiwacm.com
Banking/Diversified Financials (Taiwan) Jerry YANG (852) 2773 8842 jerry.yang@hk.daiwacm.com
Banking (Hong Kong, China) Queenie POON (852) 2532 4381 queenie.poon@hk.daiwacm.com
Regional Head of IT/Electronics; Semiconductor/IC Design (Regional) Eric CHEN (852) 2773 8702 eric.chen@hk.daiwacm.com
IT/Electronics - Semiconductor/IC Design (Taiwan) Ashley CHUNG (852) 2848 4431 ashley.chung@hk.daiwacm.com
Regional Head of Materials; Materials/Energy (Regional) Alexander LATZIER (852) 2848 4463 alexander.latzier@hk.daiwacm.com
Materials (China) Felix LAM (852) 2532 4341 felix.lam@hk.daiwacm.com
Regional Head of Small/Medium Cap; Small/Medium Cap (Regional) Mark CHANG (852) 2773 8729 mark.chang@hk.daiwacm.com
Small/Medium Cap (Regional) John CHOI (852) 2773 8730 john.choi@hk.daiwacm.com
Head of Solar Pranab Kumar SARMARAH (852) 2848 4441 pranab.sarma@hk.daiwacm.com
Transportation – Aviation, Land and Transportation Infrastructure (Regional) Kelvin LAU (852) 2848 4467 kelvin.lau@hk.daiwacm.com
Regional Head of Clean Energy and Utilities; Utilities; Power Equipment; Renewables (Hong Kong, China) Dave DAI (852) 2848 4068 dave.dai@hk.daiwacm.com
Head of Custom Products Group; Custom Products Group Justin LAU (852) 2773 8741 justin.lau@hk.daiwacm.com
Custom Products Group Philip LO (852) 2773 8714 philip.lo@hk.daiwacm.com
Custom Products Group Jibo MA (852) 2848 4489 jibo.ma@hk.daiwacm.com

South Korea

Head of Research; Strategy; Banking/Finance Chang H LEE (82) 2 787 9177 chlee@kr.daiwacm.com
Regional Head of Automobiles and Components; Automobiles; Shipbuilding; Steel Sung Yop CHUNG (82) 2 787 9157 sychung@kr.daiwacm.com
Banking/Finance Anderson CHA (82) 2 787 9185 anderson.cha@kr.daiwacm.com
Capital Goods (Construction and Machinery) Mike OH (82) 2 787 9179 mike.oh@kr.daiwacm.com
Consumer/Retail Sang Hee PARK (82) 2 787 9165 sanghee.park@kr.daiwacm.com
IT/Electronics (Tech Hardware and Memory Chips) Jae H LEE (82) 2 787 9175 jhlee@kr.daiwacm.com
Materials (Chemicals); Oil and Gas Jihye CHOI (82) 2 787 9121 jihye.choi@kr.daiwacm.com
Telecommunications; Software (Internet/Online Games) Thomas Y KWON (82) 2 787 9181 yskwon@kr.daiwacm.com
Custom Products Group Shannen PARK (82) 2 787 9184 shannen.park@kr.daiwacm.com

Taiwan

Consumer/Retail Yoshihiko KAWASHIMA (886) 2 8758 6247 y.kawahima@daiwacm-cathay.com.tw
IT/Technology Hardware (Communications Equipment); Software; Small/Medium Caps Christine WANG (886) 2 8758 6249 christine.wang@daiwacm-cathay.com.tw
IT/Technology Hardware (Handsets and Components) Alex CHANG (886) 2 8758 6248 alex.chang@daiwacm-cathay.com.tw
IT/Technology Hardware (PC Hardware - Panels) Chris LIN (886) 2 8758 6251 chris.lin@daiwacm-cathay.com.tw

India

Head of India Research; Pharmaceuticals and Healthcare Kartik A. MEHTA (91) 22 6622 1012 kartik.mehta@in.daiwacm.com
Deputy Head of Research; Strategy; Banking/Finance Punit SRIVASTAVA (91) 22 6622 1013 punit.srivastava@in.daiwacm.com
Automobiles and Components Ambrish MISHRA (91) 22 6622 1060 ambrish.mishra@in.daiwacm.com
Capital Goods/Utilities Saurabh MEHTA (91) 22 6622 1099 saurabh.mehta@in.daiwacm.com
FMCG; Consumer Percy PANTHAKI (91) 22 6622 1063 percy.panthaki@in.daiwacm.com
### Singapore

