1998
Establishes SSMC joint venture with Royal Philips Electronics and EDB Investments in Singapore

2012
Initiates "TSMC Grand Alliance"

2016
Establishes TSMC Nanjing Company Limited

2017
Transforms its Volunteer Club into the TSMC Charity Foundation, chaired by Mrs. Sophie Chang

2020
Becomes the first semiconductor company in the world to join "RE100"

2020
Announces the construction and operation of an advanced semiconductor fab in Arizona that will use 5nm process technology for semiconductor wafer fabrication

5. Operational Highlights

5.1 Business Activities

5.1.1 Business Scope

As the founder and a leader of the dedicated semiconductor foundry segment, TSMC provides a full range of integrated semiconductor foundry services, including leading advanced process, specialty technologies, advanced mask technologies, 3DFabric™ advanced packaging and silicon stacking technologies, excellent manufacturing productivity and quality, as well as comprehensive design ecosystem support, to meet a growing variety of customer needs. The Company strives to provide unparalleled overall value to its customers and views customer success as TSMC's own success. As a result, TSMC has gained customer trust from around the world and has experienced strong growth and success of its own.

5.1.2 Customer Applications

TSMC manufactured 12,302 different products for 535 customers in 2021. These chips were used across a broad spectrum of electronic applications, including computers and peripherals, information appliances, wired and wireless communication systems, high-performance computing servers and data centers, automotive and industrial equipment, as well as consumer electronics such as digital TVs, game consoles, digital cameras, AI-enabled IoT and wearables, and many other devices and applications.

The rapid ongoing evolution of end products prompts customers to pursue product differentiation using TSMC's innovative technologies and services and, at the same time, spurs TSMC's own development of technology. As always, TSMC believes success depends on leading rather than following industry trends.

5.1.3 Consolidated Shipments and Net Revenue in 2021 and 2020

Unit: Shipments (thousand 12-inch equivalent wafers) / Net Revenue (NT$ thousands)

		2021		2020	
		Shipments	Net Revenue	Shipments	Net Revenue
Wafer	Domestic (Note 1)	2,562	172,814,551	2,038	113,838,353
	Export	11,617	1,232,485,722	10,360	1,064,617,920
Others (Note 2)	Domestic (Note 1)	N/A	13,055,166	N/A	12,452,935
	Export	N/A	169,059,598	N/A	148,345,603
Total	Domestic (Note 1)	2,562	185,869,717	2,038	126,291,288
	Export	11,617	1,401,545,320	10,360	1,212,963,523

Note 1: Domestic means sales to Taiwan.
Note 2: Others mainly include revenue associated with packaging and testing services, mask making, design services, and royalties.

5.1.4 Production in 2021 and 2020

Unit: Capacity / Output (million 12-inch equivalent wafers) / Amount (NT$ millions)

Wafers			
Year	Capacity	Output	Amount
2021	13-14	14-15	791,459
2020	12-13	12-13	643,051

5.2 Technology Leadership

5.2.1 R&D Organization and Investment

In 2021, TSMC continued to invest in research and development, with total R&D expenditures amounting to 7.9% of revenue, a level that equals or exceeds the R&D investment of many other leading high-tech companies.

Faced with the continuous challenge to significantly scale up semiconductor computing power every two years, thereby extending Moore's Law, the Company has focused its R&D efforts on contributing to customers' product success by offering leading-edge technologies and design solutions. In 2021, the Company started risk production of 3nm technology, the sixth generation platform to make use of 3D transistors, while continuing the development of 2nm, the leading-edge technology in the semiconductor industry today. Furthermore, the Company's research efforts pushed forward with exploratory studies for nodes beyond 2nm.

In addition to complementary-metal-oxide-semiconductor (CMOS) logic, TSMC conducts R&D on a wide range of other semiconductor technologies that provide the functionality required by customers for mobile SoC and other applications. Highlights in 2021 included:

- Qualifying the fifth generation (Gen-5) chip on wafer on substrate (CoWoS®) with Si interposer area up to 2,500mm^2, which can accommodate at least two SoC logic and eight HBM (high bandwidth memory) chiplet stacks
- Successfully qualifying InFO-PoP Gen-7 for mobile applications with enhanced thermal performance
- Initiating high-volume manufacturing of integrated fan-out on substrate (InFO-oS) Gen-3, which provides more chip partition integration with larger package size and higher bandwidth
- Expanding the 12-inch Bipolar-CMOS-DMOS (BCD) technology portfolio on 90nm, 55nm, 40nm and 22nm, targeting a variety of fast-growing applications of mobile power management ICs with various levels of integration
- Maintaining stable high yield and achieving technical qualification of 28nm eFlash for consumer electronics grade and automobile electronics grade-1 applications
- Entering volume production of 40nm resistive random access memory (RRAM), 28nm and 22nm nodes ready for production as a low-cost solution for the price sensitive IoT market
- Increasing productivity of 22nm magnetic random access memory (MRAM), and achieved technical qualification in 2021, for next generation embedded memory MCUs, automotive devices, IoT and AI applications
- Achieving 13% pixel size scaling down on Quad Phase Detection (QPD) CMOS image sensors structure for the mobile imaging market.

In 2021, TSMC developed or introduced the following technologies:

Logic Technology

- 3nm fin field-effect transistor (FinFET) (N3) technology development is on track and making good progress. Volume production is expected to start in the second half of 2022.
- N3E technology, an enhanced version of N3 technology, development is on track and making good progress. This technology will continue to provide industry-leading advantages for both mobile and high-performance computing applications. N3E volume production is scheduled for one year after N3.
- 4nm FinFET (N4) technology, an enhanced version of 5nm FinFET (N5) technology, started risk production for customer products in 2021 and volume production is expected in 2022.
- 4nm FinFET Plus (N4P) technology development is on track and making good progress. Risk production is expected to start in 2022.
- N4X technology, introduced in 2021, is TSMC's first high performance computing (HPC)-focused technology, representing the ultimate performance and maximum clock frequencies in TSMC's 5-nanometer family. Risk production is expected in the first half of 2023.
- 5nm FinFET Plus (N5P) technology, a performance-enhanced version of 5nm technology (N5), started volume production in 2021.
- 6nm FinFET (N6) technology, which started volume production in 2020, was widely adopted in mobile, high performance computing, and consumer products in 2021.
- 7nm FinFET (N7) and 7nm FinFET plus (N7+), which have been in volume production for customers' 5G and high-performance computing products for several years, expanded to consumer and automotive products in 2021.
- 12nm FinFET compact plus (12FFC+) technology started volume production in the first quarter of 2021.
- N12e™ technology, which leverages TSMC's 12FFC+ baseline and IP ecosystem, introduced new ultra-low-leakage extreme high threshold voltage (eHVT) devices in 2021.

- 22nm ultra-low leakage (22ULL) technology introduced new enhanced low leakage and cost-effective devices in 2021, further enriching this platform to support customers in broader applications.

Specialty Technology

- 5nm automotive foundation IPs development is on track and making good progress. These IPs are expected to complete AEC-Q100 Grade-2 qualification in 2022.
- N6 radio frequency (N6 RF) technology completed development in 2021. Customer product tape-outs are expected to start in 2022.
- 16FFC FinFET compact (16FFC) RF technology received multiple customer tape-outs in 2021.
- 22ULL RF technology started volume production in 2021, covering consumer and automotive applications.
- 22ULL embedded RRAM technology, TSMC's second generation RRAM solution, features balanced cost and reliability. Several customers qualified products with this technology and ready for production in 2021.
- 22ULL embedded MRAM technology IPs completed qualification for over one million cycles endurance and reflow capability in 2021. This technology demonstrated automotive AEC-Q100 Grade-1 capability and has started volume production for customer wearable products for several years.
- 28nm ULL eFlash technology, which completed AEC-Q100 Grade-1 reliability qualification, qualified security products in 2021 for customer volume production.
- 40nm Silicon on Isolator (N40SOI) technology on 12-inch wafers, which provides industry-leading competitive advantages, received multiple customer tape-outs in 2021 and is expected to start volume production in 2022.
- 12-inch 90nm Bipolar-CMOS-DMOS (BCD) Plus technology passed qualification in 2021. TSMC helped customers complete new tape-outs and started volume production for this technology in 2021.
- Gallium Nitride (GaN)-on-Silicon Gen-1 technology platform was further enhanced in 2021 to support customers' various market applications. Gen-2 technology is under development and with completion planned for 2022.
- CMOS Image Sensor (CIS) technology was further refined to support the strong demand in advanced smartphone cameras. In 2021, TSMC helped customers roll out products with the smallest pixel size in the world.
- TSMC successfully used piezoelectric MEMS (micro electro-mechanical systems) technology to support customers in delivering single chip MEMS speakers in 2021.

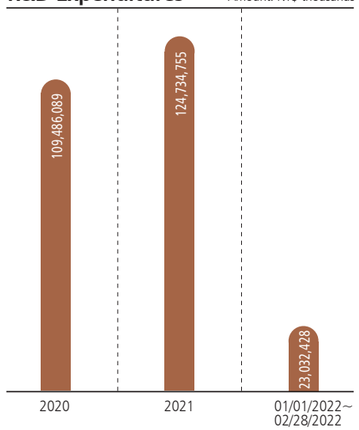
3DFabric™ - TSMC 3D Silicon Stacking and Advanced Packaging Technologies

- For TSMC-SoIC™ (System on Integrated Chip) for 3D silicon die stacking technologies, TSMC successfully demonstrated Chip on Wafer (CoW) technology with good electrical performance on heterogeneous integration of SRAM with logic on a customer product in 2021.
- CoWoS®-S (Chip on Wafer on Substrate with silicon interposer), featuring a new embedded deep trench capacitor (eDTC) option and an interposer up to 3-reticle size, was qualified to enable more logic and high band width memory (HBM) integration for customers' high performance computing applications in 2021.
- CoWoS®-R (Chip on Wafer on Substrate with redistribution layer interposer) technology was qualified in 2021.
- Fine pitch copper (Cu) bump technology for flip chip packaging on N4 silicon successfully entered risk production in 2021.

In 2021, TSMC maintained strong partnerships with many world-class research institutions, including SRC in the U.S. and IMEC in Belgium. The Company also continued to expand research collaboration with leading universities throughout the world for two grand purposes: the advancement of semiconductor technologies and the nurturing of human talent for the future.

R&D Expenditures

Amount: NT$ thousands



5.2.2 R&D Accomplishments in 2021

Highlights

- 3nm Technology

In 2021, TSMC established platform support of N3 technology for both HPC and SOC applications, started risk production, and planned to launch volume production in the second half of 2022. The Company also started the development of the N3E technology, which features an improved manufacturing process window and better performance and power, with volume production scheduled for one year after N3.

- 2nm Technology

TSMC entered the development stage of 2nm technology in 2021, focusing on test vehicle design and implementation, mask making, and Si pilot runs. Major progress was made in enhancing baseline process setup, transistor and interconnect performance.

- Lithography Technology

In 2021, TSMC R&D achieved solid imaging with improved wafer yield for 3nm risk production. The Company also enhanced EUV application, material quality and planarization for 2nm technology development. In addition, TSMC R&D worked on reduction of mask defects in EUV scanner and overlay errors, while lowering overall cost.

The Company's EUV program continued to make breakthroughs in EUV power output and stability, thereby further boosting productivity, with further progress made in EUV lithography process control, photoresist materials mask pellicle and mask manufacturing quality, thus improving yield to achieve HVM (high volume manufacturing) requirements. In the future, the Company will continue the research of next generation product manufacturing and energy saving opportunities for the EUV program's long-term goal of Net Zero Emissions by 2050.

- Mask Technology

In 2021, R&D focused on improving Critical Dimension and overlay performance of EUV masks to meet the lithography requirement of the 3nm node. Continuous advancement was made for EUV mask technology by fundamental development of mask materials and mask processes for the 2nm node.

Integrated Interconnect and Packaging

TSMC has named its fine pitch chip-to-chip connection leveraging existing wafer processes, the 3DFabric™, which includes Integrated Fan-Out (InFO) with chips embedded before interconnection, CoWoS® with chips placed onto pre-made RDL (re-distribution interconnection), and SoIC with chip-on-chip direct stacking.

TSMC offers a universal wafer level system integration (WLSI) technology family, including SoIC, system-on-wafer (SoW), and system-on-integrated-substrate (SoIS) to meet future computing systems integration scaling needs.

- 3DIC and TSMC-SoIC™

TSMC-SoIC™ is an innovative wafer-level frontend 3DIC chip stacking platform with outstanding bonding density, interconnect bandwidth, power efficiency, and thin profile. It extends Moore's Law through system-level scaling with sustainable performance gains and corresponding cost benefits. A SoIC integrated chip can be subsequently assembled using conventional packages or using TSMC's new 3DFabric™ technologies, such as CoWoS® or InFO, for next generation HPC, AI and mobile applications. Currently, TSMC's SoIC process is targeted to complete initial qualification in the second half of 2022. TSMC will continue pursue the scaling of SoIC technologies to align with the Company's advanced Si technologies for further gains in transistor density, system PPA (power, performance, area) and cost.

- Chip-Last CoWoS®

CoWoS® with Si interposer is the leading 2.5D technology for high-end HPC and AI product applications. The technology features a Si interposer with sub-micron routing layers and iCap (integrated capacitors), so that various chiplets such as SoC and high bandwidth memory (HBM) can be placed on it. The CoWoS® Gen-5 with a Si interposer area up to 2,500mm^2 to accommodate at least two SoC logic and eight HBM stacks was qualified in 2021. The new HBM3 (third generation HBM) certification on CoWoS® will be a major focus for TSMC in 2022.

- Chip-First InFO

In 2021, TSMC continued its industry leadership in high-volume manufacturing of InFO-PoP Gen-6 packaging for mobile applications and InFO-oS Gen-3 for HPC chip-partition applications. InFO-PoP Gen-7 was also successfully qualified for mobile applications and displayed enhanced thermal performance. InFO-oS Gen-4, which provides more chip-partition integration with larger package size and higher bandwidth, was developed on schedule.

• Advanced Interconnect

By enabling leading-edge technologies, TSMC's advanced interconnect continues to help our customers to strengthen their competitiveness. In 2021, development of novel materials enabled line resistance and capacitance reduction, which led to a boost in chip performance. In addition, innovative interconnect design on signal routing and power was proposed, which not only improves chip performance but also reduces cost.

Corporate Research

Innovation in devices and materials continues to drive higher performance and reduced power consumption in advanced logic technologies. In 2021, in collaboration with two leading universities, TSMC successfully demonstrated a contact with record low resistance between semi-metallic bismuth (Bi) and semiconducting monolayer two-dimensional (2D) transition metal dichalcogenides (TMDs), which enabled demonstration of the highest on-state current density for a monolayer MoS_2 2D transistor. News of this breakthrough was published in the May 2021 issue of *Nature*, one of the world's leading science journals. At the 2021 International Electron Device Meeting (IEDM), TSMC showcased another contact with further improved thermal stability, comparably low contact resistance, which also received good press coverage.

TSMC continues to research emerging high-density, non-volatile memory devices and hardware accelerators for AI and HPC applications. In close collaboration with key U.S. universities, several papers on the use of RRAM for compute-in-memory were presented at high-profile conferences including the International Solid-State Circuits Conference (ISSCC) and the Symposia on VLSI Technology and Circuits (Symp. VLSI). A memory selector is a key device to enable high density non-volatile memories. At the 2021 Symp. VLSI, TSMC demonstrated a high-performance arsenic-free Germanium-Carbon-Tellurium (GeCTe)-based threshold-type selector with record high endurance over 10^{11} cycles together with low threshold voltage ~1.3V and low leakage current ~5nA. At the 2021 IEDM, TSMC further introduced a nitrogen doped GeCTe selector that is BEOL (back end of line) compatible and has ultra-low cycle-to-cycle variation of threshold voltage. Also at the 2021 Symp. VLSI, the Company presented several novel techniques to achieve the multi-level cell (MLC) data storage for neural network applications, including an MLC phase change memory (PCM) with retention time improved by a factor of 100,000 while keeping the inference accuracy degradation within 3%.

Specialty Technologies

TSMC offers a broad array of technologies to address a wide range of applications:

• Mixed Signal/Radio Frequency (MS/RF)

With the advent of the 5G mmWave (millimeter wave) era, TSMC has already delivered a number of competitive technology solutions leveraging RF design-technology co-optimization (DTCO). In 2021, TSMC continued to offer 6nm RF technology for 5G transceiver designs, 40nm special process for 5G RF frontend module (FEM) in sub-6 GHz designs, and 28nm HPC+ process for 5G mmWave FEM designs.

• Power IC/Bipolar-CMOS-DMOS (BCD)

In 2021, TSMC expanded its 12-inch BCD technology portfolio on 90nm, 55nm, 40nm and 22nm, targeting a variety of fast-growing applications for mobile power management ICs, such as dedicated 5V power switches to handle increasing power demands driven by Li-ion batteries. Production of 90nm BCD technology started smoothly, covering a wide spectrum of applications from 5V to 35V, as did mass production of 40nm BCD 20/24V technology with ultra-low-power baseline, integrated RRAM module. The Company plans to continue developing 28V and 5-16V HV devices to cover more PMIC applications.

• Micro-Electromechanical Systems (MEMS)

TSMC's piezoelectric MEMS technology was qualified to produce MEMS speakers with high audio quality and fast response in 2021. Future plans include the development of next-generation high-sensitivity piezoelectric microphones, total solutions for MEMS optical image stabilization (OIS) systems on 12-inch wafer, medical single chip ultrasound probes and automotive MEMS applications.

• Gallium Nitride (GaN)

In 2021, TSMC qualified an improved version of the first generation of 650V enhanced GaN high electron mobility transistors (E-HEMT) and went into full load mass production with over 130 adaptors launched in the market. The Company continues to expand production capacity to meet customer demand. The second generation of 650V and 100V power E-HEMT, both with 50% FOM (figure of merit) improvement, will start production in 2022. The 100V depleted GaN high electron mobility transistor (D-HEMT) completed device development and will start production in 2022. In addition, TSMC started the development of the third generation 650V power E-HEMT with delivery expected in 2025.

• Complementary Metal-Oxide-Semiconductor (CMOS) Image Sensors

In 2021, TSMC made several major technical advances in CMOS image sensor technology including: (1) 13% pixel size scaling down on innovative quad phase detection (QPD) sensor structure for the mobile imaging market; (2) implementation of pixel-embedded 3D high density metal-insulator-metal (MiM) capacitors on dual conversion-gain and LOFIC (lateral overflow integrating capacitor) image sensors for high-dynamic-range machine vision and security camera applications; (3) production of a new generation automotive image sensors with 25dB higher dynamic range and three times lower dark current than those of previous generations, and the enablement of ADAS (advanced driver assistance systems) capability.

• Embedded Flash/Emerging Memory

TSMC reached several major milestones in embedded non-volatile memory (NVM) technologies in 2021. At the 28nm node, the Company's embedded flash development for high-performance (HP) mobile computing and HP low-leakage platforms maintained a stable high yield and achieved technical qualification for consumer electronics grade and automotive grade-1 applications. These NVMs are scheduled for technical and product qualification in automotive highest grade-0 in 2023. TSMC also offered RRAM as a low-cost embedded NVM solution for the price sensitive IoT market. The Company's 40nm node entered mass production, while the 28nm and 22nm nodes were ready for production.

The Company also made several major accomplishments in embedded MRAM technology. Productivity was increased in the mass production of 22nm node MRAM by simplifying integration processes, with technical qualification in 2021. Stable high yield was maintained in the 16nm node for automotive applications, with technical qualification expected in 2023. Meanwhile, TSMC achieved proof of feasibility of multi-function MRAM to meet customer requirements for high-speed and low power consumption in MCUs, AI, and VR applications.

5.2.3 Technology Platform

TSMC provides customers with advanced technology platforms that include the comprehensive infrastructure needed to optimize design productivity and cycle times. These include: electronic design automation (EDA) design flows; silicon-proven libraries and IP; and simulation and verification design kits, also known as process design kits (PDKs), and technology files.