<table>
<thead>
<tr>
<th>Position</th>
<th>Name</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head of Singapore Research</td>
<td>Tony DARWELL</td>
<td>(65) 6321 3050</td>
<td><a href="mailto:tony.darwell@sg.daiwa.com">tony.darwell@sg.daiwa.com</a></td>
</tr>
<tr>
<td>Quantitative Research</td>
<td>Josh CHERIAN</td>
<td>(65) 6499 6549</td>
<td><a href="mailto:josh.cherian@sg.daiwa.com">josh.cherian@sg.daiwa.com</a></td>
</tr>
<tr>
<td>Quantitative Research</td>
<td>Suzanne HO</td>
<td>(65) 6499 6545</td>
<td><a href="mailto:suzanne.ho@sg.daiwa.com">suzanne.ho@sg.daiwa.com</a></td>
</tr>
<tr>
<td>Banking (ASEAN)</td>
<td>Srikant VADLAMANI</td>
<td>(65) 6499 6570</td>
<td><a href="mailto:srikant.vadlamani@sg.daiwa.com">srikant.vadlamani@sg.daiwa.com</a></td>
</tr>
<tr>
<td>Regional Head of Oil and Gas; Oil and Gas (ASEAN and China); Capital Goods (Singapore)</td>
<td>Adrian LOH</td>
<td>(65) 6499 6548</td>
<td><a href="mailto:adrian.loh@sg.daiwa.com">adrian.loh@sg.daiwa.com</a></td>
</tr>
<tr>
<td>Property and REITs</td>
<td>David LUM</td>
<td>(65) 6329 2102</td>
<td><a href="mailto:david.lum@sg.daiwa.com">david.lum@sg.daiwa.com</a></td>
</tr>
<tr>
<td>Head of ASEAN &amp; India Telecommunications; Telecommunications (ASEAN &amp; India)</td>
<td>Ramakrishna MARUVADA</td>
<td>(65) 6499 6543</td>
<td><a href="mailto:ramakrishna.maruvada@sg.daiwa.com">ramakrishna.maruvada@sg.daiwa.com</a></td>
</tr>
<tr>
<td>Thematic Research</td>
<td>Amy CHEW</td>
<td>(65) 6321 3085</td>
<td><a href="mailto:amy.chew@sg.daiwa.com">amy.chew@sg.daiwa.com</a></td>
</tr>
</tbody>
</table>

### Philippines

<table>
<thead>
<tr>
<th>Position</th>
<th>Name</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head of the Philippines Research; Strategy; Capital Goods; Materials</td>
<td>Rommel RODRIGO</td>
<td>(63) 2 813 7344 ext 302</td>
<td><a href="mailto:rommel.rodrigo@daiwa.com.ph">rommel.rodrigo@daiwa.com.ph</a></td>
</tr>
<tr>
<td>Economy; Consumer; Power and Utilities; Transportation – Aviation</td>
<td>Alvin AROGO</td>
<td>(63) 2 813 7344 ext 301</td>
<td><a href="mailto:alvin.arogo@daiwa.com.ph">alvin.arogo@daiwa.com.ph</a></td>
</tr>
<tr>
<td>Property; Banking; Transportation – Port</td>
<td>Danielo PICACHE</td>
<td>(63) 2 813 7344 ext 203</td>
<td><a href="mailto:danielo.picache@daiwa.com.ph">danielo.picache@daiwa.com.ph</a></td>
</tr>
</tbody>
</table>
Daiwa’s Office

Office / Branch / Affiliate Address Tel Fax

**DAIWA SECURITIES GROUP INC**

**HEAD OFFICE**
Gran Tokyo North Tower, 1-9-1, Marunouchi, Chiyoda-ku, Tokyo, 100-6733
(81) 3 5555 1111 (81) 3 5555 0861

Daiwa Securities Trust Company 
One Evertrust Plaza, Jersey City, NJ 07302, U.S.A.
(1) 201 333 7300 (1) 201 333 7726

Daiwa Securities Trust and Banking (Europe) PLC (Head Office) 
5 King William Street, London EC2N 7JH, United Kingdom
(44) 207 320 8000 (44) 207 410 0120

Daiwa Securities Trust and Banking (Europe) PLC (Dublin Branch) 
Level 3, Block 5, Harcourt Centre, Harcourt Road, Dublin 2, Ireland
(353) 1 603 9900 (353) 1 478 3469

**DAIWA CAPITAL MARKETS LIMITED**

**HEAD OFFICE**
Gran Tokyo North Tower, 1-9-1, Marunouchi, Chiyoda-ku, Tokyo, 100-6753
(03) 5555 3111 (03) 5555 0661

Daiwa Capital Markets America Inc 
Financial Square, 32 Old Slip, New York, NY10005, U.S.A.
(1) 212 612 7000 (1) 212 612 7000

Daiwa Capital Markets America Inc. San Francisco Branch 
555 California Street, Suite 3300, San Francisco, CA 94104, U.S.A.
(1) 415 955 8100 (1) 415 956 1935