For the latest advanced technologies such as 3nm, 4nm, 5nm and TSMC 3DFabric™, the Company provides EDA tools, features and IP solutions for adoption at various design stages by customers for system innovation to meet their product requirements. To help customers plan new product tape-outs incorporating library/IP from the Company's Open Innovation Platform® (OIP) ecosystem, the OIP ecosystem features a portal to connect customers to solution providers from 16 EDA partners, six Cloud partners, 46 IP partners, 22 design center alliance (DCA) and eight value chain aggregator (VCA) partners.

5.2.4 Design Enablement

TSMC's technology platforms provide a solid foundation to facilitate the design process. Customers can design using the Company's internally developed IP and tools or use tools available from TSMC's OIP partners.

Tech Files and PDKs

EDA tool certification, an essential element for IP and customer designs to ensure that features meet TSMC process technology requirements, can be found on TSMC-Online™. Corresponding tech files and PDKs are available for customers to download and use with certified EDA tools. TSMC provides a broad range of PDKs for digital logic, mixed-signal, radio frequency (RF), high-voltage driver, CMOS image sensor (CIS) and embedded flash technologies across a range of nodes from 0.5μm to 3nm. In addition, the Company provides tech files for design rule checking (DRC), layout verification of schematic (LVS), resistance-capacitance (RC) extraction, automatic place and route, and a layout editor to ensure that process technology information is accurately represented in EDA tools. By 2021, TSMC had provided customers more than 38,000 tech files and 2,600 PDKs.

Library and IP

Silicon intellectual property (IP) is the basic building block of IC designs. Various IP types are available to support different customer design applications including: foundation, analog/mixed-signal, embedded memory, interface and soft IP. TSMC and its alliance partners offer customers a rich portfolio of reusable IPs, which are building blocks for many circuit designs. To support 3DIC customer needs, TSMC introduced 3DIC IP in 2019. In 2021, the Company expanded its library and silicon IP portfolio to contain more than 40,000 items, a 14% increase over 2020.

Design Methodology and Flow

Design reference flows are built on top of certified EDA tools to provide additional design flow methodology innovations that can help boost productivity. In 2021, TSMC addressed critical design challenges associated with the new 3nm and 4nm technologies through OIP collaboration and announced the availability of design reference flows for mobile and HPC platforms. In addition to process technology advancements, the Company continued to develop and offer TSMC 3DFabric™ design solutions for both 3D chip stacking and 2.5D advanced packaging technologies. For 3D chip stacking, the Company offers TSMC-SoIC™ design solutions; for 2.5D advanced packaging, TSMC updated its InFO and CoWoS® design solutions to improve design productivity. These design reference flows feature FinFET-specific and 3DFabric™ design solutions to optimize PPA (performance, power and area).

5.2.5 Intellectual Property

For a long time, TSMC has been protecting R&D innovation and operation development by way of utilizing patents and trade secrets as dual tracks under the established comprehensive IP management system, encouraging Company's innovation culture, and strengthening Company's competitive strengths so as to fulfill the Company's ESG vision. TSMC's General Counsel updates the Board of Directors on the status of the intellectual property management scheme.

TSMC's comprehensive patent management system includes: Patent management strategies, such as Global patent deployment, Exploratory invention mining, Patent portfolio expansion, and Patent exploitation and exercise; and Patent management rules, such as Tier-based IP evaluation, Patent competition rewards, Educational patent promotion, and Patent professional training. We have established technological patent road maps by way of innovative patent strategy, strict management and risk-control measures; analyzed and monitored competitors by using intelligent patent maps; conducted core technology mining through invention workshops; expanded patent families on key technologies; filed and maintained patents by tier-based management, further enhanced patent protection through quality control on patent applications and continued to construct massive global patent portfolio with high quality; and, diversified exploitation of patent assets. In terms of patent filings, TSMC has accumulated more than 71,000 patent applications worldwide as of end of 2021, including 8,800+ applications filed in 2021. TSMC ranked No.3 among global US patent applicants, and No.1 among patent applicants in Taiwan. In terms of patent grants, TSMC has accumulated 50,000+ patents worldwide as of end of 2021, including 5,100 global patents received. TSMC ranked No.4 among U.S. Patentees, and No.1 among patent patentees in Taiwan. In terms of patent quality, the allowance rate of TSMC's U.S. applications approached 100%.

In 2013, TSMC pioneered the trade secret registration (TSR) system and the Golden Trade Secret Awards. Meanwhile, TSMC continues to consistently innovate trade secret management (TSM) services and methods. The TSR system records a wealth of technological inventions and innovations, and is a patent mining treasure trove. The TSR system also contains business trade secrets relating to capacity planning, pricing strategy, etc. The TSR system strengthens the Company's overall competitive advantage by operating in tandem with the Company operating systems, including the Contract Management System and Human Resource Management System to maximize synergy. TSMC presents the coveted "Golden Trade Secret Award" to distinguished innovators of registered trade secret cases, selected only after rigorous review to effectively promote the Company's innovative culture. As of the end of 2021, more than 1,900 Golden Trade Secret Awards have been granted and over 160,000 technical or commercial trade secrets have been registered on the TSR system. Through the following innovative measures, implemented in 2021, TSMC has continued to realize its vision of sustainable operations: (1) A "Green Trade Secret Award" initiative has been launched to encourage more innovation and registration of trade secrets with significant contribution to the area of energy management, water management, waste management, air pollution prevention; (2) A "Supply Chain Strategic Partners' Trade Secret Management Sharing" public service project has been initiated to strengthen the soft power of a sustainable supply chain. Meanwhile, TSMC also shares and promotes its TSM system and experiences with members of the Taiwan Semiconductor Industry Association to raise the industry's awareness and effectiveness of TSM. As a good corporate social citizen, TSMC will continue to initiate TSM innovation, and promote further sharing in the future.

TSMC received a AAA (the highest tier) certificate by Taiwan Intellectual Property Management System (TIPS) in December 2021, valid for 3 years.

TSMC's IP team works closely with technical teams from R&D in early stage to mass production, and actively constructs IP portfolio for each key innovative technology, including the latest 3nm and 2nm technology nodes, so as to ensure Company's technology leadership in semiconductor field; TSMC's revenue reached historical highs for 12 consecutive years, and we utilize patents and trade secrets as dual tracks to successfully protect Company's main business including process technologies, designs, manufacturing and sales, and have been strategically utilized for defense and cross-license negotiation, so as to secure freedom of business operation worldwide.

5.2.6 TSMC University Collaboration Programs

In recent years TSMC has collaborated closely with a number of prestigious universities in Taiwan to carry out a variety of joint research projects. These collaborations encourage more university professors to conduct leading-edge semiconductor research in areas such as novel devices, process and materials technologies, semiconductor manufacturing and engineering, and specialty technologies for electronic applications. Meanwhile, these projects provide hands-on training for interested students to prepare for and join the semiconductor industry after graduation. Back in 2013, TSMC established research centers at four top universities in Taiwan – National Yang Ming Chiao Tung University, National Taiwan University, National Cheng Kung University and National Tsing Hua University. In the past eight years, more than 3,200 students with backgrounds in the disciplines of electronics, physics, materials, chemistry, chemical engineering, and mechanical engineering have joined the research centers. TSMC also proactively supports the establishment of research colleges at four top universities and will continuously sponsor advanced research in the semiconductor field as well as professor recruitment. In 2019, the Company jointly launched TSMC-NTHU Semiconductor Program to enhance the quality and number of domestic semiconductor students and attract more outstanding students to a career in the semiconductor industry. In 2021, the list of school partners had grown to eight universities, including National Taiwan University, National Cheng Kung University, National Yang Ming Chiao Tung University, National Taipei University of Technology, National Taiwan University of Science and Technology, National Central University, and National Sun Yet San University, and had attracted more than 2,000 students to enroll in the program. In addition, TSMC conducts strategic research projects at top overseas universities such as Stanford, MIT, UC Berkeley and so on. The focus is on innovative capabilities in transistors, interconnect, materials, device simulation and circuit design.

TSMC University Shuttle Program

The TSMC University Shuttle Program was established to provide professors at leading research universities worldwide with access to the advanced silicon process technologies needed to develop innovative circuit design concepts. In 2021, as the COVID-19 pandemic continued to spread, remote and contactless work accelerated global industrial transformation, but it also worsened the global chip shortage. Nevertheless, TSMC continued the University Shuttle Program that links motivated professors and graduate students with enthusiastic managers at TSMC in order to promote excellence in the development of advanced silicon design technologies and to nurture new generations of engineering talents in the semiconductor field. The University Shuttle Program provides access to TSMC silicon process technologies for digital and analog/mixed-signal circuits, RF designs, non-volatile memory design and ultra-low power designs. TSMC and the University Shuttle Program participants enjoy a win-win collaboration through the program, which allows graduate students to implement exciting designs and achieve silicon proof points for innovation in various end-applications.

5.2.7 Future R&D Plans

To maintain its technology leadership, TSMC plans to continue investing heavily in R&D. While TSMC's 3nm and 2nm advanced CMOS logic nodes are progressing through the development pipeline, the Company's reinforced exploratory R&D work is focused on beyond-2nm nodes and on areas such as 3D transistors, new memories and low-R interconnect, to establish a solid foundation to feed into future technology platforms. TSMC's 3DIC advanced packaging R&D is developing innovations in subsystem integration to further augment advanced CMOS logic applications. The Company has intensified its focus on new specialty technologies such as RF and 3D intelligent sensors, aiming at 5G and smart IoT applications. The corporate research function continues to focus on novel materials, processes, devices, and memories that may be adopted in eight to ten years and beyond. The Company also continues to collaborate with external research bodies from academia and industry consortia alike with the goal of gaining early awareness and adoption of future cost-effective technologies and manufacturing solutions for its customers. With a highly competent and dedicated R&D team and its unwavering commitment to innovation, TSMC is confident in its ability to drive future business growth and profitability for years to come by delivering competitive semiconductor technologies to its customers.

Summary of TSMC's Major Future R&D Projects

Project Name	Description	Risk Production (Estimated Target Schedule)
3nm logic technology platform and applications	6th generation 3D CMOS technology platform for SoC	2021
Beyond-3nm logic technology platform and applications	3D CMOS technology platform for SoC	2024
3DIC	Cost-effective solutions with better form factor and performance for System-in-Package (SiP)	2018 - 2022
Next-generation lithography	EUV lithography and related patterning technology to extend Moore's Law	2018 - 2022
Long-term research	Specialty SoC technology (including new NVM, MEMS, RF, analog) and transistors with 8 to 10 years horizon	2018 - 2026

The projects above account for roughly 80% of the total R&D budget for 2022. Total R&D budget is estimated to be around 8% of 2022 revenue.

5.3 Manufacturing Excellence

5.3.1 GIGAFAB® Facilities

Maintaining reliable production capacity is TSMC's key manufacturing strategy. The Company currently operates four 12-inch GIGAFAB® facilities – Fab 12, 14, 15 and 18. The combined capacity of the four facilities exceeded ten million 12-inch wafers in 2021. Production within these facilities support 0.13μm, 90nm, 65nm, 40nm, 28nm, 20nm, 16nm, 10nm, 7nm and 5nm process technologies, including each technology's sub-nodes. 3nm risk production is currently on track at Fab 18, with plans to start volume production in the second half of 2022. Besides, an additional portion of capacity is built at Fab 12 for R&D work on leading-edge manufacturing technologies, which currently supports the technology development of 2nm nodes and beyond.

The GIGAFAB® facilities are coordinated by a centralized management system known as super manufacturing platform (SMP) to provide customers with consistent quality and reliability, improved flexibility to cope with demand fluctuations, faster yield learning and time-to-volume production, as well as lower-cost product requalification.

5.3.2 Engineering Performance Optimization

As advanced technology continues to evolve and IC geometry keeps shrinking, the need for tighter process and quality control becomes extremely challenging for manufacturing. TSMC's unique manufacturing infrastructure is tailored to handle a diversified product portfolio, which uses strict process control to attain tightened specs and meet higher product quality, performance and reliability requirements. To achieve excellence in both quality and manufacturing, TSMC's process control systems have been integrated with numerous intelligent functions. Through intelligent detection, smart diagnosis, and cognitive action, the Company has demonstrated remarkable results in yield enhancement, quality assurance, workflow improvement, fault detection, cost reduction and shortening of the R&D cycle.

In the meantime, with the advent of the 5G era's stricter quality requirements for mobile, high performance computing (HPC), automotive and the Internet of Things (IoT), TSMC has further implemented artificial intelligence (AI) and machine learning technologies and integrated foundry know-how to build up a knowledge-based engineering analysis platform and leverage digital transformation to continuously optimize engineering performance.

5.3.3 Agile and Intelligent Operations

The Company's sophisticated, agile and intelligent operating systems continue to drive manufacturing excellence. TSMC has integrated intelligence of processes, machine tuning, manufacturing know-how, and AI technologies to create an intelligent manufacturing environment. Intelligent manufacturing technologies are widely applied in scheduling and dispatching, employee productivity, equipment productivity, process and equipment control, quality defense, and robotic control in order to optimize quality, productivity, efficiency, and flexibility, while achieving real-time information analysis, improving forecast capability, maximizing cost effectiveness, and accelerating overall innovation. TSMC has also integrated new applications such as intelligent mobile devices, IoT, and mobile robots, and combined with intelligent automated material handling systems (AMHS) to consolidate wafer manufacturing data collection and analysis, utilize manufacturing resource efficiently, and maximize manufacturing effectiveness. TSMC continues to intellectualize semiconductor production through AI that utilizes massive amounts of production data to achieve agile and intelligent operations. In addition, the Company has implemented augmented reality (AR) technology to diagnose remote equipment problems, and improve equipment installation efficiency during the pandemic period.

5.3.4 Digital Transformation

To meet the strong, pent-up demand of the ongoing pandemic era, TSMC continues to implement technology to transform the "automatic fab" into the "intelligent fab," with the simultaneous improvement of the product quality, equipment capacity, and personnel effectiveness. Intelligent fab has integrated the domain knowledge of semiconductor manufacturing, kept the system self-learning, and expanded the application of AI and machine learning, which includes dispatching, equipment tuning, process control, equipment diagnosis and maintenance, and quality inspection. As the result, today's engineers can focus on problem solving. This digital transformation platform will free up the limitations of workplace, combine the expertise of those in different locations, and make centralized management of global manufacturing a reality.

5.3.5 Raw Materials and Supply Chain Management

In 2021, TSMC continued to review and resolve supply issues and quality issues as well as potential supply chain risks through the collaboration of teams formed by fab operations, quality control and business organizations. TSMC also worked with suppliers to further advance material and process innovation, improve quality and create recycling savings with benefits from win-win solutions.

Raw Materials Supply

Major Materials	Major Suppliers	Market Status	Procurement Strategy
Raw Wafers	FST GlobalWafers SEH Siltronic SK siltron SUMCO	These 6 suppliers together provide over 90% of the world's raw wafer supply.	•TSMC's suppliers of silicon wafers are required to pass stringent quality certification procedures. •TSMC procures wafers from multiple sources to ensure adequate supplies for volume manufacturing and to appropriately manage supply risk. •Raw wafer quality enhancement programs are in place to support TSMC's technology advancement. •TSMC regularly reviews the quality, delivery, cost, sustainability and service performance of its wafer suppliers. The results of these reviews are incorporated into subsequent purchasing decisions. •A periodic audit of each wafer supplier's quality assurance system ensures that TSMC can maintain the highest quality in its own products. •TSMC takes various approaches with suppliers to better manage the cost and supply.
Chemicals	Air Liquide BASF DuPont Entegris Fujifilm Electronic Materials Kanto PPC Kuang Ming Merck RASA Shiny Tokuyama Wah Lee	These 12 companies are the major worldwide suppliers of chemicals.	•Most suppliers have relocated their new operations closer to TSMC's major manufacturing facilities, thereby significantly improving procurement logistics and reduce supply risk. •All supplied products are regularly reviewed to ensure that TSMC's specifications are met and product quality is satisfactory. •TSMC encourages and engages with chemical suppliers to implement innovative green solutions for waste reduction.
Lithographic Materials	3M Fujifilm Electronic Materials JSR Nissan Shin-Etsu Chemical Sumitomo Chemical T.O.K.	These 7 companies are the major worldwide suppliers of lithographic materials.	•TSMC works closely with suppliers to develop materials that meet all application and cost requirements. •TSMC and suppliers periodically conduct programs to improve their quality, delivery, sustainability and green policy, and to ensure continuous progress of TSMC's supply chain. •Some major suppliers have relocated or plan to replicate their manufacturing sites closer to TSMC's major manufacturing facilities, thereby significantly improving procurement logistics and reducing supply risks.
Gases	Air Liquide Air Products Central Glass Entegris Linde LienHwa Praxair SK Materials Taiwan Material Technology Taiyo Nippon Sanso	These 9 companies are the major worldwide suppliers of specialty gases.	•The majority of these suppliers have facilities in multiple geographic locations, which minimizes supply risk for TSMC. •TSMC conducts periodic audits to ensure that they meet TSMC's standards.
Slurry, Pad, Disk	3M AGC Cabot Microelectronics DuPont Fujibo Fujifilm Electronic Materials Fujimi	These 7 companies are the major worldwide suppliers of CMP (Chemical Mechanical Polishing) materials.	•TSMC works closely with suppliers to develop materials that meet all application and cost requirements. •TSMC and suppliers periodically conduct programs to improve their quality, delivery, sustainability and green policy, and to ensure continuous progress of TSMC's supply chain. •Most suppliers have relocated or plan to replicate some of their manufacturing sites closer to TSMC's major manufacturing facilities, thereby significantly improving procurement logistics and reducing supply risks.

Suppliers Accounting for at Least 10% of Annual Consolidated Net Procurement

Unit: NT$ thousands

Supplier	2021			2020		
	Procurement Amount	As % of 2021 Total Net Procurement	Relation to TSMC	Procurement Amount	As % of 2020 Total Net Procurement	Relation to TSMC
Company A	14,469,081	20%	None	13,144,243	20%	None
Company B	13,352,067	19%	None	11,010,731	17%	None
Company C	7,784,013	11%	None	6,445,912	10%	None
Others	35,181,148	50%	-	35,959,770	53%	-
Total Net Procurement	70,786,309	100%	-	66,560,656	100%	-

- **Reason for Increase or Decrease:** No significant change.

5.3.6 Quality and Reliability (Q&R)

TSMC strives to provide excellence in semiconductor manufacturing services to all its customers worldwide. The Company is dedicated to quality in every facet of its business and maintains a culture of continuous improvement to assure customer satisfaction. TSMC implements containment and preventive measures to protect customers from potential product defects.

In the technology development stage, the Q&R organization helps customers design in superior product reliability. In 2021, Q&R worked with R&D in advanced logic, specialty and advanced packaging technologies throughout development and qualification stages continuously to ensure meeting commitments to customers for device characteristics, process yield and product reliability.

For advanced logic technology, Q&R in 2021 successfully certified technology quality and reliability for risk production of 4nm FinFET, an enhanced version from 5nm. For specialty technologies, Q&R successfully completed IP qualification of 40nm embedded RRAM (resistive random access memory). In high voltage technologies, Q&R qualified second generation 0.5μm 650V GaN. In addition, TSMC's advanced packaging solutions enabled system improvement of the wafer level process by integrating the frontend wafer process and the backend chip packaging. In 2021, Q&R achieved qualification of the TSMC 3DFabric™ technology platform and successfully qualified larger scale InFO and CoWoS® technologies for HPC products and to provide better system level integration through heterogeneous chip package interaction.