Daiwa Capital Markets Europe Limited 
5 King William Street, London EC2N 7AX, United Kingdom
(44) 20 7597 8600 (44) 20 7597 8600

Daiwa Capital Markets Europe Limited, Frankfurt Branch 
Trianon Building, Mainzer Landstrasse 16, 60325 Frankfurt am Main, Federal Republic of Germany
(49) 69 717 080 (49) 69 723 340

Daiwa Capital Markets Europe Limited, Geneva Branch 
30 rue du Rhône, P.O.Box 3018, 1211 Geneva 3, Switzerland
(41) 22 818 7300 (41) 22 818 7341

Daiwa Capital Markets Europe Limited, Milan Branch 
Via Senato 14/16, 20121 Milan, Italy
(39) 02 763 271 (39) 02 763 27250

Daiwa Capital Markets Europe Limited, Moscow Representative Office 
25/9, build. 1, Per. Sivtsev Vrazhek, Moscow 119002, Russian Federation
(7) 495 617 1960 (7) 495 244 1977

Daiwa Capital Markets Europe Limited, Bahrain Branch 
7th Floor, The Tower, Bahrain Commercial Complex, P.O. Box 30069, Manama, Bahrain
(973) 17 534 452 (973) 17 535 113

Daiwa Capital Markets Europe Limited, Dubai Branch 
The Gate village Building 1, 1st floor, Unit-6, DIFC, P.O.Box-506657, Dubai, UAE.
(971) 47 090 401 (971) 47 230 332

Daiwa Capital Markets Hong Kong Limited 
Level 28, One Pacific Place, 88 Queensway, Hong Kong
(852) 2535 3121 (852) 2845 1621

Daiwa Capital Markets Singapore Limited 
6 Shenton Way #36-05, Raffles Place, Singapore 048689, Republic of Singapore
(65) 6220 3666 (65) 6223 6998

Daiwa Capital Markets Australia Limited 
Level 34, Rialto North Tower, 525 Collins Street, Melbourne, Victoria 3000, Australia
(61) 3 9916 1300 (61) 3 9908 1350

DBP-Daiwa Capital Markets Philippines, Inc. 
18th Floor, Citibank Tower, 8741 Paseo de Roxas, Salcedo Village, Makati City, Republic of the Philippines
(632) 813 7344 (632) 848 0105

Daiwa-Cathay Capital Markets Co Ltd 
14/F, 200, Keeling Road, Sec 1, Kai Tak, Taiwan, R.O.C.
(886) 2 2723 9668 (886) 2 2345 3638

Daiwa Securities Capital Markets Korea Co., Ltd. 
One IFC, 10 Gukjegeumyung-Ro, Yeouido-gu, Seoul, 129-897, Korea
(82) 2 787 9100 (82) 2 787 9911

Daiwa Securities Capital Markets Co Ltd, Beijing Representative Office 
Room 3003/3004, SK Tower, No.6 Jia Jianguomen Wai Avenue, Chaoyang District, Beijing 100022, People’s Republic of China
(86) 10 6500 6688 (86) 10 6500 3594

Daiwa SSC Securities Co Ltd 
47/F, Hang Seng Tower, 1000 Leighton Road, Pok Faing, HSPA 1001, People’s Republic of China
(852) 2385 3100 (852) 2385 2111

Daiwa Securities Capital Markets Co Ltd, Bangkok Representative Office 
Level 8 Suedkline House, 1 Sloom Road, Bangkok 10500, Thailand
(66) 2 231 8381 (66) 2 231 8121

Daiwa Capital Markets India Private Ltd 
10th Floor, 3 North Avenue, Maker Maitry, Bandra Kurla Complex, Bandra East, Mumbai – 400051, India
(91) 22 6622 1000 (91) 22 6622 1019

Daiwa Securities Capital Markets Co., Ltd, Hanoi Representative Office 
Suite 405, Pacific Palace Building, 83B, Ly Thuong Kiet Street, Hoan Kiem Dist. Hanoi, Vietnam
(84) 8 3946 0460 (84) 8 3946 0461

**DAIWA INSTITUTE OF RESEARCH LTD**

**HEAD OFFICE**
15-6, Puyuki, Koto-ku, Tokyo, 135-8460, Japan
(81) 3 5620 3100 (81) 3 5620 5903

**MARRONOUCHI OFFICE**
Gran Tokyo North Tower, 1-9-1, Marunouchi, Chiyoda-ku, Tokyo, 100-6756
(81) 3 5555 7011 (81) 3 5202 2021

New York Research Center 
11th Floor, Financial Square, 32 Old Slip, NY, NY 10005-3504, U.S.A.
(1) 212 612 6000 (1) 212 612 8317

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3/F, 5 King William Street, London, EC2N 7AX, United Kingdom
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