To continuously reduce product defects, enhance process controls, facilitate early detection of abnormalities and prevent quality problems, Q&R collaborates with other operational entities to establish real-time defense systems using advanced statistical methods and quality tools. Since 2017, the Company's Q&R and fabs have worked together on enhancements for automotive product quality improvement, including design rule implementation and migration to Automotive Quality System 2.0. This covers process capability requirements to tighten in-line and wafer acceptance testing in fabs and the handling of maverick wafers and lots. Q&R also provides dedicated resources for field/line return analysis and timely physical failure analysis (PFA) for process improvement to meet automotive customers' stringent DPPM (defective parts per million) requirements.

To stimulate employee problem-solving and develop related quality systems and methodologies, Q&R held several company-wide symposia and training programs on total quality excellence (TQE) and quality audit in 2021. Q&R is also accelerating digital transformation in area of raw materials management, statistical process control (SPC), metrology and laboratory analysis. Use of machine learning to identify correlation has enabled intelligent which helped overcome the impact of the COVID-19 pandemic and make seamless quality control across worldwide fab network a reality. In 2022, Q&R will continue the development of employee capabilities by promoting quality methods and professional trainings and applying machine learning to enhance TSMC competitiveness.

Q&R is committed to green manufacturing, responsible supply chain and sustainable management practices. In 2021, Q&R set up a new advanced chemical laboratory to enhance continuous quality monitoring of raw materials. This helped R&D make significant innovations in materials and it provided services to enhance the technologies in the industry supply chain. Q&R collaborates with the corporate ESH organization to ask suppliers to declare that their materials to ensure compliance with international regulation for carcinogenic, mutagenic and reprotoxic (CMR) substances and to classify all risky materials and carry out test sampling. In 2020, Q&R had 100% inspection capability for CMR substances and shared its inspection methods and capabilities with major material suppliers to enhance monitoring of hazardous substances and control capability in the supply chain. Furthermore, in 2021 Q&R assisted TSMC subsidiaries in setting up inspection capability for hazardous substances to enhance corresponding monitoring and control capability for industry supply chain. At the same time, Q&R provided state of art material analysis and applied the best knowledge management method to assist the capacity expansion of new raw material production lines or new suppliers with quality fundamental to optimize the balance between quality and capacity.

Q&R also worked with manufacture teams for the recycling and reuse of chemical acids and successfully achieved several impurity improvements in recycling chemical acids during 2020 and enabled several recycling chemicals to achieve the quality level for electronic grade in 2021. In 2022, Q&R will continue sharing its technical knowledge to assist chemical suppliers in developing further recycling and reuse projects and will work with operations to implement engineering validation for recycling chemicals to achieve TSMC's quality requirements and the sustainable goal of friendly environment. Q&R is also committed to the continual improvement of local supply chains and developing local talent. In 2021, Q&R again collaborated with Semiconductor Equipment and Materials International (SEMI) to hold the third Strategic Materials Conference (SMC) in Taiwan to motivate talented domestic personnel and share the win-win strategy for technology and sustainable development as well as ESG (environmental, social, and governance) in TSMC and industrial wide topics to elevate the competitiveness of the local supply chain.

TSMC fully supports continuous improvement programs to strengthen the work culture, improve product quality and production efficiency, reduce production costs, and improve customer satisfaction. These programs encourage colleagues to strive for excellence, drive cross-departmental observation and learning, and enhance their innovative and problem-solving abilities – all traits that greatly contribute to achieving a win-win outcome of honing TSMC's competitive edge and building customer satisfaction. In addition to internal cross-organizational learning and exchange, TSMC participates in the Taiwan Continuous Improvement Competition to promote the development of other local industries by sharing its experience, and to enhance the problem-solving and innovation ability of its colleagues by observing the improvement methods of other industries. In 2021, TSMC's outstanding performance was recognized with five gold awards, three silver awards and one "best improvement and innovation" award. In addition to Operations organizations that were recognized, the IT (information technology) organization participated in the competition for the first time and was also awarded a gold award. That is consistent with our continue focus to proliferate total quality culture from technology and production to every organization in TSMC. At the same time, Q&R coached domestic material suppliers to participate in the competition for local suppliers' quality culture and capability enhancement. In 2021, Q&R encouraged 67% of backend material suppliers to participate in the competition to promote the quality culture of continual improvement.

Thanks to qualification in technology development, real-time defense systems and innovative applications in semiconductor manufacturing services, as well as its continuous quality improvement culture, TSMC had no major product recalls in 2021. Meanwhile, a third-party audit verified the effectiveness of TSMC's quality management systems in compliance with IATF 16949: 2016 and IECQ QC 080000: 2017 certificates requirements. In 2021, TSMC's four backend Fabs also acquired the certification of American National Standards Institute ANSI/ESD (Electrostatic Discharge) S20.20 standard for the first time. Regular customer feedback indicates that products shipped from TSMC have consistently met or exceeded all field quality and reliability requirements. In these ways, TSMC helps customers improve time-to-market delivery and competitiveness with excellent, reliable products for the five major growth markets the Company serves: mobile communications, high performance computing (HPC), the Internet of Things (IoT), automotive and digital consumer electronics.

5.4 Customer Trust

5.4.1 Customers

TSMC's customers make a wide variety of products that deliver excellent performance across the semiconductor industry. Customers include fabless semiconductor companies, system companies, and integrated device manufacturers such as Advanced Micro Devices, Inc., Broadcom Inc., Intel Corporation, MediaTek Inc., NVIDIA Corporation, NXP Semiconductors N.V., OmniVision Technology, Inc., Qualcomm Incorporated, Renesas Electronics Corporation, and many more worldwide.

Customer Service

TSMC is committed to providing the best possible service, which is critical to customer satisfaction, retention, relationship enhancement and attracting new customers. TSMC has established a dedicated service team that strives to provide world-class services to support customers in product design, mask making, wafer manufacturing, and backend services, hence TSMC can increase customer satisfaction and win customer trust in order to maintain sales and profitability of the company.

To improve customer interaction on a real-time basis, TSMC-Online™ offers a suite of web-based applications to provide more proactive customer service and support in design, engineering and logistics. Customers thus have 24-7 access to critical information and are able to create customized reports. TSMC-Online™ facilitates design collaboration by maintaining data availability and accessibility and providing customers with accurate up-to-date information at each stage of design process. Engineering collaboration includes engineering lots, wafer yields and wafer acceptance test analysis, as well as quality and reliability data. Logistics collaboration includes information on wafer fabrication, backend processes, and order shipments.

Customer Satisfaction

To ensure customer satisfaction, TSMC must fully comprehend its customers' needs. To this end, the Company appoints third-party consulting firms to conduct annual customer satisfaction surveys (ACSS) with majority of existing customers either via online surveys or direct interviews. In addition to the survey, TSMC also conducts quarterly business reviews (QBRs) with customers to collect their feedback on a regular basis. Customer feedback is routinely reviewed, analyzed and then used to develop appropriate improvement plans, all in all becoming an integral part of the customer satisfaction process. Through surveys and feedback reviews, TSMC is able to closely interact with customers, provide better services, and enhance the quality of customer collaboration.

Customer Information Protection

TSMC complies with applicable regulations and international standards in terms of customer information protection and has received ISO 27001 international information security certification. Relevant proprietary information protection policies and standard work process are established to ensure only authorized personnel can access the engineering and production data of a specific customer.

Customers Accounting for at Least 10% of Annual Consolidated Net Revenue

Unit: NT$ thousands

Customer	2021			2020		
	Net Revenue	As % of 2021 Total Net Revenue	Relation to TSMC	Net Revenue	As % of 2020 Total Net Revenue	Relation to TSMC
Customer A	405,402,955	26%	None	336,775,511	25%	None
Customer B	153,740,831	10%	None	N/A (Note)	N/A	None
Customer C	N/A	N/A	None	167,390,758	12%	None
Others	1,028,271,251	64%	-	835,088,542	63%	-
Total Net Revenue	1,587,415,037	100%	-	1,339,254,811	100%	-

Note: Revenue less than 10% of the Company's net revenue.

- **Reason for increase or decrease:** The changes of sales amount and percentage were mainly due to customer product demand change.

5.4.2 Open Innovation Platform® Initiative

Innovation has always been an exciting challenge. Competition continues to intensify in the face of increasing industry consolidation and the commoditization of technology at more mature, conventional levels, and thus semiconductor companies must find ways to keep innovating in order to survive and prosper. One way to promote innovation is through active collaboration with external partners. At TSMC this is known as "Open Innovation®". It is an "outside in" approach to complement traditional "inside out" methods. TSMC has chosen this path to stimulate innovation via its OIP initiative, which is a key part of the TSMC Grand Alliance.

The OIP initiative is a comprehensive design technology infrastructure that encompasses all critical IC implementation areas to lower design barriers and improve first-time silicon success. OIP promotes the speedy implementation of innovation amongst the semiconductor design community and its ecosystem partners using TSMC's & partners' IP and process technology in design implementation and backend services.

Crucial to OIP are ecosystem interfaces and collaborative components initiated and supported by TSMC to empower innovation throughout the supply chain and, in turn, drive the creation and sharing of new revenue and profits. TSMC's active accuracy assurance (AAA) initiative is key to OIP, providing the precision and quality required by the ecosystem interfaces and collaborative components.

TSMC's Open Innovation® model brings together the creative thinking of customers and partners under the common goal of shortening each of the following: design time, time-to-volume, time-to-market and, ultimately, time-to-revenue. The model features:

- the foundry segment's earliest and most comprehensive electronic design automation (EDA) certification program, delivering timely design tool enhancement required by new process technologies;
- the foundry segment's largest, most comprehensive and most robust silicon-proven IP (intellectual properties) and library portfolio; and
- comprehensive design ecosystem alliance programs covering market-leading EDA, IP, and design service partners.

TSMC's OIP alliance consists of 16 EDA partners, six Cloud partners, 46 IP partners, 22 design center alliance (DCA) partners, and eight value chain aggregator (VCA) partners. TSMC and partners work together proactively and engage much earlier and deeper than ever before in order to address mounting design challenges at advanced technology nodes. Through this early and intensive collaboration effort, TSMC's OIP is able to deliver the needed design infrastructure with timely enhancement of EDA tools, early availability of critical IPs and quality design services when customers need them. Taking full advantage of the process technologies once they reach production-ready maturity is critical to customers' success. Hence, this helps to achieve design technology co-optimization (DTCO) among TSMC process technologies, OIP design solutions and customer product designs.

TSMC's OIP partner management portal facilitates communication with ecosystem partners for efficient business productivity. Designed with a highly intuitive interface, this portal can be accessed via a direct link from TSMC-Online™.

TSMC held its online OIP Ecosystem Forum in October 2021. This annual event demonstrates how TSMC and its ecosystem partners jointly develop design solutions on top of TSMC's advanced technologies through OIP collaboration. It is also a good opportunity to maintain contact with customers and ecosystem partners during the COVID-19 pandemic. At the forum, TSMC made key presentations on 3nm that continues the full-node Power Performance Area (PPA) scaling trend together with the offering of high density and high performance libraries and design solutions for the support of smartphone and HPC design applications. The Company also made presentations on 4nm and 5nm design solutions and ecosystems that have already been applied to actual customer chip production. Other presentation topics included: N12e™, featuring further enhancement to support 0.4V operation with design solutions for IoT products that can further reduce power consumption; comprehensive automotive design enablement platform (ADEP) with design solutions and ecosystems previously developed for 16nm and 7nm and the same ADEP in 5nm, already under development; comprehensive RF technology portfolio to support general RF, millimeter Wave and RF frontend products; and TSMC 3DFabric™ design solutions that include TSMC-SoIC™ for 3D chip stacking, and InFO (Integrated FanOut) and CoWoS® (Chip on Wafer on

Substrate) for 2.5D advanced packaging currently available to support chip, package, system integration, implementation and verification for improved system performance. The availability of the aforementioned design ecosystem solutions will help customers successfully pursue opportunities in all major markets: mobile, high performance computing, the IoT, automotive and digital consumer electronics.

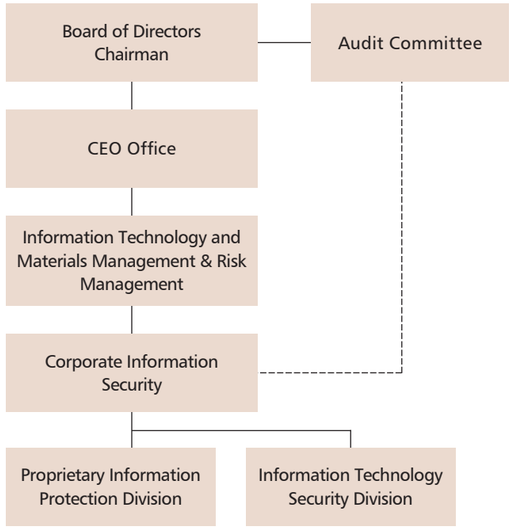
5.5 Information Security Management

5.5.1 Information Security Policy and Organization

Technology leadership, manufacturing excellence, and customer trust are the key advantages for TSMC's continued growth. The Company is committed to information security and confidentiality protection for its customers, shareholders, and partners. To this end, TSMC has clearly formulated relevant policies, management procedures, and regulations to achieve complete information security and confidentiality protection. TSMC adheres to the spirit of corporate sustainable management, and has issued the "Information Security Declaration" declaring the Company's determination to promote and actively strengthen information security and confidential information protection mechanisms, all for the purpose of defending the interests of its customers and partners.

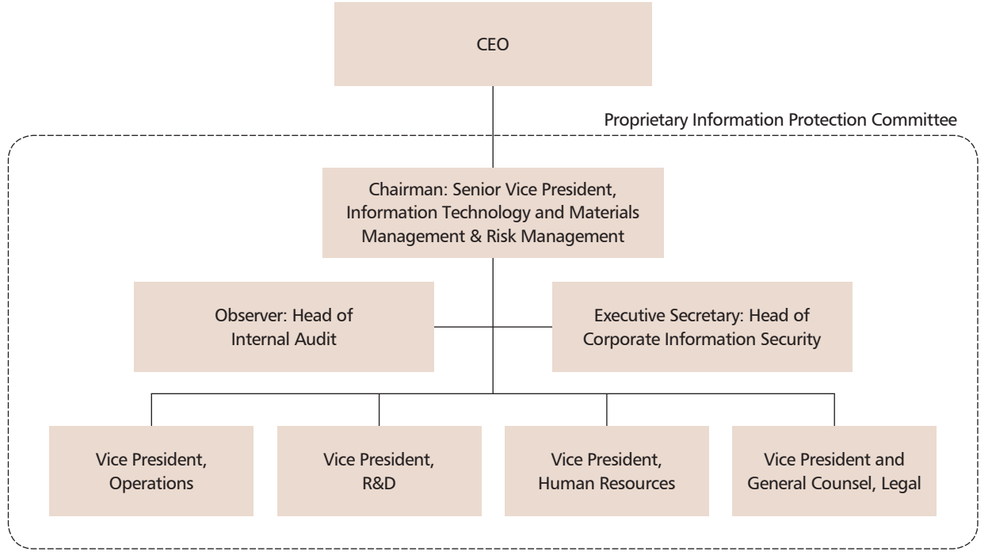
In order to achieve excellent governance of TSMC's information security, in 2019 TSMC established the Corporate Information Security (CIS) organization, which is responsible for formulating and planning company information security policies and implementation procedures. Through policy implementation and regulatory compliance checks, TSMC continuously reviews the effectiveness of information security risk control mechanisms, and is constantly strengthening the Company's information security. The head of CIS reports to the Audit Committee every six months on the implementation plan and result.

Corporate Information Security Organization Structure



TSMC executives are involved in planning the direction and implementation of TSMC's information security strategy with the goal of achieving excellent information security management. The Company has established an Exclusive Information Protection Committee, chaired by the Senior Vice President of Information Technology and Materials & Risk Management. The Vice Presidents of Legal, Human Resources, R&D, and Operations are also members of this Committee, and the head of CIS serves as its Executive Secretary. The Committee holds quarterly meetings to review and decide information security and information protection policies to ensure the realization of TSMC's goals and commitments in this area.

Proprietary Information Protection Committee Structure



5.5.2 Information Security Management Strategy and Resources

CIS actively strengthens security and confidentiality protection mechanisms to maintain TSMC's competitiveness. To achieve TSMC's information security management goals, CIS sets clear regulations, standards, and practices, enhances continuously the Company's management system and technology, and implements comprehensive risk controls. CIS regularly performs information security risk assessments and sets its priorities based on the magnitude and probability of a risk, and the cost in reducing such risk. CIS adopts the plan-do-check-act (PDCA) methodology to structure multi-layer information security defenses and establish information security key performance indicators (KPI). In 2021, TSMC invested in excess of NT$1 billion to strengthen information security, employs currently more than 500 employees for information security-related activities, and has more than 1,000 external security personnel engaging in the physical aspects of information security related services.

5.5.3 Information Security Incident Handling and Notification

TSMC has established enterprise risk management mechanism and information security incident handling procedures. The mechanism and procedures define relevant process and measures including information security incident notification procedure, designation of personnel responsible for handling material information security incidents, assessment of losses suffered and additional measures needed, assessment of impact of information security risks on the Company's financial and operations, and proposed countermeasures to information security risks. In 2021 and as of the date of this Annual Report, TSMC has not suffered any losses due to material information security incidents.

5.6 Human Capital

Human capital is TSMC's most treasured asset. Provide employees with meaningful work content, continuous learning, safe and fun work environment, high-quality compensation and benefits, and build the company into a diverse and inclusive environment. TSMC goes beyond this, however, by actively encouraging employees to nurture and enjoy a healthy family life, develop personal interests, expand social participation, and, in general, live a happy life.

5.6.1 Human Rights Policy and Specific Actions

TSMC believes that respecting human rights and promoting a decent work environment are important throughout the Company and its supply chain. TSMC abides by local laws and regulations in all countries and regions where we operate, and upholds the human rights of all workers, including regular, contract and temporary employees, and interns. We also require our suppliers to act in the same fashion, as addressing human rights issue in complex supply chains is a shared responsibility. We support the *UN Universal Declaration of Human Rights (UDHR)*, and are committed to treating all workers with dignity and respect as understood by international human rights standards, including *The International Bill of Human Rights*, The International Labour Organization's (ILO) *Declaration on Fundamental Principles and Rights at Work*, *The UN Guiding Principles on Business and Human Rights (UNGPs)*, *The OECD Guidelines for Multinational Enterprises* and *The Ten Principles of The United Nations Global Compact (UNGC)*. We also align our actions with the *Responsible Business Alliance (RBA) Code of Conduct*. The guiding principles for TSMC's Human Right Policy are as follows, and *TSMC's Supplier Code of Conduct* requires all of our suppliers to follow the same standards.

Guiding Principles

- Embed respect for economic, social, cultural, civil, and political rights, as well as the right to development, in the way we operate
- Provide a safe and secure work environment that is free of harassment
- Eliminate unlawful discrimination and ensure equality in the workplace
- Zero tolerance for child labor
- Forbid forced labor
- Commit to responsible sourcing of minerals
- Protect labor rights of vulnerable groups or marginalized groups such as indigenous peoples, women, migrant workers, contracted labor and persons with disabilities
- Comply with all applicable wage laws and regulations, and legal limits to working hours
- Provide fair living wage and pay in full and on time with pay slips to state legitimate deductions
- Enable a communication-friendly environment and maintain an open-style management system
- Support the physical and psychological well-being of employees, and the balance between work and life
- Make diverse open dialogue channels available for stakeholders such as suppliers, business partners, and others to report concerns or suspected violations to the Company, including ways to report anonymously
- Monitor and assess relevant risks, practices, and impacts regularly to respond to evolving situations and stakeholders' needs

In 2021, the Company used the Responsible Business Alliance's Self-Assessment Questionnaire (SAQ) to identify the greatest risks regarding "labor, health and safety, environment, and ethics" matters and to formulate substantive actions and managerial response. The SAQ scores of each of TSMC's operating fabs were in the low risk range, defined as 88 points or above.

In 2021, TSMC held a course on "TSMC Human Rights Policy: Anti-Harassment." A total of 58,904 colleagues completed the training with the pass rate for the post-exam of 100%. The total number of training hours for all human rights related training in 2021 was 181,314 hours with a total of 62,822 colleagues completed the training, accounting for 96% of all employees. As for the person-times of participants, the total number is more than 150,000.

TSMC respects the rights of employees to form and join labor unions of their own choosing. The Company regularly holds labor-management meetings and listens to employee concerns through diverse internal communication channels to ensure a harmonious relationship between labor and management.

5.6.2 Diversity and Inclusion

TSMC firmly believes in the value of a diverse workplace and cultivates future semiconductor talents in an inclusive fashion enabling our industry to unlock the full potential of all human resources available. TSMC further believes that the mix of employees should reflect that of society. A diversified management and employee composition will help the Company strengthen its competitive advantages and achieve sustainable development.

In 2021, TSMC established a women's employee resource group – "Women@TSMC", to provide a platform for female employees to support each other, strengthen the network within the Company, and encourage female employees to dare to pursue their career goals and personal development. The Company has set the goals that 30% of newly hired technical employees be female and 20% of managers be female by 2030.

5.6.3 Workforce Structure

At the end of 2021, TSMC had 65,152 employees worldwide, including 6,635 managers, 31,920 professionals, 6,620 assistants and 19,977 technicians. The following two tables summarizes the makeup of TSMC's workforce and female in management as of the end of February 2022:

Workforce Structure

		12/31/2020	12/31/2021	02/28/2022
Job	Managers	5,857	6,635	6,741
	Professionals	27,767	31,920	32,161
	Assistant Engineer/Clerical	4,832	6,620	6,865
	Technician	18,375	19,977	20,164
Total		56,831	65,152	65,931
Gender	Male (%)	62.9%	64.6%	64.8%
	Female (%)	37.1%	35,4%	35.2%
Education	Ph.D.	4.4%	4.1%	4.1%
	Master's	46.7%	47.3%	47.2%
	Bachelor's	25.7%	27.6%	27.8%
	Other Higher Education	9.8%	8.9%	8.9%
	High School	13.3%	12.0%	12.0%
Average Years of Age		36.4	36.0	36.0
Average Years of Service		9.1	8.6	8.6

Female Ratio in Management

	12/31/2020	12/31/2021	02/28/2022
Female Ratio in Junior Management	13.0%	13.4%	13.6%
Female Ratio in Senior Management	11.8%	12.5%	12.6%
Female Ratio in Top Management	10.0%	8.3%	8.3%

Note: Junior management positions include first-line managers; top management positions include Vice Presidents and higher as well as CEO.

5.6.4 Recruitment

Key elements of TSMC's success and growth depend on a common vision and values shared by the Company's employees. To strengthen growth momentum, the Company is committed to recruiting top-notch professionals in all positions. TSMC is an equal opportunity employer and practices open and fair recruitment. The hiring principles are "integrity" and "ability," and the Company evaluates all candidates according to their qualifications as related to the requirement of each position without regard to race, gender, age, religion, nationality or political affiliation.

TSMC adheres to its core values and continues to move forward with a lofty vision. It has always attracted the attention of many young and new blood in Taiwan. In 2021, "The New Generation's Most Yearning Enterprise" was held by *Cheers Magazine*. In the survey, it has won the championship for five consecutive years. In order to meet the continuous growth of operations, TSMC employed over 12,000 colleagues worldwide in 2021.

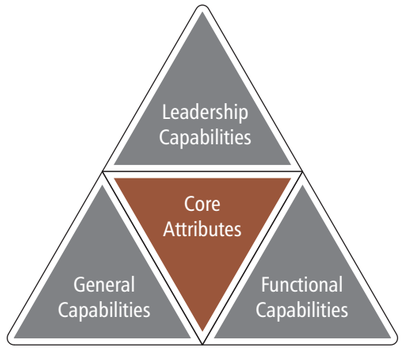
5.6.5 People Development

Employee development is an integral and critical factor for the growth of any company, and at TSMC it is goal oriented, disciplined and planned. The Company is committed to expanding and fulfilling employee potential by providing meaningful work in a world-class workplace. TSMC is also committed to cultivating a consistent and diverse learning environment. To this end, the Company has initiated the TSMC Employee Training and Education Procedure to ensure that the development objectives of both the Company and the individual can be achieved through the integration of internal and external training resources.

TSMC talent development strategies include equipping people with future capabilities and unleashing learning momentum. The Company attaches great importance to the

early development of employees' potential and actively seeks to fill the talent pipeline. Based on "TSMC Capability Model," employees' specific development needs are integrated and implemented through experience learning (70%), feedback and guidance (20%) and education and training (10%). At the same time, TSMC integrates diverse and multiple classroom and online learning resources to enhance employee awareness of independent learning opportunities to continuously promote employee growth. The Company provides on-the-job training, classroom training, e-learning, coaching, mentoring and job rotation and strives to create a learning-rich atmosphere.

TSMC Capability Model



Using TSMC capability model as the basis for talent development, the Company emphasizes core attributes (Character, Perseverance, Resilience, Initiative, Innovation, Judgement and Broadness of Mind & Breadth/Depth of Knowledge) in talent selection and development. Different training roadmaps for leadership and functional capabilities are provided for employees in different positions. At the same time, TSMC also provides a series of training courses on leadership and functional and general capabilities, allowing employees to choose independently according to their individual development needs and preferences.

TSMC provides the following training programs:

Leadership Capabilities

- Management – management development programs, including mandatory, elective and other learning programs, are tailored to the needs of managers at all levels based on their managerial capabilities and responsibilities.

Functional Capabilities

- Professional/functional – technical and professional training required by different functions within the Company. TSMC offers training courses on equipment engineering, process engineering, accounting, information technology and so forth.
- Direct labor – for production-line employees to acquire the knowledge, skills and approaches they need to perform their jobs well and to pass certification for operating equipment. Includes direct labor skill training, "Train the Trainer" training, and manufacturing leadership training.

General Capabilities

- New employee – basic training and job orientation. In addition, the newcomers' managers and a well-established buddy system are in place to support new hires in their assimilation process regarding both corporate culture and work requirements.
- General training as required by government regulations and/or the Company policies, focused on basic subjects for all employees as well as courses tailored to specific job functions. Topics include industry-specific safety, workplace health and safety, ethics and regulatory compliance, human rights, sexual harassment prevention, quality, and fab emergency response.
- English enhancement program – including online English webinars, English one-on-one consulting services, business English workshops, and the English learning zone to strengthen employees' English capability in support of TSMC's global business goals.
- Personal effectiveness training addressing topics related to professional skill sets including presentation skills, innovation, motivation and teamwork.
- Customized programs tailored to the needs of the organization and/or the employee's individual development plan.

In 2021, TSMC conducted over 1,344 internal training sessions and provided over 3.18 million hours of training and a total of more than 2.24 million attendees participated. Based on the Company's 65,152 total employment, average annual training time per employee increased to 48.9 hours. TSMC training expense reached to over NT$131 million.

Apart from internal training resources, TSMC employees are also subsidized when pursuing external short-term courses, for-credit classes and degrees.

5.6.6 Competitive Overall Compensation

TSMC employees enjoy a comprehensive compensation and benefits program above the industry average. TSMC provides a diversified compensation program that is competitive externally, fair internally, and adapted locally. TSMC adheres to the philosophy of sharing wealth with employees in order to attract, retain, develop, motivate and reward employees. Thanks to solid business results over the past years, the actual total compensation received by employees has stayed above the industry average.

TSMC's compensation program includes a monthly salary, business performance bonuses based on quarterly business results, and profit sharing based on annual profits.

The purpose of the business performance bonus and profit sharing programs is to reward employee contributions appropriately, to encourage employees to work consistently toward ensuring TSMC success, and to align employees' interests with those of TSMC's shareholders so as to achieve wins for the Company, shareholders and employees. The Company determines the amount of the business performance bonus and profit sharing based on operating results and industry practice in the Republic of China. The amount and distribution of the employee bonuses are recommended by the Compensation Committee to the Board of Directors for approval. Individual rewards are based on each employee's job responsibility, contribution and performance.

The same philosophy applies to TSMC's compensation programs in overseas subsidiaries. In addition to providing employees with a locally competitive base salary, annual bonuses are granted as a part of total compensation, in line with local regulations, market practices, and the overall operating performance of each subsidiary, to promote employee commitment and development.

TSMC believes that the long-term ownership of company shares by corporate officers helps align their interests with those of all shareholders, therefore, the Company formulated Corporate Officer Shareholding Guidelines in 2020. The required value for Chairman, CEO, and other corporate officers' holding of TSMC shares is proportional to their annual base salary (18 times for Chairman and CEO, 9 times for other officers in Taiwan, and 3 times for overseas officers). Officers shall fulfill the required value within 3 years of appointment. Officers keep the required value for the entire period of employment. Furthermore, to attract and retain corporate executives and to link their compensation with shareholder interests and Environmental, Social, Governance (ESG) achievements, TSMC established Employee Restricted Stock Awards Rules in 2021.

5.6.7 Employee Benefit System Superior to Statute

TSMC encourages employees to strive towards long-term Company development. For example, in addition to twelve national holidays per year, seven memorial days are provided as holidays. The Company also provides comprehensive group insurance plans to employees free of charge. Coverage includes life insurance, accident insurance, hospital insurance, cancer insurance, and business travel insurance. Employees also have the flexibility to participate in group insurance for their families at lower prices. The group insurance coverage is extended to employees on legal unpaid leaves. To better support new hires, TSMC offers one day of annual leave for every two months of service in the first year. In addition, TSMC provides pensions, financial assistance for emergencies, subsidies for marriage, childbirth and funerals, as well as discounts in designated shops.

To provide support in their personal and work lives, TSMC offers employees parental leave in accordance with local laws and regulations, provides comprehensive leave management system, and has set up four kindergartens for fabs in Taiwan. Employees have flexibility in making use of their vacation days to take care of their children. Employees who need to take long leaves of absence for military service or severe injuries can also apply for unpaid leave, and then apply for reinstatement after the expiration of the period.

All TSMC facilities are equipped with 24-hour health centers, where healthcare management professionals and appointed onsite physicians provide quality services beyond those required legally. The health centers work with hospitals and Employee Assistance Program services providers to offer comprehensive support for the emotional and physical well-being of employees. Annual checkups for all employees are provided as well. The company encourages employees to exercise regularly by subsidizing 63 sports clubs, improving exercise facilities, and holding regular sports events to help employees find peers with similar sports interests and balance their work and life.

- Convenient onsite services and amenities such as in-fab cafeterias, convenience stores, and other services
- Comprehensive health management services, including in-fab clinic services, post health-exam follow-up activities, and employee assistance programs
- Diverse employee welfare programs: leisure and art events, encouraging employees to participate in hobby clubs; vibrant sports center and onsite preschool service to meet employees' needs for child care; festival bonuses and emergency subsidies are also available to address employees' needs

Vacation and insurance policies at TSMC's overseas offices are designed in compliance with local regulations. In China, North America, and Europe, TSMC provides more vacation days to employees than legally required. In overseas offices, TSMC offers a more comprehensive life and medical insurance program than required by local regulations and customs.

5.6.8 Diverse Employee Recognition

TSMC sponsors various internal award programs to recognize employees for outstanding achievement, both individual and at a team level. With these award programs, TSMC aims to encourage continued employee development, which also enhances the Company's competitive advantage.

The award programs include:

- TSMC Academy: recognizes outstanding scientists and engineers whose individual technical capabilities have made significant contributions
- TSMC Excellent Labor Award: recognizes technicians whose outstanding performances have made significant contributions
- Total Quality Excellence: recognizes employees' continuous efforts in creating value at each fab
- Service Award: recognizes and shows appreciation of senior employees and their long-term commitment and dedication
- Excellent Instructor Award: praises the outstanding performance and contribution of internal instructors in training courses for employees

Apart from above recognitions, there are function-wide awards dedicated to innovation, such as the Idea Forum, the Total Quality Excellence Award and the ESG Award, which recognize employee initiative and continuous implementation of innovative practices. In addition, TSMC encourages employees to participate in external talent activities and competitions. In 2021, distinguished TSMC employees continued to be recognized through a host of awards, such as the Model Labor Award, the Excellent Young Engineers Award, the Outstanding Engineer Award, the Taiwan Continuous Improvement Awards, the National Manager Excellence Award and the National Industrial Awards.

5.6.9 Employee Engagement

The Company encourages employees to maintain a healthy and well-balanced life while pursuing their career goals effectively. TSMC continuously facilitates employee communication and provides employee caring, benefit, rewards and recognition programs.

Employee Communication

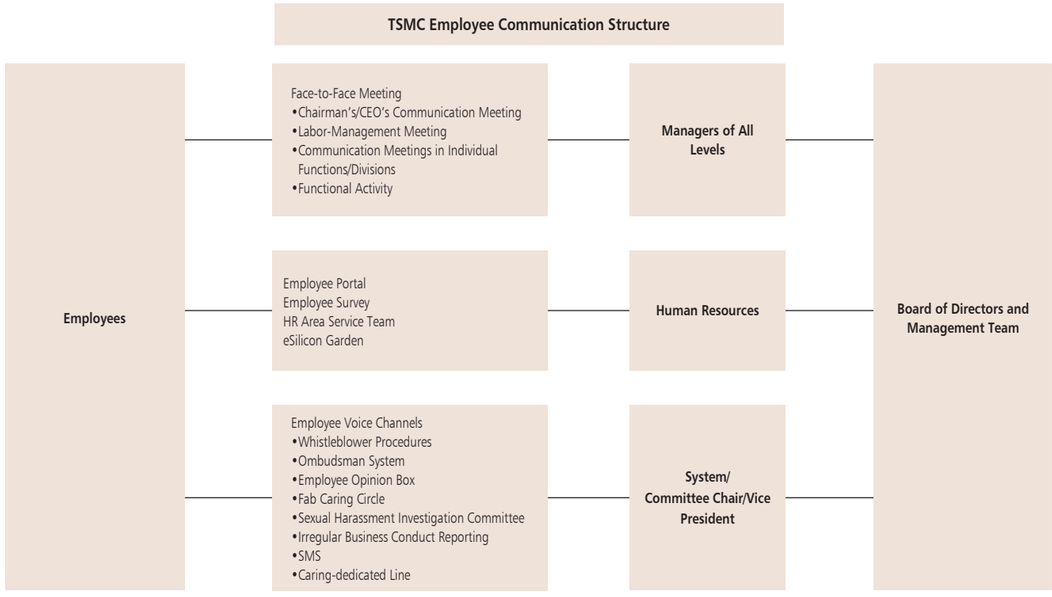
TSMC values employee communication and is committed to keeping communication channels open and transparent for management, subordinates and peers. The Company is committed to ensuring that employees are able to communicate openly and share ideas and concerns with management regarding work conditions and management practices without fear of discrimination, reprisal, intimidation or harassment.

TSMC makes continuous efforts to listen to the voice of employees and to facilitate mutual and timely employee communication, based on multiple channels and platforms, which in turn fosters harmonious labor relations.

TSMC supports a host of various communication channels, including:

- Communication meetings for various levels of managers and employees; for example, the executives communication meeting, skip levels and communication meetings in individual functions/divisions
- Quarterly labor-management meetings to provide business updates and discuss issues of concern for employees
- "Employee survey on Core Values" taken biennially to understand the Company's implementation of core values and employees' commitment
- "Global Employee Engagement Survey" taken biennially to systematically understand the work experience of employees, and to enhance employees' engagement and sense of belonging toward company
- Periodic employee pulse surveys and service satisfaction surveys to selected employees, with follow-up actions based on survey findings
- myTSMC employee portal, an internal website featuring the Founder's, Chairman's, and CEO's talks, corporate messages, executive interviews, and other activities of interest to employees
- *eSilicon Garden*, TSMC's newsletters providing real-time updates on major activities of the Company, as well as inspirational content featuring outstanding teams or individuals
- Two channels for reporting complaints regarding managerial, financial, auditing, ethics and business conduct issues:
  - The whistleblower reporting system administered by the Audit Committee
  - The ombudsman system administered by a senior manager appointed by the CEO
- The Employee Opinion Box, which provides an opportunity to submit suggestions or opinions regarding work and the overall work environment
- The Fab Caring Circle in each fab, which addresses issues related to employees' work and personal life; the system is dedicated mainly to the Company's direct laborers
- Sexual harassment investigation committee, a channel dedicated to ensuring a work environment free from the threat of sexual harassment; the committee consists of three directors appointed by the CEO, one from human resources, one from legal affairs, and the third from other organizations

Employee Communication Channels



During 2021 and as of the date of this Annual Report, TSMC has not incurred any labor-dispute related losses. However, the Company was fined for the following labor inspection results: NT$20,000 issued on 01/06/2021 due to clerical errors resulting in wages not being paid in full directly to an employee (Labor Standards Act Article 22 Paragraph 2). NT$80,000 issued on 04/20/2021 for overtime wages not being timely paid (Labor Standards Act Article 24 Paragraph 1). NT$20,000 issued on 07/14/2021 for overtime applications not being timely processed (Labor Standards Act Article 23 Paragraph 1). NT$50,000 issued on 07/14/2021 for the extension of working hours combined with the regular working hours exceeding twelve hours a day (Labor Standards Act Article 32 Paragraph 2). NT$20,000 issued on 07/14/2021 for employees not having a break for at least thirty minutes after having worked for four consecutive hours (Labor Standards Act Article 35). NT$360,000 issued on 08/04/2021 for overtime applications not being timely processed and the extension of working hours combined with the regular working hours exceeding twelve hours a day (Labor Standards Act Article 24 Paragraph 1 and Article 32 Paragraph 2). The Company has reviewed its working hour management process, established working hour management indices, additionally defined break time in Work Rules to provide flexibility for employees, and strengthened the communication of these matters and promotion of the policies to managers and employees.

5.6.10 Retention

The Global Employee Engagement Survey was launched in 2021. Based on WTW's High Performance Employee Experience (HPEX) Model, it strives to systematically understand TSMC employees' work experience and identify the Company's areas of strengths and opportunities. The Company and each department develop actions from the survey results in order to create win-win solutions for the Company and all its colleagues.

The survey scope in 2021 included TSMC's Taiwan Fabs, TSMC (China), TSMC (Nanjing), WaferTech, TSMC North America, TSMC Canada, TSMC Europe B.V, TSMC Japan, and TSMC Korea. VisEra was not included in the survey due to its different industrial background. The valid response rate was 93% with a total of 55,491 respondents.

The survey results showed that employees agree TSMC has strong competitiveness in the market who can quickly respond to market dynamic and is able to provide innovative products and services to enable the value creation of our customers. Colleagues are also very positive about the speed of decision-making and the continuous pursuit of improvements in working process or organizational efficiency. In addition to above significant advantages of TSMC, we are continuously enhancing the following:

1. To keep communication channels open and to create mutual respectful environment, so that our colleagues are encouraged to put forward their ideas, and supervisors are able to accept different opinions and make corresponding changes in a timely manner.
2. Enable supervisors to unleash potential of our employees, in order to encourage and inspire our colleagues find out the joy of work, feel more involved, and to gain the high level of accomplishment.
3. Encourage supervisors better utilize non-monetary reward tools to recognize and retain talents.

TSMC's employee turnover rate was 6.8% in 2021 which was higher compared to 2020 yet it still falls in the defined healthy range of 5% - 10%.

5.6.11 Retirement Policy

TSMC's retirement policy is set according to the labor standard laws and labor pension practices of various respective regions. Thanks to the Company's sound financial condition, it is able to ensure solid pension contributions and payments, which encourages employees to make long-term career plans and further deepen their commitment to TSMC.

5.7 Material Contracts

TSMC is not currently a party to any material contracts, other than those entered into in the ordinary course of its business. The Company's "Significant Contingent Liabilities and Unrecognized Commitments" are disclosed in Annual Report section (II), Financial Statements, page 70-71.